An evaluation of the socio-economic costs and benefits of the invasive *Rubus* (Blackberry/Bramble) genus at selected sites in South Africa.

A Thesis

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ABSTRACT

Rubus L. (brambles, blackberries, raspberries, or dewberries) are a globally recognised genus due to the edible fruit and negative impacts they can have as invasive species. There are at least 23 species of *Rubus* subgenus *Rubus* in South Africa. These include native, alien, naturalised alien, and invasive alien species. The invasive *Rubus* species are becoming an increasing problem in South Africa with experts in invasion biology urging caution regarding the genus (Henderson, 2011). The taxonomy of indigenous, alien and alien invasive species of *Rubus* are poorly understood and therefore efforts to understand the genus, the impacts and solutions to those impacts have been very limited (Stirton, 1981; Henderson, 2011; Sochor *et al.,* 2018a). There has also been little research conducted on the economic or ecological impacts on the species or genus of species in South Africa (du Plessis *et al.*, 1984; Botha, 2005), and yet species in the genus have been earmarked for prioritization by invasive species legislation. The potential value of certain species as well as the cost associated with their impacts could potentially create a complex conflict of interest scenario which has not been investigated. This study is an effort to inform future policy decisions regarding this suite of species by investigating the economic impacts of the invasive *Rubus* species.

A method was developed unique to the study that incorporated research tools from environmental economics and geography to identify the nature of interactions between economic agents, experts, and alien and invasive *Rubus* species in South Africa. Two questionnaires were developed to generate economic data and ground proofing was used to develop geographic data. One questionnaire was directed specifically at researchers and academics that attended the 46th National Symposium on Biological Invasions that took place between 15–17 May 2019, at Waterval Country Lodge, Tulbagh and the other an economic agent questionnaire for economic agents that met strict and selective criteria relating to the impact of the six invasive *Rubus* species on their economic activity. Both questionnaires were designed with a mixed methods approach in mind. The ground proofing was aimed at understanding the composition and distribution of *Rubus* species at the selected sites: Cathcart and Hogsback (The Eastern Cape Province), Clarens (Free State Province), and Underberg (KwaZulu-Natal Province).

The study established that all economic impacts of invasive *Rubus* species at selected sites are externalities. Invasive *Rubus* species in South Africa can be attributed as (i) harbouring vermin, (ii) impeding human and animal livestock, (iii) reducing crop yields, (iv) encroaching on grazing land, (v) presenting fire hazards, and (vi) negatively impacting fire regimes. These species also (i) provide berries that are retailed on a commercial level, or have been, (ii) that are utilized for personal consumption, (iii) provide an ingredient for alcohol brewing processes, and (iv) could potentially facilitate forest regeneration. The invasive species are infrequently browsed by certain livestock and far as we could ascertain do not provide ingredients for anti-inflammatory drugs or modern cosmetics in South Africa, as they do in other regions of the globe.

The costs associated with the invasive species can be presented dichotomously; the estimated private cost-benefit ratio, for costs and benefits incurred or enjoyed by 18 private economic agents, stands at 0.33:1. A private-public benefit-cost ratio, that incorporates both private and public costs and benefits, stands at 13,5:1. The private-public benefit-cost includes public expenditure, or government control measures, directed at invasive *Rubus* and shifts the benefit-cost ratio so that costs now markedly dominate the estimated benefits. The benefits per hectare uncovered in this study stand at R13.14/ha. The private costs stand at R4.32/ha and a holistic cost, including both private and public expenditure, stands at R177,43/ha. The monetary values, when expressed per hectare, are misleading. This is due to a large standard deviation in the spread of benefits received. The benefits are enjoyed by a small number of the already small sample of respondents. The costs and benefits are not uniformly distributed across regions assessed. All benefits in this study accrue to economic agents in the Free State Province, whilst most of the costs accrued to economic agents in KwaZulu-Natal Province. The benefits appear to be primarily derived from an alien species, *Rubus* sect. Arguti.

Management of the 6 species of invasive *Rubus* could be optimised by the prioritisation of those regions that incur the highest cost and derive the lowest benefit, in this case KwaZulu-Natal Province. Likewise, those regions with the highest benefits and lowest costs, the Free State Province, could provide sites for increased use and beneficiation of berries from invasive species. Management of individual species may prove difficult, given the similar morphologies, and thus, (i) either specialised training for those engaged in control must be instituted, (ii) all species of alien *Rubus* should be earmarked for management, or (iii) highly specific biocontrol agents for the most problematic species must be found.

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To Dr. Martin, I wish to raise several points: (i) it can unequivocally be stated that this thesis would not have happened without you, it is as much yours as mine, (ii) you are an excellent supervisor and the best academic I have engaged with in my 8 years of tertiary education, (iii) thank you for teaching me how to conduct scientific field studies, (iv) I grateful for having been welcomed into your home and (v) you set me on the straight and narrow when I had turned from the path – for this, I am eternally grateful.

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Lastly, thank you to the 6 invasive *Rubus* species, without which, this study would not have been written. May you soon be under efficient management which maximises your positive impacts and curtails your negative ones.

Thank you,

Brett Mason.

An evaluation of the socio-economic costs and benefits of the invasive *Rubus* (Blackberry/Bramble) genus species at selected sites in South Africa.

General Information

Chapter 1: "Introduction"- an introductory chapter aimed at introducing the main themes of the thesis, setting the context in which the project was undertaken and stating the aims and objectives of the project.

Chapter 2: "Literature review"- a review of literature that seeks to fuse, on an epistemological level, the fields of invasion science and economics. The main themes of the project are covered in detail, the definition of invasion science is based upon Richardson and Rejmánek (2013) and that of economics of Robbins (1935) and Mills (1843).

Specific Chapters

Chapter 3: "The *Rubus* genus in South Africa"- A discussion on the *Rubus* genus, the *Rubus* genus in South Africa, and the invasive *Rubus* species listed in the AIS lists.

Chapter 4: "Methods" – This chapter is devoted to discussing the aims of the study in more depth, stating, explaining, and showing how the mixed method approach was utilised through from the inception of the project to the construction of research implements and how the project identified criteria for respondent selection.

Chapter 5: "Results & Analysis"- This chapter states and analyses the result for the three separate focal areas of the study: The General Questionnaire, the Expert Opinion Questionnaire, and the Land Proofing process. Analysis is conducted simultaneously to facilitate ease of discussion further in the thesis.

Chapter 6: "Conclusion" – conclusions are made from the data generated, further research is suggested, the use of the bioeconomic model is discussed and the thesis is brought to its close.

CHAPTER 1

INTRODUCTION

"It is a capital mistake to theorise before one has data. Insensibly, one begins to twist facts to suit theories, instead of theories to suit facts."

~ Sir Arthur Conan Doyle (pg. 3, 1887).

Economics is a science of great worth where it is applied appropriately and a science with serious implications when applied inappropriately. This idea is embodied in a quote from Keynes', "Practical men who believe themselves to be quite exempt from any intellectual influence, are usually the slaves of some defunct economist." (Keynes, 1936). It is incumbent on any economist tasked with applying an economic method or engaging in an economic assessment, to understand both the field of economics and the field(s) that they are assessing. This study is principally concerned with the economic impacts of the invasive *Rubus* species in South Africa and was originally directed at *Rubus fruticosus* aggregate, however having approached the task with a comprehensive and thorough mindset it soon became evident that the entire range of invasive *Rubus* and, indeed, alien *Rubus* species, would need to be examined given the complexity inherent in the genus. Below is an introduction and overview of the project.

Rubus is a genus of plants in which several species are considered alien or invasive alien across different regions of the globe (Global Invasive Species Database, 2020). Species in the genus are commonly known as bramble or blackberry. There are at least 23 different species of *Rubus* in South Africa of which twelve are indigenous, five are naturalised alien species and six are regarded as invasive alien species (Germishuizen and Meyer, 2003; South African National Biodiversity Institute (SANBI) 2020, Plants of South Africa, 2018). The invasive *Rubus* species in South Africa and their impacts are the primary focus of this thesis. In depth discussion of each species is provided in appendix I. The *Rubus* subgenus *Rubus* is regarded as one of the most complex genera on Earth (Henderson, 2007) and provides an appropriate example of the need for economists to understand the species that they are working with. Without a sound understanding of the species, this study could make suggestions, or provide information that is misleading or biased. This can lead to inefficient resource allocation or improper management. Both are worth being avoided for evident reasons.

Alien species are species that have been intentionally or accidently introduced to regions or areas outside of their natural domain (Richardson *et al*., 2000; van Wilgen *et al.*, 2017). This process of introduction is often abetted by human factors that of which can be driven by economic incentives that either directly assist the process of introduction or else indirectly create conditions that facilitate said introduction (Scalera and Zaghi, 2004). In effect, an alien species is an organism that would not, of its own accord, be outside of the area of its native range (Brunel *et al*., 2013).

An invasive alien species is a naturalised alien species that can spread through a non-native environment unaided and, as a result, can have an impact on the native flora, fauna, and environment in general. Before an alien species becomes an invasive alien species it is usually referred to as a naturalised[1] alien species (Richardson *et al.,* 2010). Naturalised alien species are distinct from invasive alien species (Richardson *et al.,* 2000). A naturalised alien species is yet to invade natural ecosystems, semi-natural ecosystems, or manmade disturbance zones. An invasive alien species is a naturalised alien species that invades the aforementioned areas (Richardson *et al.,* 2000). Figure 1.1 details the four main stages of an alien species in the process of becoming an invasive species. The initial stage is introduction and the end stage, invasion. Naturalised alien species do not necessarily always become invasive.

Williamson and Fitter (1996) suggests that 1 in 10 introduced species becomes naturalised and, furthermore, 1 in 10 naturalised species becomes invasive. This suggests approximately 1 in 100 introduced species become invasive. There are several factors that affect the process of an alien species becoming an invasive alien species (Richardson *et al.,* 2000). These stages exist on a continuum, and it can be difficult to determine where on the continuum a species is or when, or if, it will progress to the next stage (Goodenough, 2010). These stages are presented in Figure 1.1.

[1] Naturalisation – the process by which an alien species integrates itself into a non-native environment and establishes a self-sustaining population (Pyšek *et al.,* 2020)

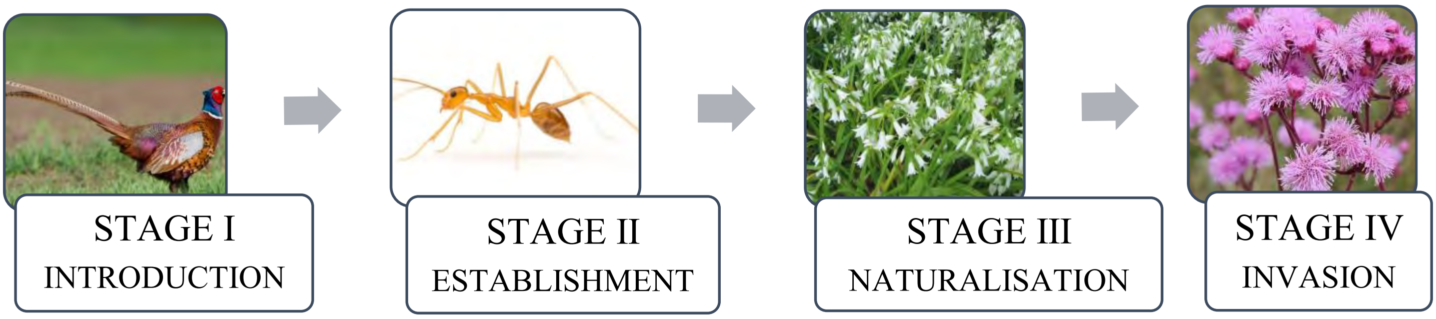


Figure 1. 1: Stages along the invasion continuum; With species that happen to occupy those stages at the time of writing. Pictures: (i) *Phasianus colchius* Linnaeus (Phasianidae) (Ring-necked pheasant) a popular introduced species as well as a valuable "game bird" (Unsplash.com, n.d.), (ii) *Anoplolepis gracilipes* Smith (Formicidae) (Yellow crazy ant) an established species of ant in Australia (White, 2018), (iii) *Allium triquetrum* Linnaeus (Amaryllidaceae) (Three-Cornered Garlic) a species of bulbous plant naturalised in South Africa (Tamar Valley Weed Strategy Working Group, n.d.) and (iv) *Campuloclinium macrocephalum* Lessing (Asteraceae) (Pompom weed) an renowned invasive species in South Africa (Capetowninvasive.org, n.d.).

Invasive alien species scientists in South Africa, like other scientists around the world face challenges in coping with invasive alien species (IAS) (South African National Biodiversity Institute, 2018). Invasive alien species consist of organisms from all six Kingdoms of life. However, invasive alien species of the plant Kingdom are considered the most damaging and attributed with the greatest environmental and economic impacts (McGeoch *et al*., 2010). In South Africa, there have been an estimated 9000 introductions of alien plants, of which 1400 have established (van Wilgen *et al.,* 2020). The success of invasive species establishing and spreading in South Africa means it is one of the most invaded countries in the world, with both natural and semi-natural ecosystems seriously affected (Moran *et al*., 2013; van Wilgen *et al.,* 2020)

The intentional introduction of alien plant species is often related to economic incentives (Perrings, 2000; Emerton and Howard, 2008). These species can also be requisite for certain economic activities such as agriculture, ornamental decoration, sport, soil control and pest control (Pimentel *et al*., 2005). The unintentional introduction of alien plants is often connected to distinctive economic activities such as trade, with a significant relationship existing between the volume of trade a country experiences and the number of IAPs present (Westphal *et al*., 2007).

The use of economics in invasion science is usually referenced for one of three reasons: (i) to discern the best management option for IAS, (ii) to determine how individual behaviour is influenced by IAS policy and (iii) an evaluation of the impacts of IAS (Marbuah *et al*., 2014). However, these three reasons could be limited in their theoretical understanding of the two fields of economics and invasion science. At present, these three are a description of the uses of various tools provided to invasion science through certain branches of economics. It is not an understanding of underlying subject fields and their epistemological relationship. This is an issue raised in Hanley and Barbier (2009) and one that appears to be regularly glossed over in studies of this nature. There is a need to observe the interaction between economics and invasion science on an epistemological level in order that the methods applied in this study and results obtained as a result are congruent with this epistemological interaction. The start of this understanding is the definitions of the two fields.

Invasion science is defined as "…the study of the causes and consequences of the introduction of organisms to the areas outside of their native ranges. It concerns all aspects relating to the transport, establishment and spread of organisms in a new target region, their interactions with resident organisms, and the costs and benefits of invasion with reference to human value systems." (Richardson and Ricciardi, pg. 1461, 2013). An aspect missing from this definition is the management efforts put forward by invasion science regarding invasions. Although, this could potentially fall under the term "consequences", a central tenet to invasion science is solutions to the problems of invasions. This aspect will be included in the definition for this study. The definition provided above can be deconstructed into eight core tenets:

i. Transport of alien species.
ii. Introduction of alien species.
iii. Establishment of alien species.
iv. Spread of alien species.
v. Interactions of alien species with environment and surrounding ecosystems.
vi. Causes and consequences of alien species.
vii. Costs and benefits associated with alien species presence.

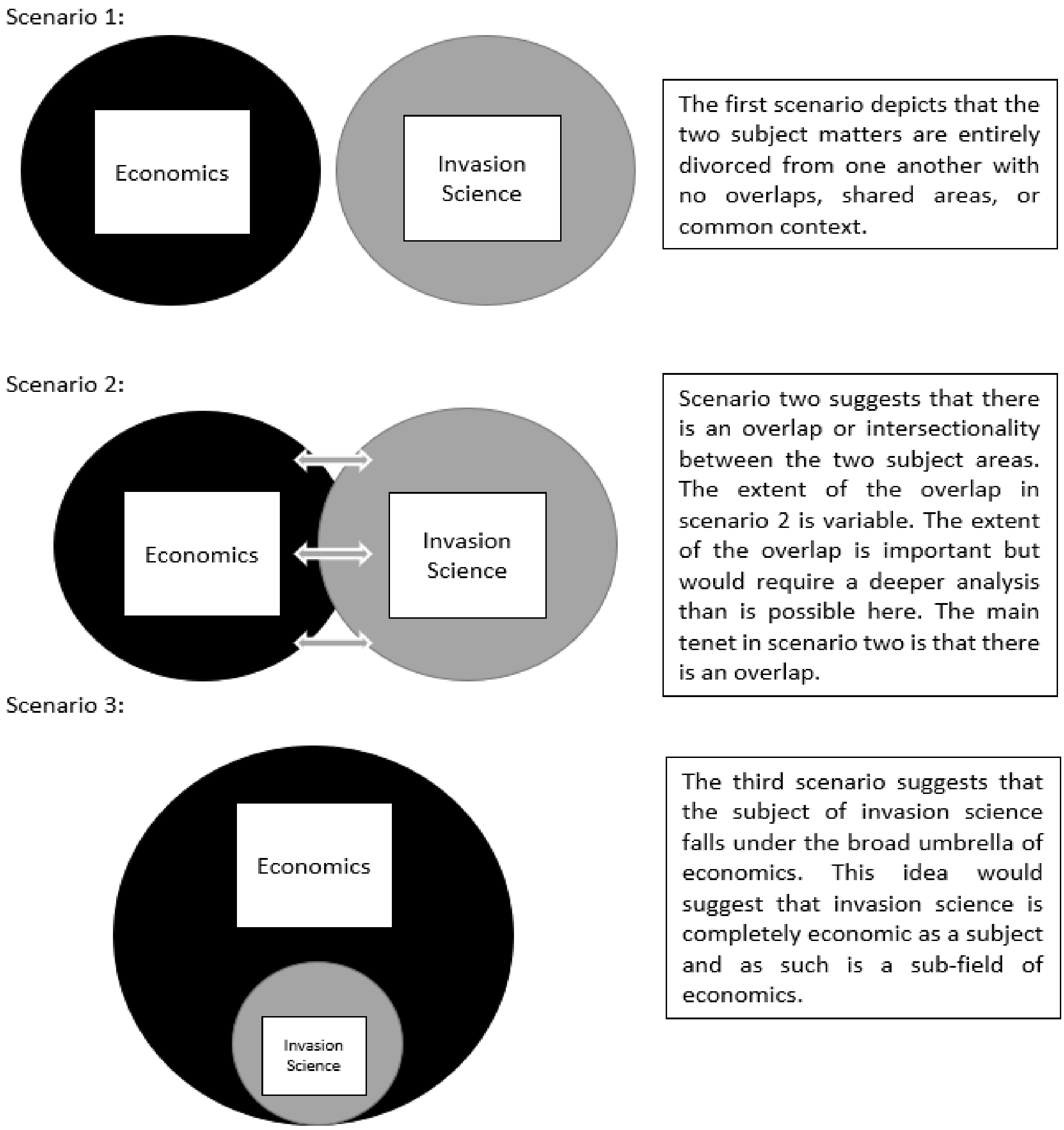
viii. Solutions and resolution towards alien species.

These eight tenets provide the epistemological parameters that encapsulate the field of invasion science. An understanding of these core tenets, what causes them, how they work, their interaction with one another, and the general knowledge surrounding them will lead to an understanding of invasion science. Suffice to say, this is a substantial task and one that is beyond the scope of this study. An effort has been made in appendix II to draw some inference between the eight tenets of invasion science and economics by exploring the literature surrounding these tenets. The end objectives being to ascertain the underlying nature of the tenets as economic or non-economic. This appendix is essential to understanding the nature of relationship between economics and invasion science and understanding what this relationship is and how it works.

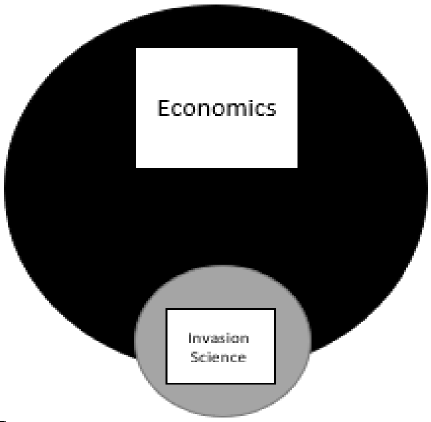
There is no single definition of economics. It is generally agreed that Robbins' (1935) definition embodies the foundational essence of economics "… the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses." This definition primarily postulates that economics is concerned with human behaviour. A central paradigm of economics is that it is predicated on human behaviour and as such, is a social science. The use of valuation techniques is evident in the invasion science literature (Piementel *et al.*, 2005; Howard and Emerton, 2008; James and Lockwood, 1998; Sinden *et al.,* 2004) as well as in the economic literature dealing with invasion science (Marbuah *et al.,* 2014). Economics can certainly be used to assess the value of impacts, i.e., generate monetary values, however, this does not embody the full extent of the use of economics in the invasion science field. The involvement of economics in invasion science is not solely the derivation of financial values, the resultant interplay of policy on the economy, or even the best management method. These are simply some of the uses that economics can be put to. This study is primarily concerned with the derivation of monetary units, through economic methods, in invasion science. The monetary values generated through economic methods by invasion science can represent a heuristic for understanding the magnitude of impact of the invasive species.

Combining the definition of Robbins (1935) with John Stuart Mill's (1843) perspective on economics provides insight to the problem at hand. Mills suggests that economics is largely concerned with the consequences of an individual's pursuit of tangible wealth. In this sense, man and man's activities are driven by the need or desire for wealth. The pursuit of this wealth leads to endeavours such as the introduction of alien species into a new environment that can result in an assortment of consequences such as biological invasions. As such, invasion science could be founded predominantly on the economic rationale of individuals engaged in the pursuit of tangible wealth.

Using the definition of invasion science from Richardson and Ricciardi (2013) and the understanding of economics provided by Robbins (1935) and Mill's (1843), the epistemologies of invasion science and economics can be fused to gain a better understanding of how these two subject matters engage with each other. This fusing provides a novel opportunity to engage in a meaningful literature review that not only uncovers the existing ideas in both fields but attempts to combine those ideas into a single understanding. This will provide a framework in which to start to unpack the complex questions regarding the potential conflicts of interest surrounding Rubus in South Africa. It is necessary to understand the ideological disposition of these two fields in terms of subject matter to one another as this understanding could develop insights into the nature of the problem faced from invasive Rubus species. Supposing that the subject matters contained within these two ideological frameworks can be encapsulated within the confines of two Venn diagrams, assume that the physical boundaries of the Venn diagrams represent the intellectual boundaries of the subject matters. A Venn diagram can be created for economics and one for invasion science. These Venn diagrams are then used to present six scenarios of the fusing of the fields of invasion science and economics. These are presented below in Figure 1.2 and a description of each scenario provided.

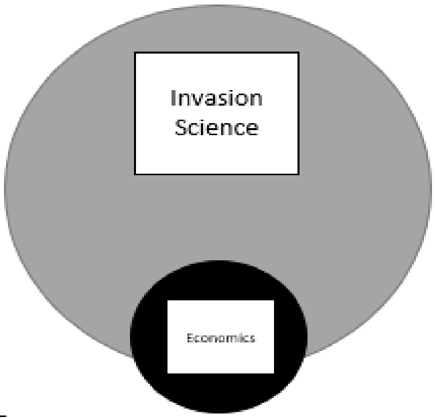


Scenario 4:



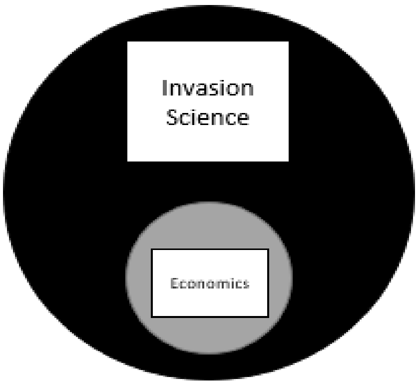
Scenario four suggests that a significant portion of invasion science falls into the economic field with aspects of the science falling outside the scope of economics.

Scenario 5:



Scenario five suggests that a significant portion of economics falls into the invasion science field with aspects of the economics falling outside the scope invasion science.

Scenario 6:



The sixth scenario suggests that the subject field of economics falls under the broad umbrella of invasion science. This idea would suggest that economics is a subfield of invasion science.

Figure 1. 2: Venn diagrams representing epistemological relationship between economics and invasion science.

This section of the study has sought to establish an understanding of the relationship between economics and invasion science (a thorough discussion of the epistemological associations is available in appendix II). Invasion science provides a specific definition whereas economics does not and as such, the definition of invasion science was used as the basis of assessment. The tenets were explored and discussed with all factors contained within each tenet that related to economics being highlighted (see appendix II). For the most part the eight tenets appeared to be either predominantly driven by economics or to have considerable economic ramifications. Those tenets that could, subjectively, be asserted as predominantly economic included: Transport of AIS, introduction, establishment, causes and consequences, costs, and benefits, as well as solutions and resolution. The other two tenets, interactions with environment and spread of alien species, are more nuanced. The interactions of alien species with the environment are based on a set of different impacts, many of which are economic or have prominent economic components. However, there are also several impacts that do not exist within the conception of economics and therefore mitigate the economic dominance of this tenet. The spread of alien species appears to be driven substantially by economics, however, whether this is a significant contribution cannot be asserted given the wide array of literature on the spreading of alien species of their own accord as well as by non-economic factors such as birds and wildlife.

Accordingly, six of eight tenets are deemed predominantly economic. The two not deemed largely economic are still supposed to have prominent economic components. As such, this study concludes that scenario 4 of Figure 1.2 best depicts the epistemological of the general relationship between economics and invasion science. This scenario suggests that invasion science is largely economic. In this sense, invasion science appears to be driven by economic factors, informed by economic rationale, quantified through economic means, and yet, still has several components that fall outside the scope of the field of economics. The scenario and Figure, 1.2, depict the general nature of the relationship between economics and invasion science. However, the question must be raised if this relationship is consistent across individual alien species? This specific thread of investigation will be addressed at the end of the study regarding invasive *Rubus* species and whether these species fit the scenario depicted in Figure 1.2.

Invasive alien species have a multitude of impacts that can be both positive and negative (Cronk and Fuller, 2001; Pimentel *et al.*, 2005). The negative impacts can be extreme and detrimental to the surrounding environment, ecosystem, and economy (Aloo *et al.,* 2017). For example, invasive alien plants produce negative impacts by penetrating natural vegetation and supplanting, altering, and transforming the native vegetation, local environments, and ecosystems (Gurevitch and Padilla, 2004; Hooper *et al.*, 2005; Pimentel *et al.*, 2005). The ability to outcompete indigenous plant species stems from a range of morphological and ecological characteristics that give the invasive alien species an advantage. These include the ability to propagate at a faster rate than natural vegetation, a lack of predation due to an absence of naturally attuned predators in the new area as well as the ability to occupy specific ecological niches in the new environment (Cronk and Fuller, 2001; Pimentel *et al.*, 2005; Batish *et al.*, 2008). These processes can result in negative environmental and economic effects. The environmental effects can include reduced biodiversity, altered fire regimes, overburdened water resources and a breakdown of ecosystem functioning (Brooks *et al.*, 2004; Hooper *et al*., 2005; Turpie *et al*., 2008; Hill and Coetzee, 2017). Many of the above effects have economic ramifications. Explicit economic effects include restriction of human and animal access to certain regions, reductions in pasture production, reduced crop yields, interference with irrigation schemes and development of pests for major primary industries such as forestry and agriculture as well as the direct cost of management (James and Lockwood, 1998; Perrings*,* 2000; Sinden *et al.,* 2004).

The impacts associated with Invasive alien species can also be positive. For example, invasive alien plants have many positive attributes (Cronk and Fuller, 2001; Geldenhuys *et al.*, 2017). These positive attributes can also be both environmental and economic. For instance, some invasive alien plants species are utilised as soil stabilisers others as a source of food (Campbell, 1987; Cronk and Fuller, 2001; Humphrey*,* 2016). This creates a paradox in which species have both positive and negative impacts. Invariably the impacts are incurred by different groups, with some groups benefitting, while others are disadvantaged. This can lead to conflicts of interest between certain groups, particularly those that benefit from the invasive alien species and those that do not (Zengeya *et al.,* 2017).

The impacts of invasive organisms on their surrounding environments can be considered externalities. An externality is a situation in which a cost or benefit is incurred by an economic entity that was not privy to the initial transaction (van Rensburg *et al.,* 2015). In other words, individual A imports a plant species, that species becomes invasive and begins to impact individual B. Individual B was not part of the process of introduction nor were they the reason the plant species was introduced. As such, the impacts incurred, both positive and negative, are externalities to individual B. Invasive alien plant related externalities differ from traditional externalities in that they are self-perpetuating whereas traditional externalities cease if the activity is stopped (Perrings, 2000; Emerton and Howard, 2008). An example would be *Acacia salinga* (Labill.) H.L. Wendl. (Fabaceae) which was introduced into South Africa as a dune stabilising plant (Cronk and Fuller, 2001). Initially the plant performed as expected, but when left unattended *A. salinga* quickly supplanted Fynbos biome species (Cronk and Fuller, 2001). *Acacia salinga* is still problematic, has enduring soil legacy effects, requires constant management to ensure that it does not spiral out of control and is the most prominent invader of the endangered Fynbos biome (Nsikani *et al.*, 2018). This characteristic is problematic as the externality self-perpetuates rather than stopping after the initial use is ceased.

Several efforts have been made to establish the value of the impacts of invasive alien plants (James and Lockwood, 1998; Sinden *et al.,* 2004; Pimentel *et al.,* 2005; van Wilgen and de Lange, 2011; Ngorima and Shackleton, 2019). These studies are often confronted by methodological issues as well as limited scope (Emerton and Howard, 2008). These were issues confronted by this study. Invasion science is not static and although there are similarities between different invasions often there are unique and complex factors that exist due to the virtue of a species or the region that species is encountered. The application of generic prescribed economic assessment methods to these unique contexts should be approached with care to avoid misrepresentation or partial elucidation of underlying impacts and the magnitude of those impacts. South Africa has a strong scientific community centred on evaluating ecological impacts of invasive alien species (Clusella-Trullas and Garcia, 2017; Foxcroft *et al*., 2017; Hill and Coetzee, 2017; Kaplan *et al*., 2017; van Wilgen *et al*., 2020). However, limited literature exists regarding the economic impacts of invasive alien species. When conducted, economic impact valuations in South Africa are either (i) country-wide (van Wilgen and De Lange, 2011), (ii) focused on institutions, such as South African National Parks or the Department of Environmental Affairs Extended Public Works Programme "Working for Water" (McConnachie *et al*., 2012, McConnachie *et al*., 2013; Foxcroft *et al*., 2017), or (iii) are species, or genus, specific (van Wilgen *et al*., 2012; Humphrey, 2016). At present, invasive alien species are estimated to cost South Africa ZAR 2 billion (US$117 205 000) annually in forgone production and control costs (van Wilgen and De Lange, 2011). The problem is growing given the expansion of current infestations and what appears to be a regular introduction of new invasive alien species (Henderson, 2007; van Wilgen *et al.,* 2020).

The impacts of invasive alien plants adhere to socio-economic patterns in which the costs are asymmetrically distributed across economic classes and industries (Pratt *et al.,* 2017). Lower economic classes and primary industries appear to bear the brunt of costs (Sinden *et al*., 2004; Pratt *et al.,* 2017). This can be problematic as lower economic classes often lack the economic resources to successfully navigate exogenous shocks to their personal economies (Shackleton *et al*., 2029). These individuals often inhabit areas that are focused on primary industry or else regions that are highly dependent on primary industry. In South Africa, primary industries such as agriculture, forestry and fisheries contributed 2.6% (the largest contribution of any industry) to economic growth in the third quarter of 2017 (Statista, 2017). The need to protect sources of economic growth is essential. To ensure the contributions of the industries are maintained, if not improved, any knowledge gaps or adverse impacts on the industries must be filled (Gurevitch and Padilla, 2004; Pimentel *et al.*, 2005).

The above-mentioned negative impacts of invasive alien species often lead to some form of macro-economic expenditure directed at providing a solution. An example of this is the Working for Water programme. This programme was founded on the premise of a government works programme directed at solving the environmental problem of invasive species (van Wilgen *et al.,* 1998). This expenditure is invariably taxpayer funded and paid through a relevant government department. In the case of Working for Water (WfW), this would be the Department of Forestry, Fisheries and Environment (DFFE). An understanding of the mechanics of financial flows inherent to programmes such as WfW is essential as these programmes appear to be the most prominent influencers on the control or mitigation of invasive alien species impacts.

DFFE has seven mandates enacted by the Parliament of South Africa and enshrined in legislation. They are commonly referred to as Acts. DFFE is required, by law, to spend the funds allocated to it on ensuring that these mandates are fulfilled. Two of these, the National Environmental Management Act (1998) (Republic of South Africa, 1998) and the National

Environmental Management: Biodiversity Act (2004) (NEMBA) relate to alien and invasive alien species (Republic of South Africa, 2014). A stipulation of NEMBA is the establishment of the Alien and Invasive Species Lists (AIS) (2016) to aid in the process of biodiversity conservation (Republic of South Africa, 2016). The AIS list contains four main categories of invasive species: 1a, 1b, 2 and 3. These categories are discussed in depth in chapter 3 and appendix II. The categorisation process for the AIS lists was expert driven and that these categories directly influence the finance available for alien and invasive species is worth noting (PAIA172588, appendix III). The category assigned to a species will determine the prioritisation of that species by DFFE and its sub-departments and the extent to which resources will be directed at the species. Direct criticisms have been made that the funds allocated to Biodiversity and Conservation is simply too low and consistently so (van Wilgen *et al.,* 2020). The nine sub-departments that make up DFFE must present proposals for funds to achieve the mandates of DFFE. There are reviews of the progress on an annual basis in Parliamentary hearings and the sub-departments are compared against one another by DFFE with an underlying emphasis on performance (Parliamentary Hearing Group, n.d.).

The idea of the government bearing the costs of negative externalities is not new. Pigou, the economist regarded as the founder of externalities, remarked that externalities almost always become the problem of the governing body (Pigou, 1932). This is as true now as it was in 1932. The public purse has several competing needs and funds received need to be utilised as efficiently and effectively as is possible. A primary concern of government funded operations is performance budgeting (Robinson, 2007). This refers to the process of creating stronger links between expenditure and results from a macro-economic viewpoint. The smaller an economy, the more that frugality of expenditure is desirable, particularly in South Africa given the plethora of demands on tax revenue (Robinson, 2007).

Thus, given the competition for funds on both a government and departmental level, the abundance of problematic invasive alien species, and myriad competing needs over finance, it is essential to ensure that those invasive species prioritised are going to maximise the marginal returns on every Rand spent. An essential component of this in invasive alien species literature is the need to address species from a neutral standpoint (Ngorima and Shackleton, 2019). Invasive alien species impact assessments need to consider both the benefits and costs of that species not only in keeping with academic rigour, in which objectivity is sought before subjectivity, but in ensuring an accurate understanding of a species is generated. Not acknowledging the positive impacts of a species could result in a biased prioritisation outcome. This lends itself to a lower real marginal return than the potential marginal return on public money spent. In other words, the benefits, positive results, or good outcomes of the expenditure made on a species, that would not have been prioritised had more information been available regarding that species, are not as large as they could have been had a different species been prioritised. Thus, candour and extensive coverage of the impacts must be pursued whenever a project intends to be utilised in the prioritisation process. Examples of this bias are contained in Leitch *et al.* (1996) and Humphrey (2016), which provide the basis for the bioeconomic models formed in chapter 4 of this study. Leitch *et al.* (1996) and Humphrey (2016) only consider the negative impacts of the species being assessed. This generates a method of enquiry that of which is not possible of elucidating the potential positive aspects of a species and immediately limits the study in its scope and range of assessment. The results of these studies are predestined to present a negative perspective of the species regardless of whether that is the case or not.

Maintaining academic rigour and objectivity produces studies that can fully inform prioritisation processes. The prioritisation process involves the categorisation of IAS into specific categories that are contained in the AIS lists previously mentioned. These lists inform management efforts, i.e., which species are focused on, what funding is dedicated to those species, and whether the management is aimed at eradication or containment. Theoretically, this process should involve an assessment of the IAS across several fields – primarily ecologically and economically – coupled with extensive stakeholder engagement as well as expert opinion. An important aspect of the assessments is the stage of invasion that the IAS currently occupies – this being predicated on the fact that the stage of invasion is usually regarded as linked to the magnitude of impacts experienced and therefore the cost of management (Richardson *et al.,* 2000). These assessments were, at the time, based mostly on the Australian Weed Risk Assessment (AWRA) document, developed in Australia. This has since been replaced by a South Africa document of a similar ilk (Kumschick *et al.,* 2018). These assessments are based primarily on literature available on the species under assessment. If the literature is not available, impacts are not known, and economic studies have not been conducted on that species, these assessments will not provide a holistic overview as they will not contain said information. The assessments will simply speak to whatever literature is available on the species. Where the literature is not available, expert opinion is used to inform decisions (PAIA172588, appendix III). In the case of invasive *Rubus* species, only one risk assessment was available for a single species of the six categorised. This assessment is based largely on Australian literature (PAIA180636, appendix IV). This suggests that the categorisation process of invasive *Rubus* species in South Africa was largely based on expert opinion – given the lack of literature or assessments available on the *Rubus* species in South Africa. This is in large part the reason why this study included an assessment of experts in invasion science – the people that make said decisions. The lack of South African literature on the invasive *Rubus* species could suggest misinformed decision making and inefficient allocation of scarce management resources regarding these species. It indeed serves as one of the validations of this study.

Species in the *Rubus* genus can grow up to 50-80mm a day and may form thickets of erect, semi-erect or sprawling thorny brushes that are highly obstructive (Zia-ul-Haq *et al*., 2014). Some *Rubus* species are listed as the third most significant weed class in Australia and are noted for impacting grazing, harbouring vermin, creating fire hazards, altering the fire regime of an area, changing the understory dynamics of forest floors, and creating impenetrable thickets along tourist paths (Thorp and Lynch, 2000; Sinden *et al*., 2004; C. Els, [Stutterheim Greater Fire Protection Association] pers. comms., 6 June 2018). Invasive alien *Rubus* species in South Africa are known to form extensive thickets and cause serious problems on grazing lands, forestry plantations and along roadsides (Botha, 2005; Henderson, 2011).

The negative impacts of species in the *Rubus* genus observed in other countries, suggests control should be considered in South Africa, while the benefits suggest that perhaps the growth and use of the genus should be promoted. A problem is knowing which *Rubus* species are useful, and which are not. This study, in part, has tried to understand the complex interplay of invasive and alien *Rubus* species in South Africa and determine which species are providing benefits, which are imposing costs, and which are doing both. Assessments of *Rubus* species have been conducted on a regional basis with a particular focus on the Cape Floristic Area – not an area covered in this study – (Sochor *et al.,* 2018a), the Eastern Cape Region

(Sochor *et al.*, 2018b) and as an independent field trip conducted under the auspices of this study in the Eastern Cape, Free State and KwaZulu-Natal provinces. What is certain is that the *Rubus* species in South Africa is complex. Assessments show a broad array of species that are alien, invasive alien, and native in addition all the species can form hybrids between them. Alien *Rubus* species in South Africa originate from Asia, Europe, and North America (Sochor, 2018). Past assessments have been entirely botanical, with emphasis on the collection of taxonomic material (Sochor, 2018). The economic assessment of invasive alien *Rubus* species in South Africa is bereft at present. Of course, the fact that species in the *Rubus* genus are still under assessment, i.e., the species are still in the process of being determined, makes it difficult to attribute impacts to specific species. This has evident implications for management.

The pressing need to study the invasive *Rubus* species in South Africa stems from contrasting indications of its positive and negatives impacts. As has been discussed above, and is deliberated on further in chapter 2, the invasive *Rubus* species are associated with both positive and negative impacts. They are also associated with commercially relevant *Rubus* species and as such, can be a cause for conflict between differing groups. This is particularly relevant in the context of biological control. Furthermore, it appears many of their benefits may accrue to rural impoverished communities of a vulnerable socio-economic standing. This makes the host of invasive *Rubus* in South Africa a particularly pressing concern from a policy making and management perspective. This is a concern that this thesis seeks to elucidate upon.

Management of the species in South Africa at present is represented by several clearing schemes which target invasive species. These programmes were not solely directed at the clearance of *Rubus* species except for one conducted in the Drakensberg (PAIA 173871, Appendix V). Conventional methods of control, such as mechanical cutting or herbicides, are often short term, expensive and cumbersome to implement (McConnachie *et al.*, 2012; van Wilgen *et al.,* 2012). Biological control agents for *Rubus* species have been tested and implemented in Australia with a degree of success against certain species of *Rubus* (Bruzzese and Hasan, 1986; Bruzzese and Mahr, 1998). At present no large scale, biological, mechanical, or chemical control has been utilised in South Africa against alien *Rubus* genus plants.

There are invasive alien *Rubus* species in South Africa. They have impacts, both positive and negative, of which many have not been determined or assessed before. These impacts, an understanding of them, an assessment of which communities they are impacting, and a range of values for those impacts would be useful in developing an effective management protocol for the *Rubus* species. This thesis is an effort to find this information and present it in a manner that allows effective and nuanced management.

1.1. AIM OF THE STUDY

The primary aim of the study is to understand the interactions between invasive *Rubus* species and economic agents[2] in South Africa. This relationship will be primarily represented through the deriving monetary values representative of the benefits and costs associated with the aforementioned interactions. The aim is purposefully broad. The objectives laid out below set out in more detail what the intention of the thesis is, what is meant by "interactions" and the questions that will be answered through the course of this thesis.

1.1.1. Research Objectives

This study will aim to quantify the following research questions:

1. Are invasive alien *Rubus* species having a net negative or net positive impact on the South African economy? Furthermore:

1.1. If so, what is are these impacts, and can they be regarded as externalities?

1.2. Where are these impacts being experienced?

1.3. What is the monetary value of these impacts?

1.4. Can these impacts be attributed to a species of invasive alien *Rubus* species?

1.5. What is the sentiment of economic agents toward invasive *Rubus* species given the above impacts?

The thesis begins with a literature review which covers the relevant botanical, economic, and invasion science literature. This is followed by a discussion of the *Rubus* genus in South Africa to provide context to the thesis. The methods section then follows detailing the approach of the study with the results of the study being presented in the next section shortly thereafter. Lastly, the thesis findings are surmised, and the thesis ended with a conclusion section.

[2] Economic agents – a term encompassing individuals, institutions, households, and businesses. The thesis is seeking to get as wide an understanding of the interactions between the invasive *Rubus* species and the economy of South Africa. This requires a term such as "economic agent" – given that this is a first assessment and it is not known which individuals, households, businesses etc are impacted – to ensure full coverage is sought.

Several appendices follow thereafter to provide the reader with extended context and details pertinent to the thesis.

CHAPTER 2

LITERATURE REVIEW

"The truth is rarely pure and never simple."

~ Oscar Wilde (pg. 6, 1895).

From an epistemological standpoint this study falls between two separate fields: economics and invasion science. Many studies have fallen in the same zone. Invariably the approach of the latter studies has been to apply economic methodology to invasion science problems. This provides results that are often useful and adequate at face value but may be devoid of vital understanding required for more nuanced decisions or prioritisation efforts. This approach to academia creates a culture of repetition and 'face value' application of generic methods rather than deep understanding. This study has already expressed a deference toward seeking objective truth and a genuine understanding of topics wherever possible. All information presented is based on pre-existing ideas, peer reviewed articles, recognised books, or otherwise credible sources.

2.1. VALUATION OF ECONOMIC COSTS AND BENEFITS

Economics is often used in invasion science to derive monetary values for impacts (Pimentel *et al.,* 2005). This invariably involves valuing invasive species interactions with the environment, the value of controlling the invasive species and the opportunity cost value of the invasive species (Sinden *et al.,* 2004; Humphrey, 2016). The establishment of value is based on several underlying economic theories.

Originally, value from an economic standpoint was believed to be intrinsic: the value of an item was implicit in an item and this value was invariably associated with a divine value imposed by a higher power such as God (Roy, 1989). In other words, entities on Earth were regarded as having an intrinsic value that was given to them by a non-human actor[3]. As economic theory developed, and the separation of Church and State became more widespread, so the value of an object was thought to be linked to the labour employed in the

[3] Actor – a participant in an action or process.

generation of that item (Roy, 1989). This theory of value then morphed into the modern concept that acknowledges that value is derived from the subjective evaluations of economic agents (Roy, 1989). In this regard value is not purely rooted in the time and effort exerted into a good or service. Rather, value is a mixture of the labour inputs as well as the basic supply and demand determinants acting on that good or service within that market. Value is thus a highly contextual idea.

Placing an economic value on an impact makes it a tangible, relatable concept that can be widely understood across most fields (Dickie *et al*., 2014). This is true of any impact be it environmental or otherwise. Such valuations are subject to value judgments, lack a method for incorporating uncertainty and can be dependent on a discounting rate (Dickie *et al*., 2014). However, even with these limitations, the inherent 'invisibility' of many ecosystem services results in a lack of valuation (Kettunen *et al*., 2012). This lack of valuation leads to ecosystem undervaluation and overexploitation (Kettunen *et al*., 2012). The results from economic valuation methods can inform policy decisions that have implications for the management of ecosystem services and can assist in avoiding undervaluation and overexploitation (Anderson and Carpenter, 2010). However, these valuations are hindered by a lack of understanding regarding the interactions between the environment and economy as well as the fact that ecosystems are, by nature, in a state of flux (Hanley and Barbier, 2009). This state of flux means that valuations can overlook certain key environmental concepts such as the fact that most ecosystems are subject to threshold values that, once passed, result in a steep decline in ecosystem functioning (Hanley and Barbier, 2009). The literature on economic valuation of ecosystem services considers and highlights the limits of the methods available (Hanley and Barbier, 2009; Anderson and Carpenter, 2010; Kettunen *et al*., 2012; Dickie *et al*., 2014). However, there is also an acknowledgement that the provision of a value, albeit generated through limited and flawed means, is better than no value whatsoever. Failure to account for the full cost of an activity or environmental phenomenon results in decisions that are misinformed (Liu *et al.,* 2008). An evident example is the revision of Chinese logging practices. Extensive logging in China resulted in large, deforested areas that increased the incidence of mass mudslides during unprecedented rainfalls. After these mudslides, the government of China recognised that the decisions surrounding the logging industry had failed to fully account for the ecosystem services provided by forests (Liu *et al.,* 2008). Once the value of ecosystem services provided by forests were taken into consideration the preservation of forests was acknowledged as more beneficial for the economy, by a factor of three, than current logging practices (Liu *et al.,* 2008). This is not an isolated case in which total environmental value was overlooked with relatively dire consequences. In Bangladesh, the practice of Shrimp farming has been promoted over and above the preservation of mangrove swamps that provide vital ecosystem services (Paul and Vogl, 2011). The shrimp sector is given over to market fluctuations, is creating social unrest due to displacement, and has created saltwater intrusion, increased sedimentation, facilitated disease outbreaks and heightened pollution (Paul and Vogl, 2011). This serves as a case study of the issues that can cascade when there is a failure to fully account for environmental services. The practice of economic valuation provides a rational and accurate template of figures from which political decisions can be made that are accurate and take cognisance of the entire spectrum of economic value. A discussion surrounding environmental science, needs to recognise that there are vested interests on all formats, from citizen science, that favours the citizen's region, to strong links between scientific research and certain industrial sectors (De Biévre and Dür, 2007). There is a need to accept that the literature is biased in some way, shape or form due to the incidence of interests from funding sources through to the interests of a group (De Biévre and Dür, 2007). Hence, most economic valuation has a degree of agenda imbedded within it that results in the promotion of ideals, the generation of certain results or conclusions that favour a certain pathway. However, the provision of a value is regarded as preferable to no value whatsoever.

The paradigm of economic valuation is broad and contextually malleable. The base assessment is that economic valuation from an environmental perspective requires as understanding that the environment[4] is an asset and needs to be viewed as such (van Rensburg *et al*., 2015). The environment is considered an asset as it contains resources (Ahmed, 2000). These resources are essential in the economic process of creating goods and services. This viewpoint is considered as the traditional environmental economics perspective (Ahmed, 2000). This original perspective was undergirded by a fixation on "stock" rather than

[4] Environment - the natural world, as a whole or in a particular geographical area, especially as affected by human activity.

“flow”. Stock and flow are economic terms used to describe the nature of economic resources. A “stock” in environmental economics is a fixed, non-flowing amount of resource. A “flow” in environmental economics describes a transference of resources between entities. Subsequently, modern environmental economics has come to value the conception of flow more than stock, this is embodied by the emphasis on ecosystem services seen in the literature (Wallace, 2007; Banzhaf and Boyd, 2007; Fisher *et al.,* 2008). Ecosystem services are defined as “…the aspects of ecosystems utilized (actively or passively) to produce human well-being.” (Fisher *et al.*, pg. 1168, 2008). They are essential to understanding the process by which man utilises nature to generate wellbeing. Ecosystem services represent flows in environmental economics and a recognition of their importance serves to highlight the shift in environmental economics from a predominantly stock perspective to a mutual appreciation of both stock and flow. Ecological economics is regarded as the opposition school to environmental economics (Costanza, 1989). The most prominent difference between the two schools is their treatment of the natural environment. Ecological economics views the economy as a subsection of the environment (Costanza, 1989) whereas environmental economics views the environment as a subsection of the economy (van Rensburg *et al.,* 2015). This study will adopt an environmental economics perspective given that the aim is to address the socio-economic context of the invasive *Rubus* species, as such, the more anthropocentric viewpoint is preferred.

Ecosystem services, stock of environmental resources and flows of environmental resources are all viewed from an anthropocentric lens. These natural elements in environmental economics are always considered from the viewpoint of man. This comes back to the original definition provided by Robbins (1935) in which humans are considered the protagonist. This understanding indicates that man and nature have interactions. It is these interactions that economics is concerned with and often economics places a “utility” or “use value” on these interactions. These interactions are categorised into use values, non-use values and option values (Tietenberg and Lewis, 2012).

Use values are regarded as the utility derived from ‘consuming’ an environmental good. Use values recognise utility derived from the non-consumptive use of the environmental goods and services and consumptive use of goods and services. The South African coal industry is a good example of a consumptive use of environmental goods. The coal is mined, transported, and burnt to generate energy. In the process of deriving utility, which is the power generated by the burning of coal, the coal is consumed and hence no longer available. An example of non-consumptive use would be the vistas available in the Drakensberg region of South Africa. Utility is derived from the viewing and visiting the natural scenes of beauty and splendour. In seeing the famous Amphitheatre in the Northern Drakensberg, or the beautiful scenes in the South an economic agent derives utility. However, that agent does not detract from that resource or diminish the amount of resource available for the next economic agent. As such, this use value is non-consumptive. Use value has been described as “First-hand enjoyment of resources and their by-products.” (Anderson and Carpenter, pg. 244, 2010).

Non-use value is broken into two separate sub-categories: bequest value and existence value (Tietenberg and Lewis, 2012). Non-use value is regarded as the utility derived from not making use of an environmental good. Bequest value specifically refers to the utility derived from leaving, or bequeathing, behind an environmental good to the next generation. Existence value is that measurable utility that can be derived from an individual knowing that an environmental good or service is still in existence. Examples of this would be the Alaskan Permanent Fund, aimed at distributing the wealth generated using Alaskan non-renewable resources across present and future generations (Alaskan Permanent Fund Corporation, n.d.), and most conservation funding provided by peoples that do not engage with polar bears, rhinos or any other endangered species and yet donate towards the conservation of those species (World Wildlife Fund, n.d.).

The last form of value is option value. It is the utility derived from the knowledge that the option to make use of an environmental good is available to the individual. Thus, an individual may not necessarily wish to make use of a pristine national park, but they have the option to do so if they so wish. An example of option value would be the shale gas reserve found under the Karoo (Shell, n.d.). South Africa as a society effectively enjoys option value at present given the fact that the exploitation of the shale gas reserves has not yet been decided upon (Githahu, 2019). Hence, the shale gas, and its resultant exploration, are an option for South African society moving forward.

The above theories of use and value are important in understanding the tools and methods available to generate a numerical figure to use as representative of the above-mentioned values. There are several methods available for deriving an environmental value, they are pointed out in table 2.1 (adapted from Tietenberg and Lewis, pg. 82, 2012).

Table 2. 1: Economic valuation methods, an adaptation from Tietenberg and Lewis, (pg. 82, 2012).

Methods	Revealed	Stated
Direct	Market Price Simulated market	Contingent valuation
Indirect	Travel cost Hedonic Property value Hedonic wage value Avoidance expenditure	Attribute-based models Conjoint analysis Choice experiments Contingent ranking

Establishing economic value for environmental goods and services can be achieved through several means. Some approaches involve distinguishing between the direct costs and indirect costs (Sinden *et al*., 2004). Whereas others recognise other levels of complexity and make use of three separate pillars of valuation: Qualitative, quantitative, and monetary (Kettunen *et al*. 2012). The assessments are often context specific and revolve around those methods highlighted in table 2.1. The process of valuation is based on two axes. These axes represent how the method of assessment is conducted. On the x-axis there is the dichotomy of revealed to stated and on the y-axis, there is the dichotomy of direct to indirect.

Revealed preferences is an assessment method where the economic agent is not explicitly aware that assessment is being conducted (Tietenberg and Lewis, 2012). The assessment is not typically conducted at the point of interaction between the economic agent and the entity under observation. Rather, these assessments are conducted retrogressively. Hence why they are referred to as "revealed". The preference or value associated with the entity by the economic agent is revealed based on the choice they made during the interaction. A good analogy in this case would be an honesty system for doughnuts in an office building. Doughnuts are left in the foyer of the office. Employees are permitted to take doughnuts. A tray is adjacent to the doughnuts, and it is made evident to the employees that they can place money in the tray for the doughnuts they take. The amount of money – including no money at all – placed in the tray by employees indicates the value placed on the doughnuts and doughnut service. Their value of the doughnuts is revealed by payments from employees. Invasive alien species present a unique instance in which there could be revealed preferences or uses by indigenous communities that have yet to be assessed or determined given the lack of investigative effort. For instance, a thicket of Black wattle (*Acacia mernsii* De Wild. (Fabaceae) may hold more value for Eastern Cape Province communities than is initially assumed (Ngorima and Shackleton, 2019).

2.1.1. Direct valuation methods (Revealed): Market Price and Simulated Markets

Direct valuation is the estimation of monetary values by assessing the prices paid by economic agents in a market or simulated market context (Anderson and Carpenter, 2010). Where market prices are available the process of valuation is made easier given the pre-existing economic infrastructure. An example of a market based economic valuation would be Lockwood and Stringham (2018). This study sought to understand the biological and economic factors leading to the release of invasive amphibians and reptiles kept as pets in America. This study used government import records and internet-based marketing sites for alien amphibian and reptile's species as data. This data is market data, i.e., it is records of transactions between economic agents involving the exchange of money for goods, the 'goods' in this case being reptiles and amphibians. This data permitted the finding that the price of alien amphibian and reptile species in America is significant in determining the release of those species into the wild (Lockwood and Stringham, 2018). An economic relationship was understood using the readily available market data. A slightly different approach is the use of simulated markets to internalise non-market goods and services. The value of national parks and free recreational access areas can be regarded as an example of this (Caparrós *et al.,* 2017). Often no market exists for these items. Economic agents use the site or area as utility is derived from this interaction and yet the economic agent does not necessarily pay for that good or service. As such no market information is available to ascertain the value of that site. A market can be simulated to attempt to generate a value for the ecosystem service being used (Caparrós *et al.,* 2017). This process involves using price data from markets that have a good or service with similar characteristics to the one under valuation. These prices are presented to the economic agents that interact with the site under observation and the reactions, approval, disapproval, challenges, and suggestions recorded. Thus, a market is simulated for the environmental good in which a demand function can be generated that reflects what could be the state of demand with a changing price for that good or service (Caparrós *et al.,* 2017). In the case of Caparrós *et al.* (2017) the possible market developed for a recreational park in Andalusia that of which could be used to inform pricing strategies by management. In the invasive alien species context, market simulation can be used to understand the reactions that might be possible given certain biodiversity policies (Marbuah *et al.,* 2014).

Another invasion science example is provided by *Lymantria dispar asiatica* Vnukovskij (Erebidae) (Asian Gypsy moth) being introduced into America. The introduction is associated with trade-based goods, specifically imported coniferous timber (Prestemon *et al.,* 2006). The moth was introduced into America through timber imports and yet timber imports continue due to market demand. Before any policy decisions are made regarding the import of the timber, the markets involved, i.e., the exporter, importer and those markets affected by the moth can be simulated and provide scenarios involving different policies. This enables the economic ramifications of policy actions to be forecast before the decisions are made. Hypothetical but pertinent questions can be raised and applied to the simulated market such as: If trade restrictions are imposed what would the ramifications possibly be? If a tariff were imposed what are the ramifications and what value of tariff would be requested? Such questions are answerable through the construction of a simulated market.

2.1.2. Indirect Valuation Methods (Revealed): Travel cost, Hedonic Property value, and Avoidance expenditure

Indirect evaluation is the estimation of monetary values by observing an individual's behaviour in the context of the entity being valued (Hanley and Barbier, 2009; Anderson and Carpenter, 2010). These methods often involve the use of proxy markets or values derived from other goods and services that of which are affected by the entity that is under observation. A great starting point to understand this idea is the Hedonic Property Pricing

(HPP) method. This method places a value on non-market goods and services by using the changes in a proxy markets price to reflect the value of the good or service (Hanley and Barbier, 2009; Anderson and Carpenter, 2010). A study in North Central Wisconsin aimed to value the impact of *Myriophyllum heterophyllum* Linnaeus (Haloragaceae) (Milfoil) and *Dreissena polymorpha* Pallas (Dreissenidae) (Zebra mussel) to lakeside-based communities (Johnson and Meder, 2013). This study used the prices of lakeside properties over a period of five years to ascertain the value of the impact of these invasive species. This situation raises the commonly cited economic assumption of "*ceteris paribus"* which means "holding all else constant". The idea here being that changes in the pricing of the lakeside-based residences would be solely because of the impact by those invasive species in the lake. The study discovered that milfoil had a significant and negative impact on the value of property and that Zebra mussels had a significant and positive effect on the pricing of property. The hedonic wage assessment is conducted in the same manner and to the same effect except using wages.

The travel cost method values environmental goods and services by observing payment made by economic agents to view, experience, or use an environmental good or service that does not otherwise have a set market (Emerton and Howard, 2008). This method was applied to the Wisconsin lakes in the United States of America invaded by Milfoil (Zipp *et al.,* 2019). This method assessed the added cost of travel placed on recreational boaters that used the lakes for recreational purposes. The results indicated that the economic cost of an invaded lake over a 15-year period in 1998 was $2.14 million per lake and in 2013 it was $1.53 million (Zipp *et al.,* 2019). These values are derived by observing the spending behaviours of recreational boaters in Wisconsin lake areas and their spending to go to a lake not invaded by Milfoil, such an evaluation could also fall into avoidance expenditure.

There are few examples of avoidance expenditure being used to value invasive alien species. The general idea would be to observe payments made by individuals to avoid a particular invasive species. A good example would be the Prickly Pear (*Opuntia monacantha* Hawthorn (Cactaceae)) invasion which used to cover large areas of the Kruger National Park (Paterson *et al.,* 2011). Assuming that certain camps were more invaded than others, the method of avoidance expenditure could be used to value the impact of Prickly Pear on the camps.

Economic agents may pay more Rands to go to a less invaded site. The differential between site payments would reflect the value of the impact on economic agents by Prickly Pear. It would also reflect the avoidance expenditure, what economic agents are willing to pay to avoid Prickly Pear infestations.

The above methods fall under the revealed preferences methodology. Not all methods fall under this methodology, some fall under the stated preferences methodology which differ from revealed preferences (Tietenberg and Lewis, 2012). Stated preferences requires the deposition of an economic agent in a research context. The economic agent is then asked questions – these questions differ and are informed by the method being utilised by the researcher – to which their responses inform the researcher of the value the economic agents place on the entity under observation. Prominent methods such as "willingness to pay" and "willingness to accept" fall under this research approach (Anderson and Carpenter, 2010). Stated choice models are rooted in the Lancastrian consumer theory, information processing, and random utility theory (Adamowicz *et al.,* 1998).

2.1.3. Direct valuation methods (Stated): Contingent valuation

Contingent valuation techniques involve asking a respondent how much they would be willing to pay or how much they would be willing to accept (MacMillan *et al.,* 2008). These are commonly heard statements in environmental economics. "Willingness to pay" refers to asking a respondent, during a contingent valuation assessment, how much money they would willingly contribute to protect or pay for an environmental good or service. Conversely, asking a respondent their "willingness to accept" is similar, yet different. When asked their willingness to accept the respondent is invariably being questioned on their disposition toward receiving a sum of money for the loss of an environmental good or service (MacMillan *et al.,* 2008). This technique is used to elicit a value that the economic agent would either willingly accept or else willingly pay for that environmental good or service under consideration (Emerton and Howard, 2008). Again, we consult a paper based on the Milfoil invasions in the Wisconsin area of the United States (Provencher *et al.,* 2012). A contingent valuation is utilised to assess the willingness to pay of lakeshore property owners to avoid having a milfoil invasion. This value is \$30 550 in one region and \$23 614 in another

(Provencher *et al.,* 2012). These figures serve as a basis from which to assess the potential economic impact of milfoil but also as an indicator of the value of the lakeshore to residents.

2.1.4. Indirect Valuation methods (Stated): Attribute-based models and Conjoint analysis

Attribute based models require the deconstruction of the environmental good or service under assessment into the attributes that comprise that good or service (Holmes and Adamowicz, 2003). Those attributes are then presented to a respondent group in a set of scenarios that vary the quality or quantity of attribute and the prices paid. In this way, the value placed on various attributes can be determined. There are no examples of this in the literature surrounding invasive alien species. A hypothetical example can be constructed to convey the point in an invasion science context. *Euwallacea fornicatus* Eichhoff (Curculionidae) (Polyphagous shot-hole borer) has noticeable impacts on several species of tree within South Africa. If a value for the damages ascribed to the borer was being considered, an attribute-based model could utilise camping sites as a potential site for assessment. The borer is causing the complete destruction of the trees at these sites. The trees are one of the attributes of the campsite when it comes to campers site selection. Thus, the attribute of tree cover could be included in a set of scenarios in which it is varied – 0% tree cover to 25% to 50% and so on – and respondents are asked to state how much they would pay for each different scenario. In this way, the value of trees at campsites can be derived. This value is a proxy for the cost of the impact of *E. fornicatus*.

2.1.5. Invasive Species as a Source of Externalities

Externalities in the economic context are both positive and negative. Yet, the predominant starting point is invariably a discussion of the negative externalities (van Rensburg *et al.,* 2015). For IAP species, a discussion of the negative impacts appears to be the first step in many investigations (Leitch *et al.,* 1996; Humphrey, 2016; Warren *et al.,* 2017). However, if the intention of these studies is to inform decision makers regarding a species of IAP then as much information as possible must be provided from both sides of the 'externality fence'. Failure to do so will bias the outlook toward an IAP and will 'paint' an incomplete picture. A full examination – in as much as this is possible – is essential in the South African context.

An externality is regarded as a cost or benefit that is imposed on a third party (Tietenberg and Lewis, 2012). A definition of an externality would be, "A cost or benefit from production or consumption, accruing without compensation to someone other than the buyers or sellers of the product (van Rensburg *et al.,* pg. 550, 2015). Another similar yet broader definition is, "The welfare of some agent, either a firm or household, depends on the activities of some other agent. The externality can take the form of either an external economy or external diseconomy." (Tietenberg and Lewis, pg. 626, 2012). The thread of similarity in the definitions being an external impact, good or bad, introduced or inflicted on a third party. In the early 1900's the Eastern Cape region of South Africa became heavily infested with *Opuntia fiscus-indica* (L.) Mill. (Prickly Pear) (Moran *et al.,* 2013). This plant was introduced for its sweet fruit and the abundant production of this fruit. It forms part of the Cactaceae family (Cactus), has a plethora of sharp spines, forms high standing, up to two meters, dense, impenetrable, thickets in invaded regions. Using Prickly Pear to explain the nature of externalities requires a fictitious scenario be created. Imagine two farmers with adjacent properties in the Eastern Cape Province of South Africa. One farmer decides to introduce Prickly Pear on to his property to make use of marginal spaces and provide additional food for the farm inhabitants (Farmer A). The other farmer has no interest in Prickly Pear and does not introduce it at all (Farmer B). Prickly Pear spreads rapidly when under the conditions prevalent in the Eastern Cape Province. Initially, farmer A sees a quick increase in Prickly Pear plants. This provides more fruit and farmer A is happy. However, the Prickly pear infestations start to rapidly increase. They increase to the point that they impact the primary activities of the farm. Initially, this is simply a nuisance with activities being slowed or productivity being slightly reduced. However, rapidly the farm becomes unusable, uninhabitable, and unproductive. Farmer A is eventually forced to abandon his plot. Farmer B beings to notice prickly pear plants on his side of the fence. These plants originate from farmer A's farm. From this point, the rapid invasion of the neighbouring farm is inevitable and eventually farmer B is left with no choice but to abandon his plot. The actions of famer A have implications for both his and farmer B's farms. Farmer B experiences an externality imposed upon him by farmer A. Farmer B had no role, or involvement in the introduction of Prickly Pear and yet, he is faced by the impacts because of farmer A's actions. Invasive alien species are not externalities in and of themselves rather their impacts are externalities. This is a point that does not seem to have been explicitly raised in the economics literature on invasive alien species. However, it is evidenced in some work such as the admission that the cost of Black wattle control is borne by the taxpayer and not the commercial growers (de Wit *et al.,* 2001) as well as some recognition of the nuanced appropriation of benefits by private entities whilst the costs are borne by public entities (Dickie *et al.,* 2014). The combination of invasive alien species, the externalities they generate and the understanding of property rights is an area of economics that could quite rightly be termed a wicked problem (Rittel and Webber, 1973).

It is essential that the multitude of methods available to economists for environmental evaluations be covered in detail here given that in some respects this study is seeking to value an environmental good. Having discussed the various economic evaluation methods available to economists and the motive behind conducting those evaluations, the study will now discuss the target invasive alien species – *Rubus* subgenus *Rubus* in South Africa.

CHAPTER 3

THE *RUBUS* GENUS IN SOUTH AFRICA

"Morphological and cytogenetic studies by taxonomists of the former Botanical Research Institute in the 1980s revealed that the genus Rubus in South Africa 'is a taxonomist's nightmare'."

~ *Lesley Henderson* (pg. 2, 2011).

South Africa is rich in species falling under the *Rubus* genus and has native, alien, and invasive alien species from this genus. These species have been observed as having an increasingly prominent impact on communities in and around South Africa by various invasion scientists (Henderson, 2011; Zacharaides pers. Comm ARC-PHP). Many of these observations are based on characteristics displayed by the species such as dense growth habits or widespread populations. These characteristics have negative impacts on South African communities and have been regarded as warranting control of invasive *Rubus* species (Botha, 2005). However, there is an awareness that the genus has species with positive impacts. What is not known is the extent of the positive or negative impacts – whether they be ecological or economic – nor the specific species that these impacts are derived from. This project requires a more detailed understanding of the subject species than is usually necessary given the complexity that *Rubus* species display. This understanding is necessary as IAS differ from one another and as such, those economic methods and techniques used to evaluate one species or genus may not be appropriate for a species or genus. Likewise, recommendations and economic measures targeted at IAS may not have the same impact on different species or genera. As such, it would be an oversight on this study's part to not seek to understand the botanical nature of the selected *Rubus* species. Such an understanding would help to ensure that appropriate recommendations are made regarding the management of the various invasive *Rubus* species and that economic results, and suggestions, can be interpreted, and made, with a solid understanding of the underlying species.

3.1. INTRODUCTION

The *Rubus* genus is a genus of plant that falls under the *Rosaceae* family (Mabberley, 2017). The *Rubus* genus is a taxonomic category of plants that consists of at least two-hundred and fifty species and at most seven-hundred and fifty species (Alice and Campbell, 1999) categorised into twelve subgenera. The genus was first described by Linnaeus (1707 – 1778) and has been subjected to at least two revisions (Mabberley, 2017). This can lead to confusion for non-botanists.

Species in the *Rubus* genus are given over to apomixis (the asexual reproduction of plants or "making seeds without fertilisation" (Shipunov, 2018)) and hence can reproduce without a partner plant. Many of the plants in the genus have been utilised in cultivation, particularly as a source of fruit, or as ornamental plants (Mabberley, 2017). This has resulted in a complex set of hybrids often with obscure ancestry (Mabberley, 2017). Species within the genus have been used extensively in cultivation and several modern cultivars are in use (Strik *et al*., 2007). The *Rubus* genus has an indigenous variant species on six of seven of the globe's continents (Hummer, 2010) with Antarctica being the only continent on which a species of *Rubus* is not found, indigenous or otherwise. Non-indigenous *Rubus* species can be found all over the globe as aliens in non-native regions. A select number of these alien species have gone on to become invasive (Kiraly, 2018).

Although southern Africa is not a major centre of *Rubus* diversity it does have an interesting mix of species, which is not yet fully understood, and the distinction between some native and naturalised taxa is unresolved (Sochor *et al.*, 2018b). Phylogenetic studies are, however, currently underway to offer some sort of clarification of the taxa in South Africa (Sochor, pers. comms, 2020). There are "at least 13 *Rubus* species in South Africa, five indigenous species, eight naturalised alien species, and several natural hybrids between indigenous species and between indigenous and alien species" (Henderson, pg. 1, 2011). The South African National Biodiversity Institute (SANBI, 2018) lists 23 species of *Rubus,* which includes indigenous, alien, alien naturalised, and invasive alien species. All introduced species of *Rubus* in South Africa fall under *Rubus* subgenus *Rubus* or *Rubus* subgenus *Malachobatus* (du Plessis *et al.*, 1984). A comparison of those plants listed in 1984 and those currently listed on the SANBI, Plants of

South Africa Database is provided in Table 3.1. At present, nine more species are listed as present under SANBI than were listed in 1984. This change consists of two indigenous species and seven nonindigenous species. Of these nonindigenous species three are currently recognised as invasive. This suggests either a potential uptake in the number of non-native species between the two time periods, an increase in monitoring efforts, or both.

Taxonomic assessments of the *Rubus* genus in South Africa are in the process of being conducted (Sochor, pers. comms, 2020). Past assessments were conducted on a regional basis with assessments on the Cape Floristic Area – not an area covered in this study – (Sochor *et al.*, 2018a) and the Eastern Cape Region (Sochor, 2018). An independent field trip conducted under the auspices of this study is now included in these assessments (see section 4.5 for further details). The *Rubus* genus in South Africa is complex and still not entirely resolved. Assessments show a broad array of species that are native and foreign, as well as hybrids of the two. Foreign species are from Asia, Europe, and North America (Sochor, 2018).

Table 3. 1: Comparison of 1984 Rubus species to 2020 Rubus species in South Africa.

du Plessis *et al.* (1984)	SANBI (2020)	Current Status
Rubus affinis	*Rubus affinis*	Nonindigenous; Naturalised
Rubus apetalus	*Rubus apetalus*	Indigenous
Rubus cuneifolius	*Rubus cuneifolius*	Nonindigenous; Invasive
Rubus flagellaris	*Rubus flagellaris*	Nonindigenous; Invasive
Rubus immixtus	*Rubus immixtus*	Cryptogenic
Rubus longepedicellatus	*Rubus longepedicellatus*	Indigenous; Endemic
Rubus ludwiggi	*Rubus ludwiggi*	Indigenous
Rubus pascuus	*Rubus pascuus*	Nonindigenous; Naturalised
Rubus phoenicolasius	*Rubus phoenicolasius*	Nonindigenous; Naturalised
Rubus pinnatus	*Rubus pinnatus*	Indigenous
Rubus rigidus	*Rubus rigidus*	Alien

Rubus rosifolius	*Rubus rosifolius*	Nonindigenous; Naturalised
Rubus x *proteus*	*Rubus proteus*	Indigenous
Rubus transvaalensis x *R. longepedicellatus*	*Rubus transvaalensis*	Indigenous
	Rubus apetalus var. *apetalus*	Indigenous
	Rubus armeniacus	Nonindigenous; Cultivated; Naturalised
	Rubus ellipticus	Nonindigenous; Invasive
	Rubus fruticosus	Nonindigenous; Invasive
	Rubus intercurrens	Indigenous; Endemic
	Rubus lugwiggi subspecies *spatiosus*	Indigenous; Endemic
	Rubus niveus	Nonindigenous; Invasive
	Rubus trifoliolatus	Nonindigenous; Naturalised
	Rubus ulmifolius	Nonindigenous; Naturalised

*A comparison of *Rubus* subgenus *rubus* species in South Africa. The comparison is between lists established by du Plessis *et al.* (1984) and the South African National Biodiversity Institution (SANBI) lists as part of the 'Plants of South Africa' database (2018).

In an assessment of the Eastern Cape region of South Africa, Sochor (2018) uncovered that twenty-three separate species of *Rubus* were present and originated from Asia, Europe, North America, and South Africa, with hybrids amongst these species. This assessment shows that there is a diversity of *Rubus* species in the region assessed in this study. It is also evident that the species of *Rubus* in South Africa are by no means all invasive. Henderson (2011) pointed out that any species producing blackberries in South Africa can be regarded an alien species. This means or suggests that any plant that resembles a 'bramble' and have black berry like fruit on it, should be regarded as some form of alien blackberry. This is useful information in trying to differentiate a complex host of species. However, in hindsight this information was not applicable in this study as surveying was conducted during the winter period – off-season for fruiting of *Rubus* in South Africa. It could also be possible that the extended drought in South Africa has had an impact on the fruiting of *Rubus* species. Overall, it appears that on the current understanding of the genus suggests that twenty-four percent of the species in South Africa are native, forty percent are introduced, and thirty-six percent are hybrids (table 3.2, according to Sochor, 2018).

Table 3. 2: Listing of Rubus species based on Sochor (2018)

Region of Origin				
Asia	**Europe**	**North America**	**Eastern Region of South Africa**	**Hybrids**
R. ellipticus	*R. armeniacus*	*R.* sect Arguti	*R. apetalus*	*R. rigidus agg.* x *R.* sect Arguti
R. niveus	*R. bergii*	*R.* sect Cuniefolii	*R. immixtus*	*R. rigidus* x *R. ulmifolius*
R. phoenicolsius	*R. ulmifolius*	*R.* sect Flagellaris	*R. ludwiggi*	*R. pinnatus* x *R.* sect Arguti
R. rosifolius			*R. pinnatus*	*R. rigidus* ag. X *R.* sect Flagellaris
			R. rigidus	*R. ludwiggi* x *R. apetalus*
			R. transvaalensis	*R. ludwiggi* x *R. ludwiggi* x *R. pinnatus* agg.
				R. niveus x *R. transvaalensi s*

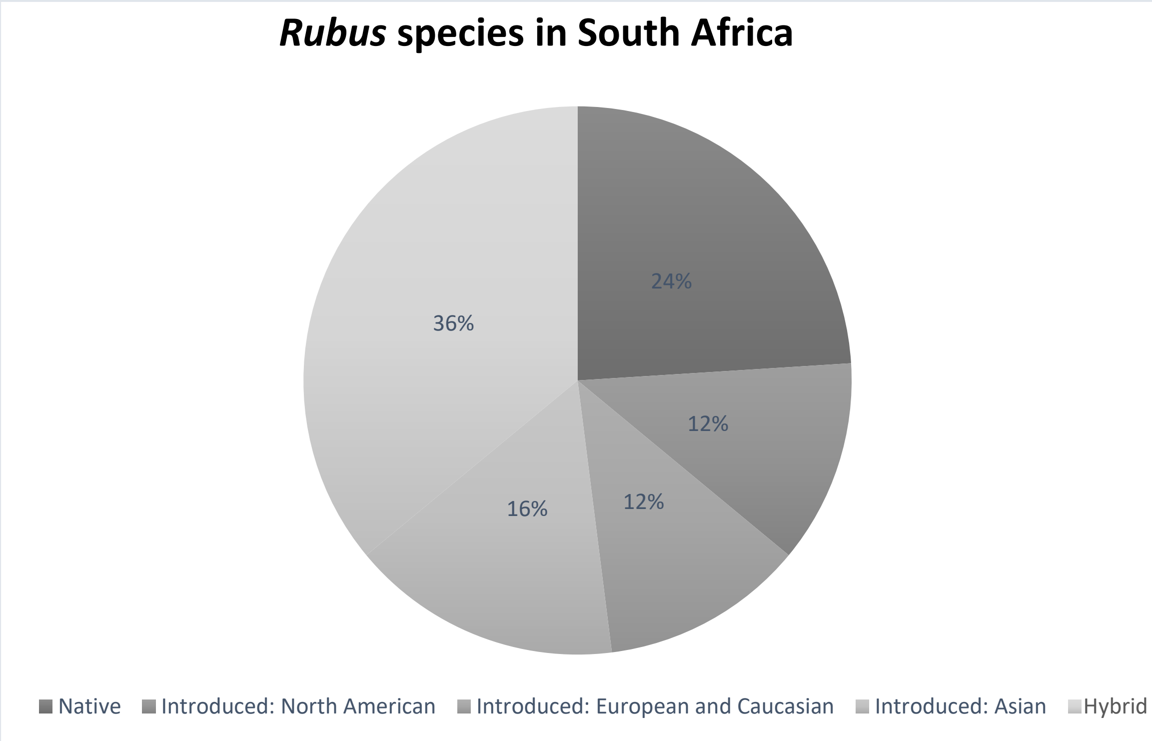


Figure 3. 1: The Rubus genus in South Africa (based on Sochor, 2018 and Sochor et al. 2018b).

3.2. KEY POINTS ON THE *RUBUS* GENUS

The *Rubus* subgenus *Rubus* genus is complex and broad from both global and South African perspectives. The genus is taxonomically complex, morphologically similar and shows variation within regions in South Africa (Stirton, 1981; du Plessis *et al.*, 1984; Henderson, 2011; Sochor, 2018). This complexity is underpinned by several botanical characteristics displayed by the genus. These complexities present challenges to the research. They are:

1. Apomixis – the ability of a species to produce seed without fertilization (Shipunov, 2018). The species in this genus can generate seed without being fertilized by a separate plant. This suggests that these species can produce multiple offspring from a single specimen. A key element in the definition of an invasive species is the ability of that species to have self-propagating populations, or for a population to be reproductively sustainable. The characteristic of apomixis contributes to the

invasiveness of this subgenus. This characteristic facilitates the spread and establishment of the genus across regions and areas from a single specimen.

2. Asexual reproduction - the species in this subgenus can engage in 'vegetative reproduction' (Stirton, 1981; Sochor, 2018). Specimens – individual plants/shrubs – in this subgenus can grow through stems or offcuts of already existing plants. Initially, a seed is required for the first plant to grow – e.g., a single plant of *Rubus cuneifolius* (Pursch) (American Bramble) grows from a seed introduced by a bird dropping. This seed germinates and develops into a plant. This plant has several stems. Some of these stems trail along the ground sprouting roots from that stem into the underlying soil. These stems can extend out and start to form other *R. cuneifolius* shrubs. In this way, a single seed goes on to develop into several plants. This characteristic facilitates the spread of the species and as such, their invasiveness.
3. Hybridization – the species in the *Rubus* subgenus *Rubus* readily engage in hybridization (Sochor, 2018). The nuances of this process have not been fully explored (Sochor, pers. comms, 2020) yet evidence suggests that there is hybridisation amongst alien species, invasive species, and indigenous species in South Africa complicating in-field identifications (Spies *et al.,* 1987). The characteristic of hybridisation is used extensively to produce a variety of *Rubus* cultivars used in commercial production (University of Arkansas, n.d.). Hybridised species are sold on the commercial market as seeds or seedlings. The University of Arkansas has several varieties of Blackberry that can be purchased. These varieties are patented by the University. Their existence simply serves an indication that the ease of hybridisation of Blackberry as well as the lucrative opportunity when used commercially. At present, none of the listed hybrids in South Africa are alien species crossed with other alien species. All hybrids appear to be native species crossed either with other native species or alien species (Sochor, 2018). The hybridization component of the *Rubus* species introduces interesting discussions around the species concept particularly where one species ends, and the other species begins (Sochor, 2018). This characteristic suggests that a new subspecies or species of *Rubus* can be encountered during a survey or assessment.

These characteristics are important as they inform the characteristics of species in the genus which then go on to affect the interaction of that species with the surrounding community.

These interactions lead to *Rubus* species being placed on South African biodiversity relevant legislation. This legislation in informed by both a process and degree of thinking that serve as an indication of the South African Parliamentary level understanding of the *Rubus* species.

3.3. SOUTH AFRICAN LEGISLATION ON INVASIVE SPECIES

Presently, South Africa has two legislative acts directed at biodiversity and alien species management. These two acts are the National Environmental Management Act (Government of the Republic of South Africa, hereafter referenced as: NEMA 1998) and the National Environmental Management: Biodiversity Act (Government of the Republic of South Africa, hereafter referenced as: NEMBA, 2004). Together these two acts dictate how South Africa deals with invasive alien species issues. South Africa has a long history of legislation directed at environmental protection and control; the relevant acts are listed in Table 3.3.

The legislation on biodiversity has a long history and sits within a complex system of international, national, provincial, local governmental policy, and law. National legislation provides mandates to both provincial and local government, however, all branches of government are given a degree of autonomy over how to best implement national policy (NEMBA, 2004). The national legislation is influenced by international law with various stipulations and international agreements affecting the manner and means by which national law is instituted.

The principal Act regarding the control of IAS in South Africa was the Conservation of Agricultural Resources Act (Government of the Republic of South Africa, 1983, hereafter referenced as: CARA 1983). This Act falls under the Department of Agriculture, Forestry, and Fisheries (DAFF) and is predominantly focused on addressing those species that pose a threat to agricultural resources (van Wilgen *et al.*, 2017). NEMA was developed under the Department of Environmental Affairs (DEA) and was aimed at the preservation of biodiversity and ecosystem functioning. After NEMA, NEMBA was promulgated which deals directly with the control of the various IAS in South Africa. One of the mandates of NEMBA was the prioritisation of invasive alien species. This process involved separating IAS into four distinct categories that of which pertain to different management regulations and legal requirements.

These categories and the species belonging to them are contained within the Alien and Invasive Species (Government of the Republic of South Africa, 2016, hereafter referenced as: AIS, 2016) lists. This list was officially sanctioned and released in 2014 when NEMBA was promulgated. Category 1 is split into 1a and 1b. Those IAS falling into category 1a are required to be removed on site and have a national management program dedicated to their eradication. Category 1b AIS are to be removed on site but do not have national management programs dedicated to their eradication. No species in either 1a or 1b may be propagated on a commercial or agricultural scale however, the harvesting of wild population's fruits or produce is legal. Category 2 species are those that may be propagated and purposefully cultivated so long as a permit specific to that use and that individual or organisation has been acquired from the DEA. Category 3 species are those that have been identified as invasive and are prohibited in terms of use or propagation however, their management is not warranted as a priority and no agricultural or economic value has been cited.

Table 3. 3: Invasive species Legislation enacted in the Republic of South Africa

Date of Promulgation	Name of Act	Acronym	Issuing authority
1861	Colonial and Provincial Noxious Weeds Legislation	N/A	Cape Colony
1937	Weeds Act of 1937	N/A	SA government
1983	Conservation of Agricultural Resources Act	CARA	Department of Agriculture, Forestry & Fishery (DAFF)
1983	Animal Diseases Act	ADA	DAFF
1983	Agricultural Pests Act	APA	DAFF
1998	National Environmental Management Act	NEMA	Department of Environmental Affairs (DEA)
2002	Animal Health Act	AHA	DAFF
2003	National Environmental Management: Protected Areas Act	NEM:PA	DEA
2004	National Environmental Management: Biodiversity Act	NEM:BA	DEA

Bennet and van Stittert (2019) noted that over the course of legislation dealing with alien species in SA, there has been a recent shift away from the protection of agriculture and towards the preservation of biodiversity. A shift in motive from a legislative perspective could be important in terms of informing the management strategies and management solutions that are generated. The shift in motive does not seem to be reflected in the evaluation of outcomes (Marire, 2016). The assessment of success of alien species management programmes, from a legislative viewpoint, appears to be anthropocentrically focused as opposed to ecocentric. Outcome evaluation in terms of efforts to retard IAS impacts focuses on job generation by organisations tasked with management effort as opposed to a more ecocentric assessment such as measurements of the reduced rate of impact, or a reduced rate of spread of invasive alien species, the number of hectares cleared, or the percent landmass occupied by invasive alien species for example (Marire, 2016). At present, the indicators of success of invasive alien species management are based predominantly on outputs such as the number of unskilled workers hired, or jobs generated from clearing operations (Van Wilgen and Wannenburgh, 2016). This is as opposed to some other, more ecologically meaningful criteria such as a reduction in hectares occupied or number of invasive species eradicated. More recent developments have tried to broaden the assessment criteria used to ensure a more holistic set of indicators are developed (van Wilgen and Wilson, 2018; Wilson *et al.* 2018)

The categorisation process that produced the AIS lists, was an expert-opinion based process with some influence from previous legislation, such as CARA (1983), and Weed Risk Assessments (WRA) (DEA, 2018, PAIA ref no: PAIA172588, appendix III). Information can be requested from the DEA itself through a Promotion of Access to Information Act (2000) form ('PAIA' form). This platform was used in this study with the initial request being for details regarding the "reasons for listing the *Rubus* genus under the 2014 Alien and Invasive Species Regulations". The DEA responded that the listing had been made to ensure consistency between the CARA and the IAS regulations as well as the use of expert opinion coupled with a Weed Risk Assessment (WRA). As a result, a WRA for *Rubus fruticosus agg.* (European Blackberry) had been produced and was forwarded to the project by the DEA. A subsequent request was made in which the weed risk assessments for *Rubus cuneifolius*, *Rubus niveus* Thunberg (Mysore raspberry), *Rubus flagellaris* Willd (American Dewberry), *Rubus ellipticus* Smith (Yellow Himalayan Raspberry) and *Rubus immixtus* was made. These five species being five of the six species of *Rubus* listed in the IAS regulations of 2016, given that the WRA for *R. fruticosus* agg. had been received already. This request confirmed that *Rubus fruticosus* L. agg. was the only species with a WRA available in South Africa. The other species of *Rubus* have not been assessed within the framework of a WRA in the South African context and as such the DEA had no record of WRA available (DEA, 2018, PAIA ref no: PAIA180636). The five species without WRA's are listed as either category 1a or 1b. Four of these five species are not listed in CARA, *R. fruticosus* agg. and *R. cuneifolius* being the two species of *Rubus* listed in CARA. Thus, the categorisation of the other five *Rubus* species, other than *R. fruticosus* agg. must have been primarily based on expert opinion. This is a rational assumption given that no WRA's were available for these species and these species were not mentioned in previous legislation.

A Weed Risk Assessment form (WRA) is based on the Australian Weed Risk Assessment form (AWRA) developed to provide a common framework for evaluating the capacity of a plant to become invasive by assessing the historical tendencies and concurrent knowledge of the plant. The assessment is based on 49 questions that address biological, ecological, and geographical attributes of the weed. Utilising these questions an 'invasiveness score' can be generated that is useful in indicating a countries perception of a plant. This score ranges from -14 to 29 with 29 indicating maximum weediness (Pheloung *et al*., 1999).

The AIS lists along with the NEMBA regulations place the weeds into categories that of which enable a streamlining of management and knowledge to be uniform across agencies involved in the control of IAS (van Wilgen *et al.,* 2017). This means that the AIS lists are essential to the governance and management of AIS in South Africa.

It must be noted that the legislation is not without fault. Brunel *et al*. (2013) suggested that analysis becomes paralysis when it comes to establishing information on invasions and making management decisions regarding IAS. Dickie *et al*. (2014) highlight that government agencies are often at 'cross-roads' to one another and can often result in conflicting views on species that hinders management plans. Bennet and van Stittert (2019) highlight that information is often based on a narrow band of interested parties such as researchers or farmers that have a particular focus and bias. As such, IAS management can often lack the input of other societal parties that may have contrarian views. Blackburn *et al*. (2014) directs criticism towards the classification of the species and provides an alternative method for classifying invasive alien species. McGeoch *et al.* (2010) suggest that even countries that have

IAS legislation lack strategies, management plans and implementation procedures to see that the legislation is enforced effectively.

When discussing legislation, a reference to the disparity between policy and legislation must be made. Policy and legislation are not the same thing. Policy refers to the plan of action that a government or department, institute to achieve their objectives or end goals (British Ecological Society (BES), 2017). Legislation is law: The overarching legal precedents and laws that govern and mandate the way individuals live within a particular society (BES, 2017). The AIS lists and the stipulations laid out in NEMBA are law, every citizen in the nation is expected to adhere to these stipulations. The various plans, schemes, and operations of governmental departments such as WfW, DEA, DFFE or the Department of Water Affairs are all policy informed by the current political agenda of the parties occupying Parliament at the time. Thus, although the policy approach may change between political regimes on any of the levels of government, the underlying mandate set out in the legislation is a constant.

An example of the complexity that exists when dealing with *Rubus* genera is that of the *Rubus fruticosus* aggregate. *Rubus fruticosus* agg. is not a species (Sochor, pers. comms, 2020) it is what is referred to as a 'species aggregate'. What this implies is that there are several species that although separate species, are so taxonomically similar that they are lumped into an aggregate for practical reasons. As such, an economic study looking into the impacts of that species would be required to have an in-depth knowledge of the nuances surrounding that *R. fruticosus* agg. This knowledge is limited to a few individuals and almost wholly retained in the minds of experts in the field (Sochor, pers. comms, 2020). This botanical complexity has a compounding impact on this study. Given these issues, the study was directed at attempting to ascertain what the general impact of invasive *Rubus* was from the perspective of landowners that were interviewed. The AIS lists have attempted to layout which species of *Rubus* are invasive in South Africa. To this end, six species have been labelled invasive. Detailed information on each species is available in appendix I. It was the endeavour of this study to understand what benefits and costs were associated with these species in South Africa. To this end, a unique method was generated and applied. It is discussed in the next chapter.

3.4. RUBUS IN THE AGRICULTURAL SECTOR

Rubus species are traditionally used in the agricultural sector (Strik *et al*., 2007). The type of fruit harvested depends on the species used. The fruit of the *Rubus* genus species has multiple uses. Corao *et al.* (2002), Harmer *et al.* (2012) and Zia-Ul-Haq *et al.* (2014) make mention of blackberries (prominently *R. fruticosus* aggregate) being utilised for anti-inflammatory drugs, as a facilitator of forest regeneration as well as in the production of cosmetics.

There is a large global market for Blackberry crops with multiple nations engaged in export of blackberry (Strik *et al.,* 2007). The species in the *Rubus* subgenus *Rubus* category are utilised on a commercial level in some regions of the world. Major exporters of Blackberry crops are Spain (25.3% of 2019 market share), Mexico (19.3%) and United States (13.3%); all top ten exporting nations are in the Northern Hemisphere (The Observatory of Economic Complexity, 2020) with Morocco the only African nation on the list of exporting countries. The value of the global export market stands at US$2.14 billion, an 8.1% increase from 2019. The five top importing nations are Germany, United Kingdom, France, Austria, and Belgium, also all in the Northern hemisphere.

In the United States most of the Blackberry production is dedicated to processed food stuffs with 82,6% of market revenue coming from processed berries (Agricultural Resource Marketing Centre, 2019). The price of processed berries (US$0,90/kg) is half that of fresh berries (US$1,85/kg) (National Agricultural Statistics, 2020). Whether this price differential is due to a supply or demand factor is not known.

When produced commercially, *Rubus* species are not referred to by species name but rather by cultivar in accordance with three main categories (Strik *et al.,* 2007): Erect, semi-erect, and trailing. These categories are based on the growth habit of the blackberries. Many of the cultivars are developed by university-level battological departments and trademarked by these institutions, examples include Cornell University, Kentucky College of Agriculture, Northern Carolina State University, Texas A&M AgriLife, and University of Arkansas. Blackberry cultivars have been under development since the 1800's with extensive hybridisation of genetic lineages (Finn *et al.,* 1999). The genetic origins of commercial cultivars are other cultivars (refer to table 3.4). Cultivars are bred for several reasons, mainly to satisfy either fresh or processed markets (Finn *et al.,* 1999). The berry's produced by different cultivars can show extraordinary variation. Some cultivars, such as Marion, produce berry's preferrable for processed products (Finn *et al.,* 1997). Other cultivars are directed at having thornless stems (Chester Thornless), berries that can withstand handling (Navaho), as well as berry size, growth rate, cane architecture, primocane fruiting, disease resistance, and fruit quality (Clark and Finn, 2011). The trademarking aspect of the cultivars makes it difficult to trace ancestry of the blackberry crops but provides market incentives for continued experimentation in the development of cultivars. Often universities engaged in the production of cultivars, provide freely available data, statistics, and resources booklets to facilitate the development of Blackberry farms (University of Kentucky, 2017). These factors undoubtedly favour the establishment of Blackberry farms in the United States.

Table 3. 4: Species composition of major blackberry cultivars

Cultivar Name	Type of Cultivar	Species	Species	Species	Species	Species
Marion	Trailing	*Rubus ursinus* Cham. (44%)	*Rubus armeniacus* Focke (25%)	*Rubus flagellaris* Willd. (13%)	*Rubus aboriginum* *(13%)*	*Rubus idaeus* L. (6%)
Black Butte	Trailing	Olallie	Boysen	Marion	*R. ursinus*	
Siskiyou	Trailing	Olallie	Boysen	Marion	Eldorado	

*Table depicting three major cultivars used in Blackberry production, with associated lineages. Note that lineages are sometimes described by cultivar names (taken from Finn *et al.,* 1997; Finn *et al.,* 1999).

South Africa's export volume of Blackberry fruits was 1.37 tonnes in 2018 (Tridge, n.d.), this is 0,4% market share of international exports. South Africa imports 51.33 tonnes of Blackberry from international markets annually. The size of South African Blackberry production has varied over time. In 2005 it was estimated that 100ha of land was under Blackberry Cultivation in South Africa (Strik *et al.,* 2007). Values of 35ha, 54ha, 54ha, and 49ha were reported for the period of 2013 to 2016 (South African Berry Producers Association, 2017). The number of hectares under cultivation has been variable over the last decade but has always been low. It is evident that the local production does not meet local demand for Blackberry products. This could present an opportunity in the South African market. However, the likelihood of South

Africa becoming a major exporter is low given the comparative advantage of other nations in producing blackberries. The extensive research, infrastructure, and patented cultivars in other nations present formidable hurdles to South Africa becoming a prominent source of blackberries globally. However, use of the invasive *Rubus* fruits could potentially result in a relatively low-cost source of abundant blackberries for the local market. The fact that the different species produce different varieties and quantities of blackberry must not be overlooked as the invasive alien species of *Rubus* in South Africa may not necessarily produce a marketable berry.

CHAPTER 4

METHOD

"An original idea. That can't be too hard. The library must be full of them."

***~ Stephen Fry* (pg. 54, 1991).**

4.1. INTRODUCTION

This section aims to discuss the bio-economic model used to derive the potential impacts of the invasive *Rubus* species. Based on these supposed impacts and the material presented in chapter 3, the mixed-methods approach for the study is presented. This includes a discussion on the sampling method as well as research hypotheses of the study.

The method of this project is outlined in Figure 4.1 and divided into two distinctly different parts. One part is aimed at facilitating the economic objectives of the study, the other part is aimed at facilitating the invasion science objectives of the study. The epistemological positioning of the study, between economics and invasion science, is an area of increasing complexity and one that requires contextually relevant observations, as opposed to broad based generalisations or extrapolations, whenever is possible. Considering this, the study has developed a dichotomous method to address both epistemological areas. The method is unique to this study with Figure 4.1 being generated to facilitate an understanding of this method. The aim of this method is to generate four distinctly different types of data. Two datasets that are derived from the economic context, a separate dataset which is derived from the invasion science context and a dataset that combines the three previous sets.

Economic agents that have interactions with invasive *Rubus* species in South Africa (and meet criteria developed further in this chapter) serve as the focus of the economic segment. The invasive *Rubus* species – i.e., individual plant populations, propagules, and berries – serve as the subject of the invasion science segment. These three datasets are the real-world embodiment of the confluence between invasion science and economics in the context of the *Rubus* species. These three datasets are combined to provide a fourth dataset. In effect, four databases are generated, two economic and one geographic, a fourth is created by combining the initial three and each is utilised in its own way to facilitate the aim of the project.

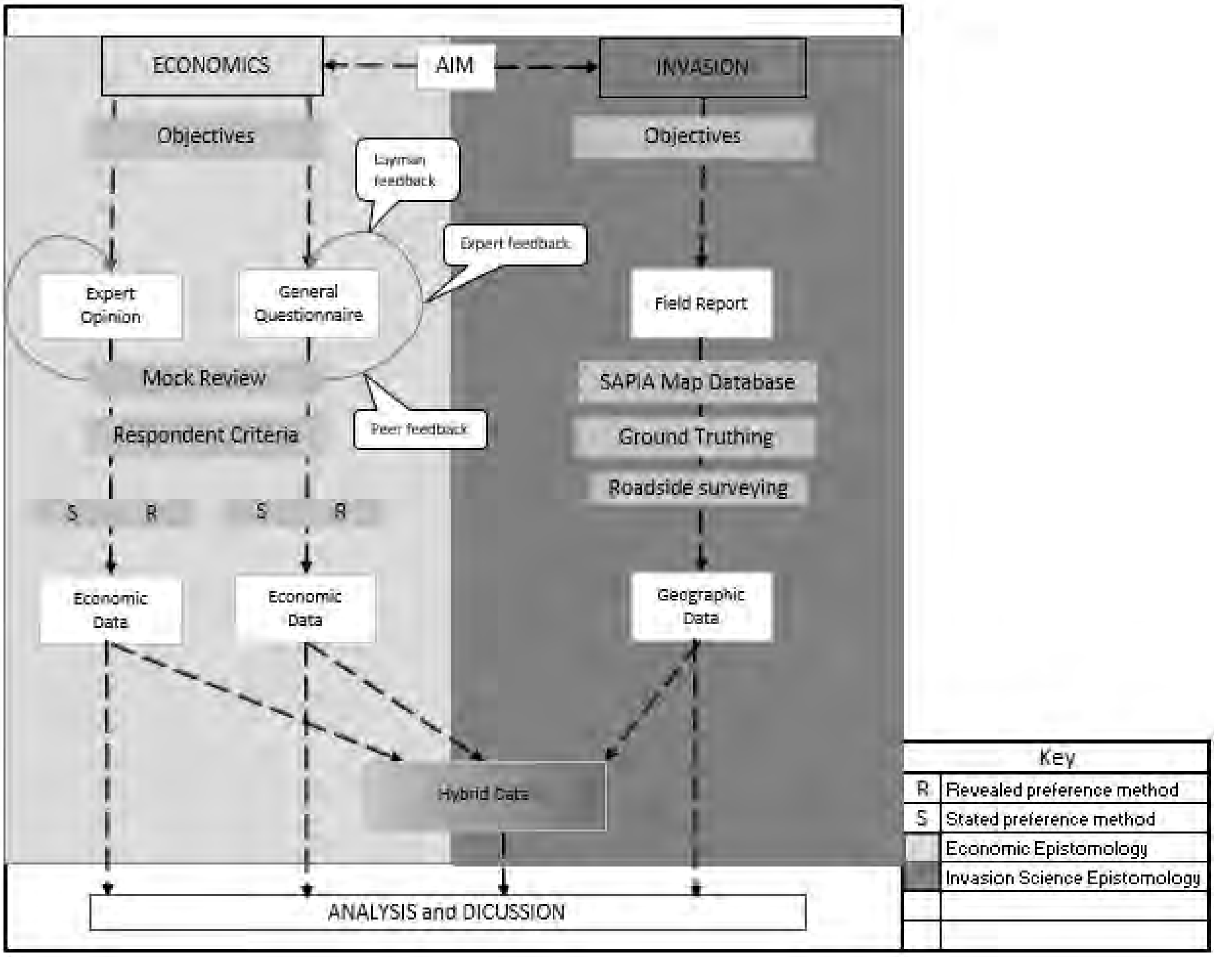


Figure 4. 1: Epistemological Schematic of mixed-method approach; a schematic of the method developed by the study depicting both epistemologies, method approaches, and resultant data.

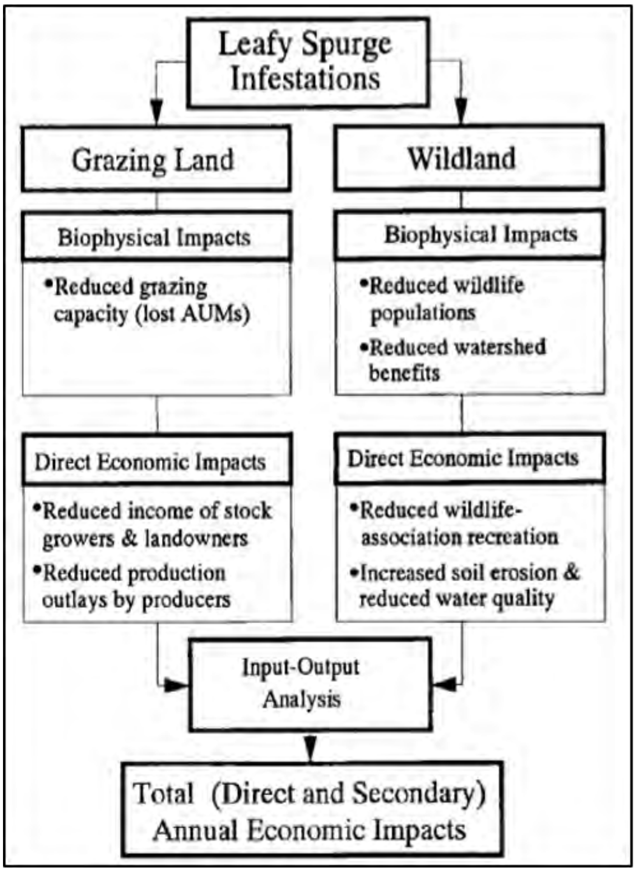
Figure 4.1 begins with the aim of the study and is informed by the epistemological investigation in chapter 2. The method is split according to the epistemologies of economics, and invasion science, and, in turn, the objectives of the study determine what the study does within those epistemologies. Study 'tools' used in the economic investigation comprise of questionnaires. This study's questionnaires were informed by a revealed preference ideology, but a stated preference ideology could be easily included, and are passed through several feedback processes to ensure that the end questionnaires are (i) credible among economic experts, (ii) understood by the target group, and (iii) accepted among academic peers. Questions were developed in line with the impacts cited in the bioeconomic models developed in Figures 4.4 and 4.5. These models served as the basis of assessment in ascertaining impacts experienced by economic agents in South Africa. The study 'tool' used in the invasion science is a field report that is based on the geographic process of data collection known as "ground proofing". The expected outcome of the application of these tools is two sets of economic data, one set of geographic data. As discussed, these three datasets are then combined into a fourth 'hybrid dataset' to provide a holistic overview of the confluence zone between economics and invasion science.

Understanding the confluence of economic and invasion science requires an understanding of the interaction between a species, its environment and the resultant impacts that can be ascribed to this interaction. To this end, a bio-economic model is employed.

4.1.1. Bio-Economic Model

A bio-economic model relates biological interactions to economic impacts (Leitch *et al*., 1996; Humphrey, 2016). These models are useful as they can be used to develop conceptual models of biological interactions that may not have been empirically identified (Leitch *et al*., 1996). Bio-economic models also provide a modelling platform to establish relationships between a biological entity, an activity it engages in and the economic outcomes due to that activity. This is a useful endeavour as it allows a more creative component to be utilised in the exploration of interactions between botanic, economic, and social fields of human endeavour. Recall that the backdrop of this study is environmental economics. As such, our primary lens in relation to all observed phenomena is from the perspective of man and man's use of the environment as an asset (van Rensburg *et al.,* 2015). Part of this process is the need to observe the phenomena in real time and make inferences regarding the cause(s) and outcomes of these interactions. This process often lacks the solid underpinning of empirical evidence. Indeed, it is partially the reason for the ascendance of qualitative methods of study. The use of the bio-economic model provides a basis for this exploration whilst still maintaining the credibility of a peer reviewed method (Leitch *et al.,* 1996; Humphrey, 2016).

The bio-economic models presented in Leitch *et al*. (1996) and Humphrey (2016) focus on the specific ecosystem being impacted by the species under assessment. In effect, they are ecosystem centric. Leitch *et al*. (1996) focused on "Grazing land" and "Wildland" as the two ecosystems of importance to an assessment of *Euphorbia esula* Linnaeus (Euphorbiaceae) (Leafy Spurge) infestations in the USA. Humphrey (2016) focuses on “Grazing lands” in an assessment of *Robinia pseudoaccacia* Linnaeus (Fabaceae) (Black Locust) in South Africa. The models presented in Figures 4.4 and 4.5 – which have been generated as part of the effort of this study - differ from Leitch *et al*. (Figure 4.2; 1996) and Humphrey (Figure 4.3; 2016) in that the primary focus of the model is not the ecosystem under assessment but rather the species itself.



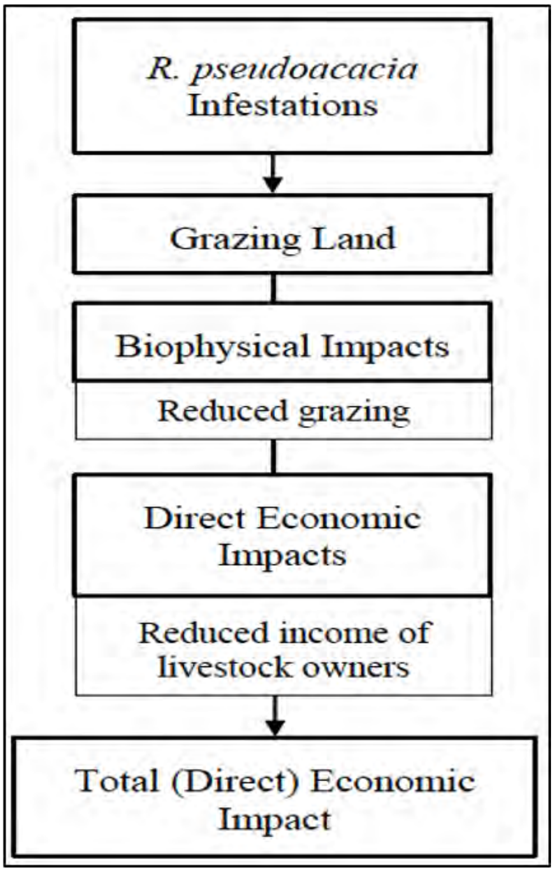


Figure 4. 2: Bioeconomic model from Leitch et al. (1996). Figure 4. 3: Humphrey (2016).

In this manner the bioeconomic model developed in this study is less ecosystem centric and more species centric. This ties in well with the aim of this study as the study was not associated with an explicit ecosystem but a genus. Thus, an altered bio-economic model was produced that differs from Leitch *et al.* (1996) and Humphrey (2016), it is shown in Figure 4.4. The construction of bio-economic models is important. It aids in the process of uncovering unknown impacts of IAPs as mentioned by van Wilgen *et al*. (2001). Invasions are complex and involve numerous stages that are often dependent on regional and climatic conditions. They are also not time consistent across species, i.e., different species have different rates of invasion, and the same species can have different rates of invasion in different environments (Pyšek *et al.,* 2015). For example, an *R. ellipticus* infestation in Hawaii can create large scale impacts in a short period of time and yet have little to no effect in a different region of the globe (Ding *et al.,* 2008). As such, engaging with the species in question in the framework of a bio-economic model is essential to the process of preventative management. Many IAP impacts are poorly understood and rarely explored in an economic context (Brown and MacLeod, 2011). A contributing factor to this issue could be the lack of engagement with economic agents (Ngorima and Shackleton, 2019). A plethora of impacts – positive and negative – may be overlooked, unknown and unquantified simply due to the lack of engagement of economic agents that regularly engage or partake in those impacts. A bio-economic model enables an academic interested in the uncovering of those impacts to model the potential impacts of a species based on morphological characteristics as well as general observations. Figure 4.4, below, is the bioeconomic model developed specifically for this study and models the potential impacts of an invasive *Rubus* genus species in South Africa.

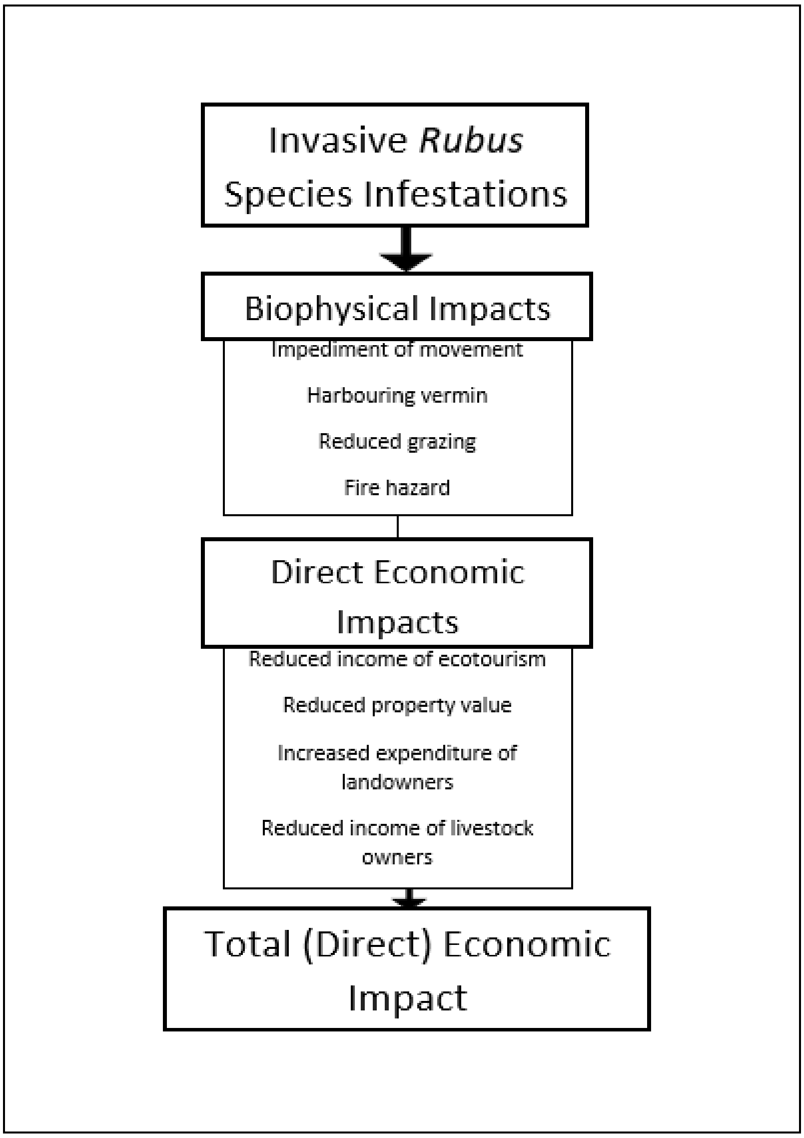


Figure 4. 4: Bio-economic model for invasive Rubus genus species in South Africa

The bio-economic model in Figure 4.4 allows for a conceptualisation of the negative impacts of invasive *Rubus* species in South Africa. The attractiveness of the model presented by Leitch *et al*. (1996) and Humphrey (2016) is that the impacts do not necessarily need to have been substantiated prior to inclusion in the model. In Figure 4.4, two of the included impacts have been cited in literature in South Africa; reduced grazing (Botha, 2005) and impediment of movement (Erasmus, 1984; Henderson, 2011) with the other impacts being suggested by consideration of the morphology of the plant. One of the aims of the study is to determine if these impacts are experienced by economic agents in South Africa. Figure 4.4 permits unknown impacts to be raised and explored in socio-economic based assessments.

One of the limitations of the bioeconomic models of Leitch *et al*. (1996) and Humphrey (2016) is a failure to consider the positive impacts of the species assessed. The models solely address the negative biophysical impacts and related costs. This study was concerned with a holistic approach to the impacts and as such considered not only the negative impacts but the positive ones as well. Figure 4.5 is a bio-economic model that has been altered to focus on the positive biophysical impacts and associated potential direct economic benefits of the invasive *Rubus* species.

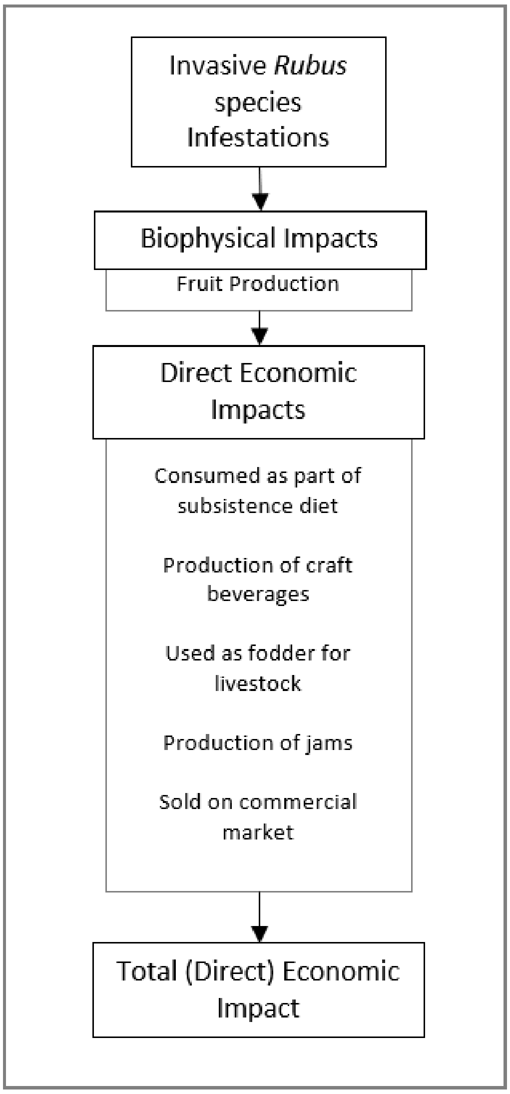


Figure 4. 5: Bio-economic model addressing positive impacts of invasive Rubus genus species (Leitch *et al*., 1996; Humphrey, 2016).

As mentioned, part of the usefulness presented by the bio-economic models is the ability to create relationships between a biological entity, its interactions with an environment and the socio-economic impacts of these interactions. Figures 4.4 and 4.5 present potential interactions that invasive *Rubus* species could be having in South Africa. An aim of this study is to question whether these interactions are occurring and if so, establish the total direct economic impact.

Invasive alien species are often regarded as negative because of their impacts. An indirect objective of this study is to explore this mindset toward invasive *Rubus* species in South Africa. Leitch *et al*. (1996) and Humphrey (2016) both display a negative mindset towards the IAPs under assessment. The bio-economic models laid out in the two studies focus solely on negative impacts. The positive contributions of the species in the two studies are not granted the same regard. This study sought to ensure that both forms of impact– i.e., positive, and negative impacts – were given due regard in the presentation of the bio-economic models.

4.2 STUDY DESIGN: MIXED-METHODS APPROACH

This study used a mixed methods approach. The mixed methods paradigm utilised is referred to as pragmatism (Wahyuni, 2012). Wahyuni, (2012) lists paradigms into ontological ideals, epistemological disposition, axiological stance, and research methodology (see Figure 4.6 for clarification – Wahyuni, pg. 70, 2012). This study required a mixed methods approach given certain unknowns as well as because of inherent nature of the study.

The first issue confronted by the study was the number of potential respondents was unknown. From its inception, the project was directed at engagement with economic agents. However, who these agents would be, and the size of the respondent pool was ambiguous. A thought experiment was conducted, and categories of economic agents believed to be affected by invasive *Rubus* was determined and included (i) researchers and academic practitioners, (ii) farmers of blueberry, blackberry, dairy, sheep, chicken, beef-cattle, and grape, (iii) conservation groups, (iv) landowners, (v) the DFFE of South Africa, and (vi) brewing operations. These categories represent economic agents that either suffer a negative externality from invasive *Rubus* species, enjoy a positive externality, experience a direct cost, or generate a direct benefit from invasive *Rubus* species. The study had to be broad in its engagement with economic agents. In as much as Roy (1989) was correct in his supposition that any objectivity must – in the end – be subjective, the study was committed to maintaining objectivity for as long as feasible. In any investigation directed at the study of invasive alien species this is necessary. Invasive alien species are often labelled as negative (Zengeya *et al*., 2017).

However, as discussed, there are positive contributions made by invasive alien species that must be addressed (Ngorima and Shackleton, 2019). This is of particular concern for a species that presents characteristics showing an evident benefit – such as easily harvested fruit, or strong timber – *Rubus* species that produce berries being an example of this**.** Approximately 100ha of land was under commercial blackberry cultivation in 2005 in South Africa (Strik *et al*., 2007). Compared to the global area under cultivation this is less than a percent – at the time global area stood at 20 035ha. The low area indicates the production of Blackberry was not widespread in South Africa and that there could be a small pool of respondents engaged in the commercial production.

Given that the study was not only concerned with the commercial production of the invasive *Rubus* species but with a more widespread assessment – the small area could be overlooked. Strik *et al.* (2007) indicated that the commercial production of Blackberry had risen by 45% globally. There were indications that the South African markets could have grown too (South African Berry Producers Association, 2017). However, this growth was from an area of less than 100ha suggesting that there was a reduction in blackberry cultivation in SA between 2007 (Strik *et al.,* 2007) and 2017 (South African Berry Producers Association, 2017). There was no clear indication before the study was initiated what the size or nature of the respondent pool was potentially going to be. Yes, the South African Berry Producers Association (2017) provided vague indications that some commercial farming operations could exist and that several small businesses might make use of the plan. However, the South African Berry Producers Association (2017) indicated that this did not provide full coverage of the blackberry market

	Research Paradigms			
Fundamental Beliefs	*Positivism (Naïve realism)*	*Postpositivism (Critical Realism)*	*Interpretivism (Constructivism)*	*Pragmatism*
Ontology: the position on the nature of reality	External, objective and independent of social actors	Objective. Exist independently of human thoughts and beliefs or knowledge of their existence, but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best achieve an answer to the research question
Epistemology: the view on what constitutes acceptable knowledge	Only observable phenomena can provide credible data, facts. Focus on causality and law-like generalisations, reducing phenomena to simplest elements	Only observable phenomena can provide credible data, facts. Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, the reality behind these details, subjective meanings and motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: the role of values in research and the researcher's stance	Value-free and etic Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Value-laden and etic Research is value laden; the researcher is biased by world views, cultural experiences and upbringing	Value-bond and emic Research is value bond, the researcher is part of what is being researched, cannot be separated and so will be subjective	Value-bond and etic-emic Values play a large role in interpreting the results, the researcher adopting both objective and subjective points of view
Research Methodology: the model behind the research process	Quantitative	Quantitative or qualitative	Qualitative	Quantitative and qualitative (mixed or multi-method design)
Based on Saunders et al.(2009, p.119),Guba and Lincoln (2005), and Hallebone and Priest (2009)				

Figure 4. 6: Fundamental Beliefs of research Paradigms in Social Sciences (Wahyuni 2012).

Secondly, the ease with which quantitative data could be obtained was unknown. Many economic evaluation studies are aimed at generating an overall figure or monetary value for the invasive species under observation. This has been done several times in Australia for example: Dellow and Vere (1984) estimated a value of AUS$4.7 million in costs to Central Western New South Wales, James and Lockwood (1998) estimated AUS$41.5 million cost to Australia and Sinden *et al*. (2004) AUS$3 554 million for Australia, the Sinden *et al.* (2004) assessment was for all weeds in Australia but included Blackberry which was the second most prolific, and widespread, weed in Australia at the time. Attempts have also been made in South Africa to generate a number, for the damages inflicted on the economy, by invasive alien species: Hoffman (2016) estimated $13.7 million, specifically looking at *Opuntia* (known as "Prickly pear") and van Wilgen and De Lange (2011) estimated the value to R6.5 billion for all invasive alien species in South Africa. These evaluation techniques are all rooted in extrapolation. They involve sampling one or several regions, establishing a quantitative dataset, and extrapolating that data across a larger area taking into consideration slight nuances between the regions and providing a range to provide a more realistic estimate. These studies invariably involve the use of large databases (Dellow and Vere, 1984; Lockwood and James, 1998; Sinden *et al.,* 2004; Blignaut and de Wit*.,* 2006). They are almost all directed at opportunity cost and the estimate of cost is usually directed at the potential economy and not the real economy. Invariably the sampling favours looking at economic industries and is based on macro-economic observations and methods.

This macroeconomic perspective has advantages and disadvantages. It enables broad economic estimates of the impacts felt due to invasive alien species across an economy. However, it can fail to address the micro-economic experience of economic agents. This study attempted to engage directly with economic agents that represent said industries, not from the macro-economic perspective but from the micro-economic perspective. Observing the direct experience of economic agents within the context of the economic industry they represented and in relation to the invasive *Rubus* species, provides an indication of the macro-economic experience whilst not losing sight of the micro-economic factors. This approach enables a direct understanding of the interaction between the economic agents and the subject of the study, invasive *Rubus*. This enables first-hand experience of the issues – costs and benefits – being experienced. It means that rather than looking at changes in output, reductions in revenue, decreases in yield or lower grazing area for an area that is heavily invaded with invasive *Rubus* and making inferences about the extent to which *Rubus* contributes to these reductions, one can ascertain from the economic agents whether invasive *Rubus* species play a significant role in those changes. This ensures that impacts are not mislabelled or inflated but more appropriately quantified. However, this approach can be limited in its ability to generate large scale quantitative data. In the previous studies listed, the advantage that researchers have is that the phenomenon under observation had largely been quantified already. The changes in yield and area infested by invasive *Rubus* would have been surmised already and all that would be left to do is draw inference. In the micro-economic approach, one is dealing directly with the phenomenon and not with the quantified data. In that regard it could be difficult to ascribe numerical values as the economic agents being dealt with are not all imbued with the same degree of numerical capacity, a shared conception of value may not be universal for respondents and the respondents have not been made pre-emptively aware of the study and as such have not been paying increased attention to their interactions with invasive *Rubus* species – particularly in an economic context.

Thirdly, doubts were raised regarding the ease with which qualitative data could be obtained and the extent of knowledge that respondents held regarding the invasive *Rubus* species in question. Qualitative data by its nature is regarded as more subjective and less objective than quantitative data. Qualitative data is almost always accessible when dealing with human economic agents. A mixed methods approach equips a study with the methodological malleability to accommodate qualitative data from a variety of non-uniform respondents. The extent of knowledge regarding invasive *Rubus* species among respondents was completely unknown. Not only does this study take into consideration a broad plethora of economic agents – and by extension their industries – but it marries at least three different subjects into one project: botany, economics, and invasion science. The study was dealing with one of the less well-known genera of invasive plant in South Africa and one of the most complex taxonomically globally. The mixed methods approach provided the malleability to accommodate varying degrees of knowledge regarding invasive *Rubus* species.

These factors represent 'blind spots' in the creation of the project. Using a mixed method approach enabled the study to generate appropriate solutions and provide insight into the problem at hand without being committed to a stricter method or approach.

4.3. DATA COLLECTION AND SOURCES

Primary and secondary data were both utilised in this study. Primary data is information that of which is collected by a study itself (Ajayi, 2017). The execution of that study's method results in the collection of information that is unique to the study and was used to answer the research questions. Secondary data is information used by a study that was not derived from the execution of that study's method (Ajayi, 2017). The nature of the study lent itself to the use of both sources of data. Secondary data came in the form of the South African Plant Invasion Atlas (SAPIA) dataset.

4.3.1. Primary Data Collection

Primary data was generated through surveys facilitated by questionnaires in different regions of the country. Some of the surveys were conducted as face-to-face interviews and others electronically - over either telephone or email. Survey participants were selected based on region, interaction with invasive *Rubus* species or through recommendation by other participants. Four regions of South Africa were assessed: Cathcart and Hogsback both in the Eastern Cape Province, Clarens in the Free State Province and Underberg in KwaZulu-Natal Province. These regions were selected based on secondary data (discussed in the next section). The selection of participants in these regions was conducted based on criteria (discussed in section 4.4.1). Two questionnaires were developed and implemented. One was directed specifically at researchers and academics that attended the 46th National Symposium on Biological Invasions that took place between 15–17 May 2019, at Waterval Country Lodge, Tulbagh and the other an economic agent questionnaire for economic agents that met the selection criteria. These two questionnaires will be termed "Expert Opinion Questionnaire" and "Economic Agent Questionnaire" respectively. They will be discussed separately.

4.4. SAMPLING AND SAMPLE REPRESENTATIVITY

The experimental method used in this study has similarities to the method known as the participant selection model (Doyle *et al*., 2009). The participant selection model is a two-phase model aimed at answering a research question. The first phase utilises quantitative data to identify participants and the second phase attempts to generate qualitative data from those participants to answer the research question (Creswell *et al*., 2003). This study is based on the participant selection model because the initial phase utilises quantitative data to identify suitable study regions in which participants can then be found. In the case of this study, the Geographical Positioning System data (GPS) provided by SAPIA was used to ascertain regions that participants could be found in. This GPS data are a form of quantitative data. By using the known locations of alien and invasive *Rubus* species sightings the study was able to sample the surrounding economic agents in that area. The second phase of Creswell *et al.* (2003) seeks qualitative data from respondents in those regions to answer the research question at hand. In this study's case, the questionnaires were used to derive not only qualitative information but quantitative data as well. Of course, unlike Creswell *et al.* (2003) this study sought both qualitative and quantitative information, not solely qualitative information. A characteristic of the participant selection model is that respondents are specifically selected as opposed to surveying a broad plethora of random respondents. This approach was thought best given the nature of the study. By engaging in specific selection of respondents the study could put in place quality assurance measures, using respondent criteria, and avoid input from respondents that might bias the end results. Two separate criteria were utilised for the two distinct questionnaires.

4.4.1. Economic Agent Questionnaire: Respondent Selection Criteria

The economic agent questionnaire is directed at the following research hypothesis: Economic agents will not experience any economic impacts directly or indirectly related to the invasive alien species of the *Rubus* genus found in the vicinity of their economic actions.

The following basic criteria were used to select economic agents to administer the economic agent questionnaire to:

1. Respondents that grow *Rubus* species commercially. These respondents were of the utmost interest to the objectives of the study. One of the main threads of this study was the querying of a categorisation made by Zengeya *et al.* (2017). Zengeya *et al*. (2017) ascribed invasive *Rubus* species as a "destructive" species. The study was directed at defining conflict of interest species. Given the wide range of uses that invasive *Rubus* species supposedly have the categorisation of "destructive" was questionable. By exploring if any commercial projects were actively underway the study could seek to understand the extent to which a conflict of interest might exist for invasive *Rubus* species.

2. Respondents that grow *Rubus* species for personal consumption. The study wanted to question individuals that were using the fruit as a substitute in their diet. This criterion was essentially directed at the farm workers and labourers that lived in and around farming operations consulted in accordance with criteria 1 and 3.
3. Respondents that have a commercial operation, not a reference to blackberry farmers or farmers only, that is impacted by invasive *Rubus* species infestations. Given the propensity of IAP's to produce externalities, a key population to interview was farming or commercial operations that are impacted by invasive *Rubus* species. These economic agents were also thought to be one of the better sources of quantitative data. Given the nature of their operations and the need for administrative monitoring it was hoped these economic agents would be a viable source of quantitative data.
4. Respondents that have invasive *Rubus* species on their property. The general homeowner, or landowner, could not be disregarded as a source of qualitative and quantitative data for the study.
5. Respondents that have a business or commercial operation that in some way utilises invasive *Rubus* species.
6. Respondents that can be reasonably justified as falling into a relevant category that harmonises well with the study's aims and objectives. This was a 'loophole' criterion that was created should be the study come across a segment of economic agents that could be rationally included as respondents in the study and did not fall into one of the previous brackets.

4.4.2. Expert Opinion Questionnaire: Respondent Selection Criteria

The expert opinion questionnaire is directed at the following research hypothesis: Expert opinions and sentiments on invasive *Rubus*, the impacts or management of the species, will not differ from those espoused by the economic agents selected in the economic agent questionnaire.

Two criteria were used in the selection of experts for this study:

1. The respondent's profession must be in the invasive alien plant field.

2. The respondent was required to have a (i) Professorship in invasive science, (ii) Doctorate in invasion science (or be pursing one), or (iii) 10 years of working experience in the invasion science field or related industry. This ensured that respondent would have had good exposure to invasion science and well versed in the nuances of the field.
3. Respondents that did not fall into the above categories and yet, through logical reasoning, could be justified as participants in the study.

4.5. ETHICAL CONSIDERATIONS

This research abided by the Rhodes University Research Ethical Standards Policy. The requirements of this policy were observed throughout the study. The survey instruments (questionnaires) were given ethical approval by the Department of Economics Ethical Standards Sub-committee. This ensured that the rights, privacy, and anonymity of participants were protected and respected. It also requires that all results, surveys, and this thesis are kept on record for five years after the closure of the study. All respondents were required to sign a consent form. This form ensured that the participants were not coerced into the study, that they were permitted to leave the study at any point in time and that they were informed as to the precise aim of the study. Feedback will be provided to participants in the form of a summary report. This project was approved by the Rhodes University Human Ethical Standards Committee. Having executed the method proposed in this chapter the project was then able to engage in analysis and report back on findings.

CHAPTER 5

RESULTS & DISCUSSION

"Ask yourself, what is this thing, by its own special constitution? What is it in substance and in form, and in matter? What is its function in the world? For how long does it subsist?"

~ Marcus Aurelius (pg. 94, 2004).

In this chapter the economic data is presented followed by the geographic data and then the "hybrid" dataset that of which is a combination of the former two. The three are discussed and analysed separately and then combined to provide the 'hybrid' dataset, referred to in Figure 4.1, which is used to draw more conclusions and inferences.

5.1. RESULTS: ECONOMIC AGENT QUESTIONNAIRE

The overarching goal of the study was to understand the economic impacts experienced by economic agents in South Africa because of invasive *Rubus* species. Eighteen different economic agents were consulted in this study. These respondents all met the criteria outlined in section 4.4.1. of the methods chapter. These eighteen respondents are best classified according to provinces: five from the Eastern Cape, six from the Free State and seven from KwaZulu-Natal provinces. One of these respondents was a government funded conservancy group based in KwaZulu-Natal Province, the rest were independent of government. The predefined regions assist in understanding the environmental and economic conditions that the respondents could be experiencing and help to determine if there are regional differences associated with invasive *Rubus* in South Africa. The first thing to be addressed is the size of the sample pool. Although the sample pool appears small, recall that a highly selective sampling approach was utilised and that strict criteria were enforced in selecting respondents. The eighteen respondents represent a small fraction of economic agents considered for the study and are the most suitable economic agents available in the study regions to provide information on the invasive *Rubus* species. However, this is a relatively small sample given that in economic literature a sample of 40 or more is a large sample (Gujarati and Porter, 2009). The sample size of the study cannot be regarded as statistically significant but can be regarded as an indication of the trends and values associated with the invasive *Rubus* species.

The first three questions of the questionnaire were utilised to (i) ascertain the appropriateness of the individual contributing to the survey, (ii) an attempt at species verification, and (iii) a subjective assessment of invasive *Rubus* species spread. As has been made evident, all respondents were deemed suitable according to criteria. Respondents were largely unable to identify the exact species under consideration. Many respondents simply replied that they had “bramble” or “blackberry” on their land, only using the common names. Fifty percent of respondents indicated that a noted increase in *Rubus* patches had occurred, with thirty-three percent indicating no perceived change (Figure 5.1). The results of this questioning varied across the regions assessed and within the regions themselves (Figure 5.2).

Respondents in the Eastern Cape Province all indicated that they had noted an increase in area invaded by the invasive *Rubus* species under consideration. Respondents in the Free State Province indicated that they had not noted any change in the *Rubus* patches. KwaZulu-Natal Province respondents were the least uniform group in terms of responses regarding the spread of *Rubus*. Forty-three percent indicated an increase and likewise, forty-three percent indicated a decrease. Further questioning led to an indication that this variation in responses could have been because of management practices on the land in question. This will be further discussed in the analysis.

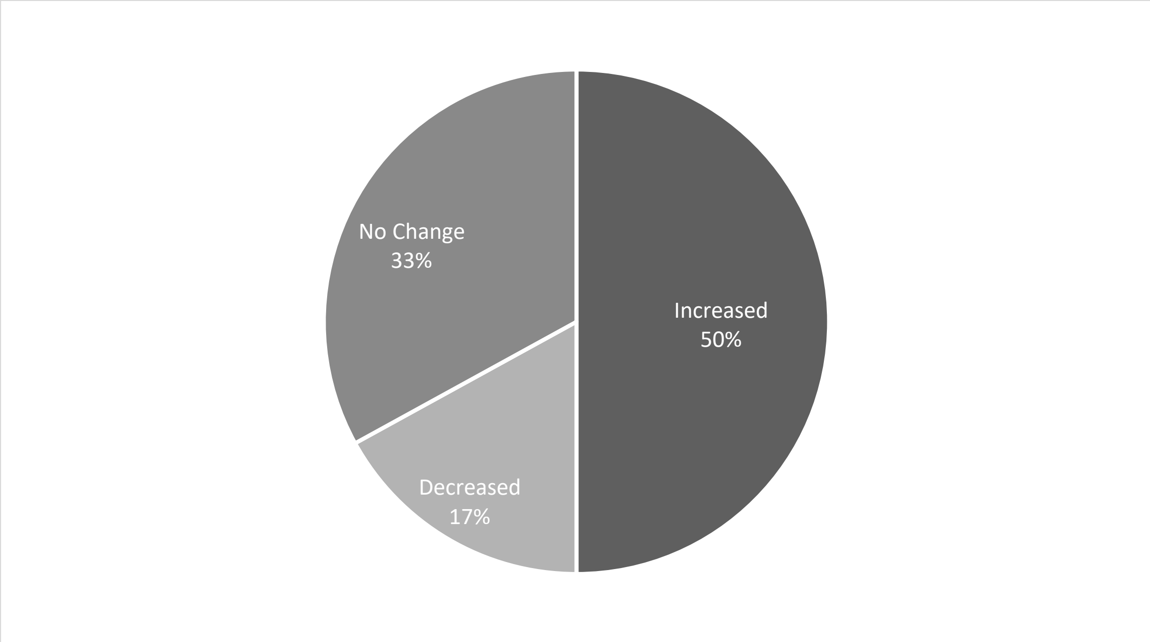


Figure 5. 1**: Percentage of respondents who felt the area occupied by the Rubus had increased, decreased, or not changed**

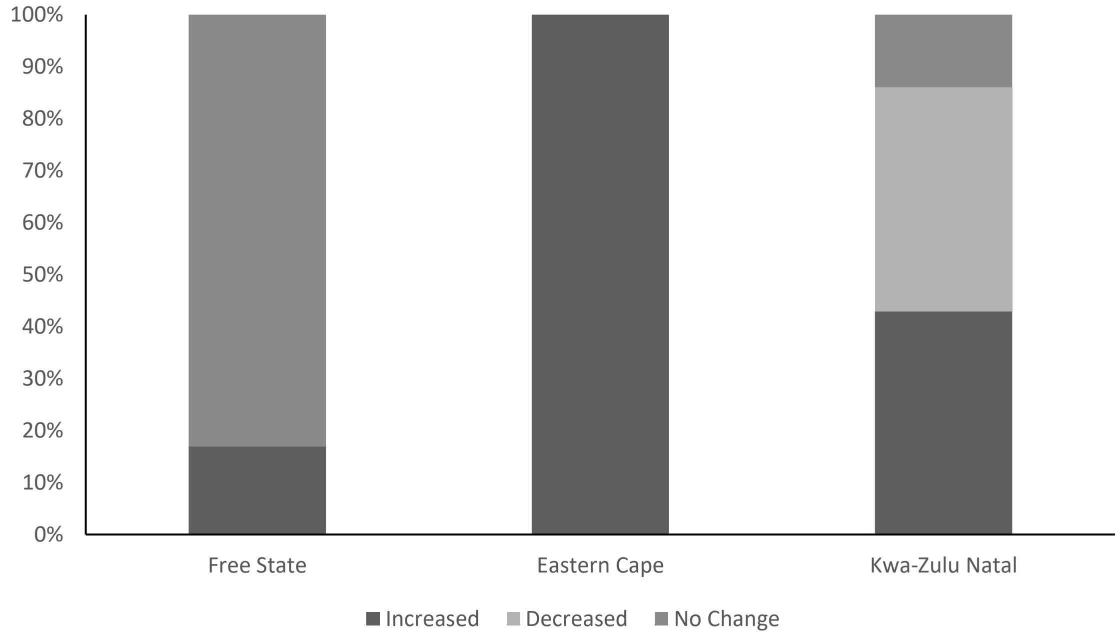


Figure 5. 2: The variation in spread of invasive Rubus species according to landowners and across the three regions sampled.

5.1.1. Questioning Externality Status

As has been highlighted, a core principle of an externality is that it must be experienced by a third party (van Rensburg *et al.,* 2015). Given this, it is important to distinguish whether the impacts faced by respondents in the case of invasive *Rubus* are indeed externalities. Recall that Pigou (1932) stipulates that an externality must be dealt with by government if the interaction that generates the externality cannot be attributed to a specific legal entity. In other words, if no legal entity can be found responsible for the externality producing entity, then responsibility falls to the government to amalgamate those externalities and deal with the entity producing them. The externality status has ramifications regarding who is to be held responsible for the costs incurred by the invasive *Rubus* species. It also has implications regarding whom the benefits should accrue to. If a respondent planted or introduced invasive *Rubus* species propagules on their land, then they can be held liable for the ramifications – good or bad. If not, then government must, theoretically, deal with the costs or promote the benefits.

A question was posed to respondents, "Did you plant this plant (in reference to invasive *Rubus* species on the respondent's property) on your property?". Ninety-four percent of respondents indicated that they had no role in planting or propagating the invasive *Rubus* species. A follow up question designed to elucidate on the source of any propagules of invasive *Rubus* species found that the small minority (6%, all of which were in the Free State Province) of respondents that had planted the *Rubus* species on their property indicated that the source of propagules for this planting was from the surrounding community. This suggests that the negative impacts that were experienced by the respondent from invasive *Rubus* populations were not because of self-planted, cultivated patches but rather wild populations present in the region prior to their own planting of the species. These responses indicate that any impacts uncovered or certified in this study from invasive *Rubus* species can be deemed externalities.

5.1.2. Understanding Respondent Sentiment

Question six queried respondents as to if they were "aware of alien invasive plants and the impacts that they pose?" The aim of the question was to ascertain the respondent's disposition towards invasive *Rubus* species. It is worth noting that the respondents were queried about their sentimental disposition toward *Rubus* based on economic attributes, did it benefit or cost them economically, and not from an environmental aspect. For example, if a respondent believed invasive *Rubus* was having an impact on local wildlife, and they did not own the wildlife nor incur costs because of this interaction, then this impact, if raised by the respondent, would be dismissed as irrelevant.

Ninety-four percent of respondents indicated that they indeed did have an awareness of IAP prior to the study. This suggests that respondents had prior interaction with some form of IAP based organisation, literature or an individual informed by these sources. Knowing the state of the respondents IAS knowledge informed the study of the potential bias they may hold. Had respondents been entirely ignorant of general IAP or IAS impacts then any impacts the respondent cited regarding *"Rubus"* could be accepted as being entirely divorced from the general literature on IAPs. In this sense, these respondents could be regarded as entirely devoid of any bias that may have been introduced from general IAP knowledge. This can only be said to be the case for six percent of respondents. Having derived the general knowledge of the respondent group, the sentiment of respondents towards invasive *Rubus* was sought using the question:

"What is your feeling towards the statement: "This plant (invasive *Rubus* plants specifically) is beneficial and should be allowed to propagate and expand over new areas."?"

Forty-five percent of respondents strongly disagreed that invasive *Rubus* species were beneficial and should be allowed to propagate (Table 5.1). This number can be contrasted with the opinion of experts – covered in detail further in the chapter – of which eighty-two percent were opposed to the promotion of *Rubus* species. In total, sixty-seven percent of respondents indicated that they did not support the propagation or spread of invasive *Rubus* species. Twenty-one percent did support the spread and propagation of invasive *Rubus* species. However, no respondents strongly agreed with the notion (Table 5.1). All respondents from KwaZulu-Natal Province indicated a "Strongly Disagree" or "Disagree" stance regarding the notion. Every region had respondents that disagreed whereas not every region had respondents that agreed. The region with the most "Agree" responses was in the Free State. The region with the most "Strongly Disagree" responses was in KwaZulu-Natal Province.

Table 5. 1: Positive sentiment toward invasive Rubus species among economic agent questionnaire respondents

	Responses				
Province	***Strongly Disagree***	***Disagree***	***Indifferent***	***Agree***	***Strongly Agree***
Free State		5%	12%	16%	
Eastern Cape	12%	12%		5%	
KwaZulu-Natal	33%	5%			
All	***45%***	***22%***	***12%***	***21%***	

The reverse question was then posed to respondents:

"<u>What is your feeling towards the statement: "This plant (invasive *Rubus* plants specifically) is a menace and should be eradicated.</u>"?"

There was a divergence of opinion among respondents to this question. Thirty-nine percent "Strongly Agreed" with the notion that invasive *Rubus* species are menacing and should be eradicated (Table 5.2). All these individuals were from KwaZulu-Natal Province. Twenty-eight percent simply "Agreed" with the notion. In total, sixty-seven percent of respondents agreed with the notion whilst, twenty-one percent disagreed. All regions had respondents that either "Agree" or "Strongly Agree" with the notion. Not all regions had respondents that "Disagreed" with the notion. No respondents indicated a strong opposition to the notion.

Table 5. 2: Negative sentiment toward invasive Rubus species among economic agent questionnaire respondents

	Responses				
Province	***Strongly Disagree***	***Disagree***	***Indifferent***	***Agree***	***Strongly Agree***
Free State		16%	12%	5%	
Eastern Cape		5%		23%	
KwaZulu-Natal					39%
All		***21%***	***12%***	***28%***	39%

The responses above indicate a diverse sentiment amongst respondents. Most of the respondents view invasive *Rubus* species disfavourably. However, some of the respondents view invasive *Rubus* favourably. The regional divergence of sentiment appears to be related to the use of blackberry in the local communities. The communities that made extensive use of invasive *Rubus* species, or had members that did so, appeared to have a more positive and less negative regard toward the invasive *Rubus* species in general. Those communities that did not make extensive use of invasive *Rubus* species, or have members that did so, appeared to have a less favourable opinion of the invasive species. The sentiments of communities can be contrasted with the sentiment of expert opinion, discussed in more detail further in this chapter, which was understandably against the use of *Rubus* species and calls for the control and eradication of the invasive species.

5.1.3. Positive Impact

Total value is regarded as consisting of use value, non-use value, and option value. These categories of value were discussed in chapter 2. Question eight is aimed at soliciting from the respondent as to whether they derived use value from the invasive *Rubus* species and attempted to establish any monetary values for the magnitude of that use value. Question nine then stated several positive uses that invasive *Rubus* species have according to literature and according to the bio-economic model presented in chapter four and asked respondents if they personally made use of the invasive *Rubus* species in any of the ways listed.

Fifty-six percent of respondents indicated that they did make use of invasive *Rubus* species in some manner. Of this fifty-six percent, twenty-two percent were from the Free State Province, seventeen percent from the Eastern Cape and seventeen percent were from KwaZulu-Natal provinces(Figure 5.3). Uses varied from using *Rubus* berries to make jams and gins in some regions, whilst in others the occasional personal consumption of fruits was noted. Surprisingly, this use did not feature prominently with the respondents in this study. Many indicated that the fruit is laborious to harvest, given the thorns on the bush, and does not have a good shelf-life. Special efforts in questioning were made with any farmers as regards the use of the plant by staff that lived and worked on the farm. All farming respondents indicated that the staff may occasionally pick a berry but that the berry did not seem to constitute a major contributor to their diets.

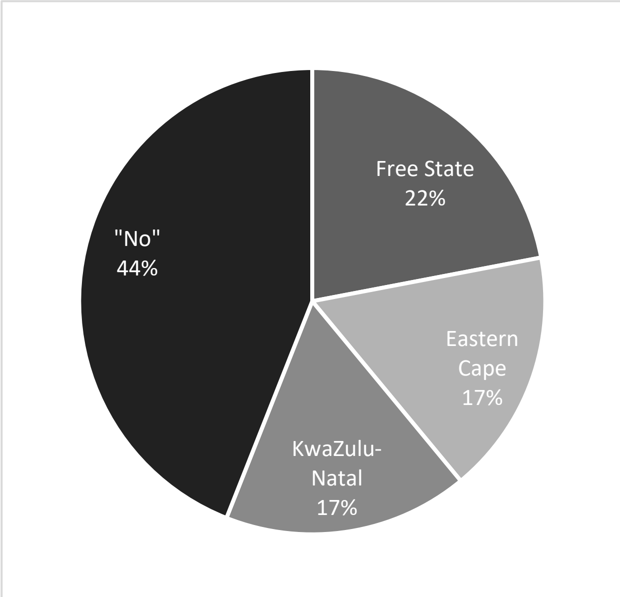


Figure 5. 3: Percentage of respondents in each region who indicated using invasive Rubus. The "No" category represents the respondents (44% of the total population) that stated they have never used invasive *Rubus* berries.

Where possible, respondents were encouraged to estimate a monetary value for any of the uses made of the invasive *Rubus* species. Respondents from each region indicated that they utilised the berries in the production of jams that were then retailed. The magnitude of the contribution of this use varied between respondents and between regions. Some respondents produced their own "bramble jam" and claimed to eat copious amounts of it as a household. A rough estimation of the annual jam jars consumed stood at fifty-four bottles per annum based on almost a single jar per week. The local price of a jar of Bramble jam stood at R45/jar. The annual savings of the household stood at R2 430 given their own home production of jam. This savings figure would need to take into consideration the input costs associated with the production process which would differ on a case-by-case basis. An estimation of these input costs does not fall within the parameters of this study. As such, some of the figures stated below may be overestimates. Alternatively, some households indicated that they made and consumed perhaps one jar of jam during the year.

One respondent, a restaurant owner, used large quantities of invasive *Rubus* berries to produce a wide array of complementary products. This varied from "Bramble jam" to "Fruit salad dressing" as well as "Sweetened cordial". These products were sold at R45/450 g, R35/250 ml and R40/750 ml, respectively. These products all formed part of a 'unique dining experience' and augmented income of the restaurant through the sale of said products. The respondent indicated that these alternative products generated R12 000 per annum. Questioning a different economic agent indicated that the berries were utilised to make certain liquors. This included a pre-made gin cocktail and a "Bramble Gin". These products were sold at R22.50 and R350, respectively. Access to a good stream of regional and foreign tourists provided a good market for these unique goods and one that permitted a high price on products. Revenue generated from these two products stood at R114 210 and R60 550 per annum. Bringing total revenue from invasive *Rubus* species products to R174 760 for this respondent. Both previously mentioned respondents were engaged in the commercial retail of invasive *Rubus* species. Both indicated that the source of berries had been the local community and that they paid per kg for invasive *Rubus* berries that were delivered to their premises by local harvesters. Payment per kg varied from R7 to R10. One respondent purchased 100 kgs and the other roughly two tonnes of berries. The berries were collected by the local community with respondents indicating that the lower economic class were the predominant collectors. This suggests that between R14 700 and R21 000 was injected into the local community through the collection and sale of invasive *Rubus* berries. This provided an alternative income stream for the local community and one that utilises invasive alien species. All indications suggest that the collection process took place over the space of 15 days to a month and therefore provided a sizeable cash injection over a relatively short period of time for the small local community. This use may also facilitate the removal of invasive *Rubus* species propagules from the surrounding region thereby reducing propagule pressure at least from the seed.

Having queried respondents regarding any use values that they recalled; the questionnaire went on to state several known uses of invasive *Rubus* species. Respondents were posed the following statement, "International studies have suggested that this plant and its berries have the following positive impacts: please indicate whether you make use of/believe you make use of the plant/berries in this/these ways.". Five different uses were then stated, in table format (refer to appendix VII, the general questionnaire), and the respondent was asked to indicate whether they did or did not use the invasive *Rubus* plant or berries in that way.

Of the five potential uses that were posed to respondents, only three were utilised by one or more respondents. Of these three uses, only two had a percentage of respondents greater than 10% and only one had more than 50% of respondents indicating a use factor (Table 5.3). Thus, of five possible uses only one was endorsed by most of the respondents. Of the other four, two had a minority of respondents indicate use and two had no endorsement by respondents at all (Table 5.3).

The use of berries or invasive *Rubus* plants as an ingredient for modern cosmetics or anti-inflammatory drugs was entirely disregarded by all respondents. This was thought to perhaps be because of the sampling effort made. Thus, a prominent cosmetic company in South Africa – The Body Shop – that would certainly have a proclivity to the use of *Rubus* berries in this fashion, given their company ethos and product ranges. The Body Shop is a global cosmetics company that employs around twenty-two thousand people across sixty-six countries and the premier cosmetics company in South Africa when considering alternative cosmetic products. The Body Shop Products team was asked if they had "any products made using blackberry (bramble/*Rubus* species)?". The response was, "We do not have any Body care ranges currently that contain blackberries or blackberry extract." (The Body Shop, pers. comms, 2020). This questioning provided the grounds to reject the use of Blackberry/Bramble in cosmetics in South Africa.

The two most endorsed uses of invasive *Rubus* species by respondents was either harvesting for commercial retail or for personal consumption. Forty-four percent, of respondents indicated that they had harvested and sold blackberry. This question was phrased to respondents in a manner that conveyed that the sale of invasive *Rubus* species berries in any way as a form of income was accepted. The sale of the blackberries by respondents was always infrequent across years and for the most part did not constitute any full-scale business. No respondents grew invasive *Rubus* species on a commercial scale. No commercial growing berry producers were encountered in any of the surveys conducted. Commercial growers located online were all based in the Western Cape Province. As discussed, some respondents made and produced several products from invasive *Rubus* species. These products formed part of the overall offerings of the business as opposed to being a mainstream of income.

Table 5. 3: The responses of respondents regarding their use of alien invasive Rubus species.

Use	Responses (% of respondent group)	
	Yes	No
To provide basic constituents for anti-inflammatory drugs?	0	100
Ingredients for modern cosmetics	0	100
Harvested for commercial retail	44	56
Harvested for personal consumption	61	39
For forest regeneration	6	94

No respondents relied on the sale of invasive *Rubus* species berries as a sole or significant form of income. Those respondents that sold products that of which required invasive *Rubus* species berries as an ingredient also indicated that those products were only a contribution to overall income and not the sole source.

Harvesting of invasive *Rubus* species berries for personal consumption was another suggested use put forward to respondents. Sixty-one percent of respondents indicated that this was a use that they had engaged in.

The eleven percent of respondents that indicated the use of invasive *Rubus* species for personal consumption were questioned further. These respondents indicated that the invasive *Rubus* species berries were not a major contributor to their diets. One respondent – representing a large conservancy agency – implied that staff in the field on foot patrol might make use of the invasive *Rubus* species berries in this fashion. The respondent indicated that the staff ingested the berries while out on patrol yet when questioned if the invasive *Rubus* species berries served a major contributor to the staff's diets the respondent replied that they did not think that was the case. It was evident that any consumption in this manner was more of a convenience than a significant contributor to food security for the economic agents involved.

A commercial blueberry and nut farmer was included in the Eastern Cape Province sample group. This respondent was well positioned to make extensive use of nearby invasive *Rubus* populations. When questioned regarding personal consumption the respondent indicated that the berries were infrequently consumed. This consumption often revolved around convenience consumption. The respondent was questioned regarding the commercialisation of invasive *Rubus* species berries. As a blueberry, raspberry, and nut farmer the respondent was thought to be a relevant economic agent to question regarding the market for blackberries. The respondent indicated that problems existed around the commercialisation of invasive *Rubus* species. They cited five concerns:

1. The berries were widely available in certain regions and as such, this undermined any efforts towards cultivating and selling the berries profitably as they were widely available in the wild.
2. The berries were "soft-shelled" and therefore did not keep well when refrigerated as they are prone to damage. This meant that longer distance markets were potentially out of reach for the respondent and fresh markets were well supplied by wild populations. Once again supporting the notion that South African wild berries may not be as suitable for market when compared to the specifically cultivated commercial varieties now available
3. The harvesting of wild populations was difficult given the growth habit of the invasive *Rubus* genus. The respondent's exact wording was that the invasive *Rubus* bushes were "hellishly" hard to harvest berries from.
4. The establishment of cultivated plantations would not be economically viable or lucrative given the above factors.
5. The blueberry and raspberry markets had presented more lucrative opportunities and hence had been preferred crops to cultivate.

This final sentiment was corroborated by the South African Berry Producers Association report of 2017. The report indicates rapidly growing markets for blueberry and raspberry products with relatively lacklustre growth for blackberry products.

A respondent also in the Eastern Cape Province that had made indications that they had sold invasive *Rubus* species berries over several years as part of a roadside based industry had noted that in the last five years a drop in sales had occurred for the berries. The respondent indicated that the berries were retailed on the roadside during season and that in his opinion, the demand for the berries via this medium had dropped markedly. The respondent did not have any conclusive suggestions as to why there had been a marked drop, merely that there was a noticeable reduction in demand. As such, this operation had been discontinued.

Three respondents indicated that they had livestock occasionally browsing on the invasive *Rubus* species but insisted this was occasional and that the livestock preferred other browsing or grazing options.

5.1.3.1. Positive Impacts: Numerical value estimates

An objective of this study was to ascribe a monetary value – in Rands – for the impacts that invasive *Rubus* species may or may not be having. Part of this process is engaging the respondents over the Rand value that they can ascribe to the impacts being explored. This was attempted with the following question, "Would you please estimate the Rand value, per year, of these benefits to yourself and your household?". It was made apparent to respondents that this question was directed at information that the respondent regarded as reliable and verifiable. At every possible point the respondent was asked if there was a manual entry, an excel spread sheet or both that could be utilised and assessed by the study to ensure reliability of figures. Many respondents indicated that they did not keep record of any Rand value benefits derived from any transactions revolving around invasive *Rubus* species. However, several respondents were able to provide credible evidence of a Rand value for benefits received.

Figure 5. 4: Total values of benefits for Free State Province based respondents.

The only region that had respondents that could attribute numerical values to the positive impacts that they experienced from invasive *Rubus* species came from the Free State Province. In all other provinces the respondents felt that they did not make use of invasive *Rubus* species frequently enough or in the correct market contexts for them to be able to submit a numerical value or evidence of a value to this question. The total value of direct benefits that met a standard of reliability and credibility in this study was R189 760. This value being solely applicable to the respondents from the Clarens region in the Free State region.

5.1.4. Negative Impact

This section of the questionnaire was conducted and constructed in the same manner as the previous section. There were nuanced changes in the questions and questioning to facilitate the fact that this section was aimed at the negative impacts that respondents might experience as opposed to the positive impacts.

Respondents were asked, “Do you personally feel that you incur any costs from this plant?”. Seventy-eight percent of respondents indicated that they incurred costs from the presence of invasive *Rubus* species on their land. Clarens, in the Free State, was the only site where there were some respondents who indicated that they did not incur costs. Recall that all respondents involved in this study either had invasive *Rubus* species on their property or represented property that had invasive *Rubus* species on it. Any respondent that indicates that they did not incur costs from the invasive *Rubus* species on the property, is indicating that there are no prominent negative impacts despite there being invasive *Rubus* species on the property obviously this is also limited to the sampled respondents. In both the Eastern Cape and KwaZulu-Natal provinces, all respondents indicated that they incurred costs from invasive *Rubus* species populations. Most respondents in the Free State Province , sixty-six percent, indicated that they did not incur any costs from invasive *Rubus* populations while, thirty-four percent indicated that they did incur costs from the invasive *Rubus* populations.

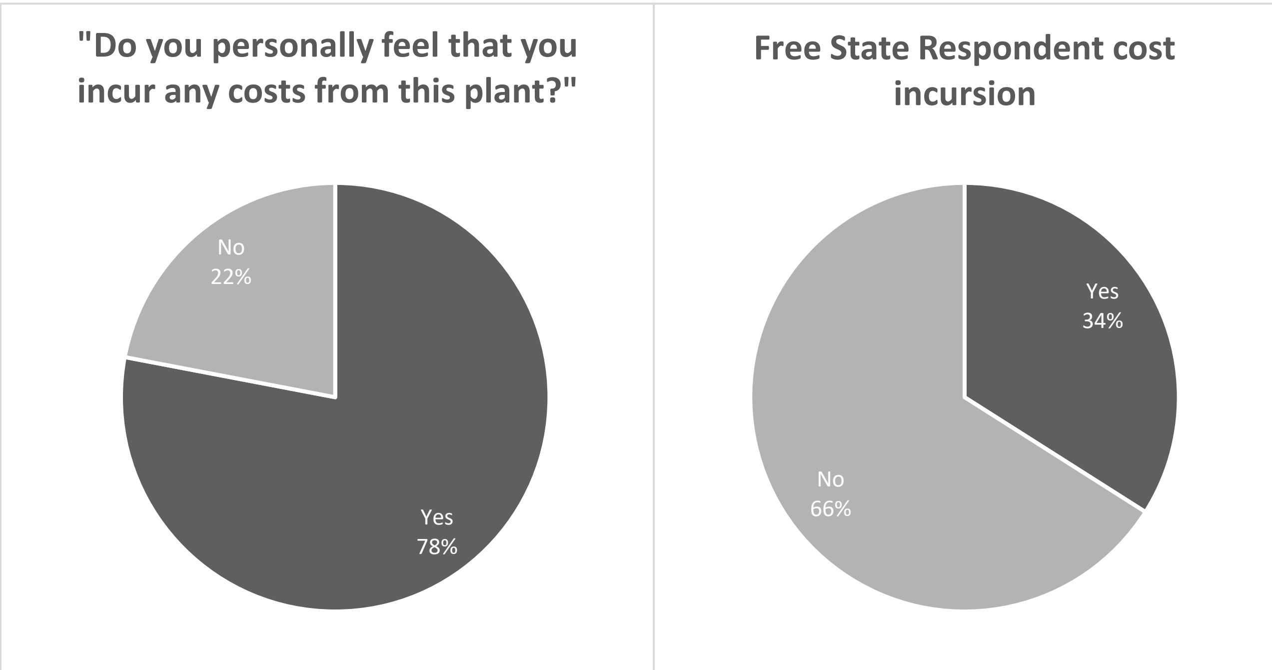


Figure 5. 5: **Cost incursion; Percentage of respondents who felt the incurred costs because of invasive *Rubus* species (Left); Percentage of respondents in the Free State who believed the incurred costs of invasive rubus species (Right). The Free State Province was the only region in which a response of “No” was recorded.**

Respondents were permitted to elaborate on what the costs incurred by them were. The following were cited by respondents as associated costs:

1. Loss of grazing land due to invasive *Rubus* species infestation.
2. Cost of control:
    2.1. Cost of herbicides.
    2.2. Cost of manual labour.
    2.3. Cost of any implements or tools used in clearing.
    2.4. Cost of burning and opportunity cost should fire become uncontrolled.

These costs associated with invasive *Rubus* species were raised by respondents of their own volition. No prompts, suggestions or bias was intentionally introduced in this question. As with the positive impacts section, a question was created to facilitate any recall on the respondent's behalf regarding any costs, negative impacts, experienced due to invasive *Rubus* species that had not been recalled initially.

The next question was phrased, "International studies have suggested that this plant has the following negative impacts: please indicate whether you experience/believe you experience the underlying effects of the plants/berries." Here after a table listed the various negative impacts associated with invasive *Rubus* species globally.

None of the impacts suggested were entirely dismissed by respondents (Table 5.4). Recall that with the positive impacts there were two potential impacts that were dismissed entirely by all respondents. Each potential negative impact received at least one "Yes" and hence none were entirely dismissed.

The altering of fire regimes was an impact informed by the bioeconomic model established in Chapter 4. This was based on the prevalence of invasive *Rubus* species in biomes that are fire reliant, and the copious biomass produced by invasive *Rubus* species. A minority of respondents indicated that they believed that the presence of invasive *Rubus* species had led to an altering of fire regime in the region. Most respondents asserted that they did not believe this to be an impact they experienced or witnessed.

Table 5. 4: Percentage of respondents who indicated either experiencing or not experiencing negative impacts of Rubus species.

Use/Impact	Responses (% of respondent group)	
	Yes	No
Altering of Fire Regime	22	78
Harbouring Vermin	44	56
Creating Fire Hazard	39	61
Developing Impenetrable Thickets	72	28
Reduction of yield by Encroachment	50	50
Reduction of Grazing Land by Encroachment	67	33

Most respondents indicated the invasive *Rubus* species on their land did not serve as a harbouring site for vermin[5]. In this context, a response of "Yes" to this query, was believed to indicate that the respondent had identified a relationship between vermin and invasive *Rubus* infestations. Whether the vermin utilised the invasive *Rubus* infestations as an abode, a refuge, as a barrier of protection or in any other way, was not explored. It was believed that a "Yes" to this question indicated that the respondents had noted enough activity between the vermin and the invasive *Rubus* species to regard the two as being linked on an ecological level. Forty-four percent of respondents indicated that they believed this to be an impact that they personally incurred. Of the Eastern Cape Province respondents, eighty percent indicated this was a problem for them. Respondents in both the Free State and KwaZulu-Natal provinces cited this as a concern as well. However, the Eastern Cape Province appeared to have the most respondents indicating a "Yes" in this category. One respondent pointed out that the invasive *Rubus* species on his land served as a barrier for baboons. The baboons utilised the infestations as a 'shield' to raid cattle feed and were a major pest.

Linked to the altering of fire regimes was the concept of creating fire hazards. A fire hazard differs from a fire regime. Fire regimes are long standing, climatically governed patterns of natural wildfires. Fire hazards can impact fire regimes if they occur frequently with a

[5] Vermin - "Wild animals that are believed to be harmful to crops, farm animals, or game." (Oxford English Dictionary, 2020).

consistency relatable to a common factor, item, plant, bush, or entity. A fire hazard is more prominent in the context of economics (Please refer to appendix II for relevant references and more information). It refers to a neglection of one or another physical entity that can provide the correct conditions for a fire to occur. Certain invasive *Rubus* species in South Africa appear to grow in a thicket fashion. They tend to have large amounts of dry biomass underlying new vegetation. The thick growing fashion with an array of densely intertwined stems appears to trap old leaves, twigs, dead plants, and other debris in and underneath the invasive *Rubus* thicket. This can provide conditions conducive to fire and was considered in the bioeconomic model and presented as a possible negative impact to respondents. Sixty-one percent of respondents indicated that this was not an impact that they experienced. Thirty-nine percent indicated that they believed that the invasive *Rubus* species did serve as a fire hazard.

There were two questions that related to fire in the negative impacts section of this questionnaire. The responses to these two questions did not corroborate across the regions with both questions receiving less than fifty percent agreement from respondents. In both questions KwaZulu-Natal Province had the most support for the impact cited. A greater percentage of respondents indicated that they have experienced fire hazards related to invasive *Rubus* species than those that indicated invasive *Rubus* species had impacted the fire regime in their area. This suggests that the fire hazard impact is more prominent than the fire regime impact in the case of the respondents or more noticeable. It also suggests that respondents recognise the difference between these two phenomena. This divergence could also indicate that the impacts faced by respondents differ based on region (refer to Figure 5.6 for detailed information). In the Eastern Cape Province, the impact of invasive *Rubus* species on the fire regime was not suggested to be prolific if compared to the KwaZulu-Natal Province respondents. There is an indication that invasive *Rubus* species could have fire related impacts in South Africa.

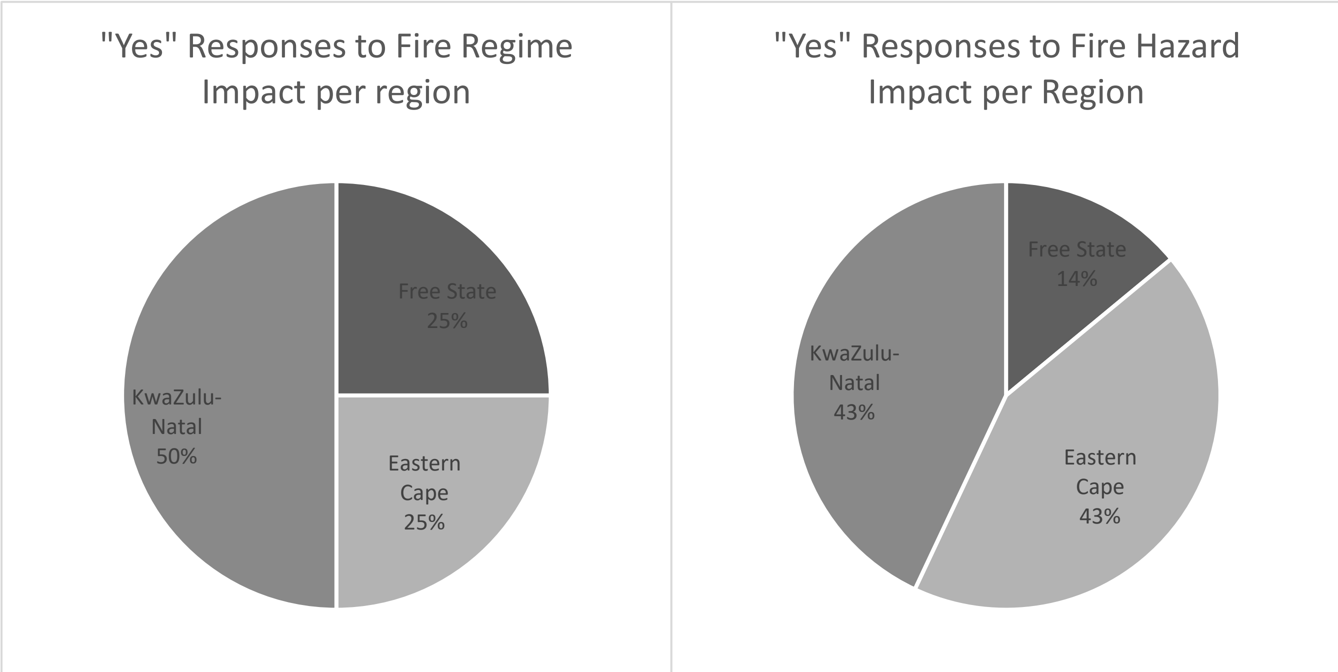


Figure 5. 6: *Rubus* fire impact; Divergence of responses over fire related impacts of questions 12a and 12c; Percentage of respondents who believed *Rubus* species impacted the fire regime in their area (Left); The percentage of respondents who believed invasive *Rubus* species were a fire hazard in their region (Right)

Seventy-two percent of respondents indicated that they believed that the invasive *Rubus* species developed impenetrable thickets that of which had a negative impact on them. Twenty-eight percent indicated that this was not an impact that they experienced. The establishment of thick impenetrable thickets by invasive *Rubus* species is linked to the growth pattern of the plants (This is covered in detail in appendix I). The main concerns respondents raised in relation to impenetrable thickets was that access to water was limited, use of foot paths for livestock management or recreation was hampered and it presented general movement issues. One respondent from the Free State Province indicated that at least one sheep was lost to the thicket growth every year. Stating “Invariably the animals pass through increasingly dense invasive *Rubus* species infestations. At least one animal a year gets caught and dies of thirst in the dense thickets given the holding nature of the thorns”. One respondent operated an activities-based company in the Eastern Cape Province. The company falls under the umbrella industry of “Adventure tourism”. One of the company’s streams of revenue is trail running events. The respondent indicated that the invasive *Rubus* species made the trails more difficult to run and less enjoyable. The respondent indicated that the invasive *Rubus* species had to be cleared frequently and that this cost the business between R500 and R1 000 in maintenance costs just for invasive *Rubus* species. An Eastern

Cape Province based farmer indicated that invasive *Rubus* species had begun to encroach on his waterways. The dense infestation was making it increasingly difficult for cattle to access the water ways and resulting in damage to the cattle's eyes and skin. This is the most widely supported impact from those presented regarding the negative impacts of invasive *Rubus* species.

A reduction in farm yield due to encroachment is an impact cited in Australian assessments of invasive *Rubus* species populations (Sinden *et al*., 2004). Fifty percent of respondents indicated "Yes" to this impact and fifty percent indicated "No". Reduction of grazing land by encroachment was a response that was cited in an Agricultural Research Council report on the state of "Bramble" in KwaZulu-Natal Province (Botha, 2005). Sixty-seven percent of respondents indicated that this was an impact that they experienced. A cattle farmer in the Free State indicated that if invasive *Rubus* species were permitted to overgrow a grazing paddock then the cattle would refuse to go into the paddock. A farm in the Eastern Cape Province was assessed when the questionnaire was administered, and it was evident that the populations of invasive *Rubus* species were encroaching on the grazing land of the farmer. Several dairy farmers in KwaZulu-Natal Province cited this impact as a major concern for their businesses. They suggested that the invasive *Rubus* species encroached on valuable land that of which was grazed for their intensive dairy operations. Several observations were made during the field report where large, dense infestations of *Rubus* were encroaching on a farmer's arable land or affecting a crop production.

5.1.4.1. Negative impacts: Numerical value estimates

An objective of the project was to estimate a numerical value for the magnitude of impacts that invasive *Rubus* species may or may not be having. A distinction must be made from the outset between the value of negative impacts and the value of the cost of control. The value of negative impacts relates to any monetary figure that can placed on an impact being experienced by a respondent which they view as detrimental. An example would be the loss of a barn from a fire that was fuelled by an invasive *Rubus* species population. The Rand value of the barn, and its contents, would represent the cost of the fire hazard impact of the *Rubus* species. Cost of control is an externality cost imposed on respondents and forms part of mitigative expenditure. It is not exactly equivalent to a cost of impacts. Cost of control will be dealt with separately to the value of negative impacts.

Respondents were asked to estimate the Rand value of the costs to them from invasive *Rubus* species. Some respondents found it difficult to respond to this question. Respondents indicated that they did not keep record of the costs incurred or that they felt unsure as to the total value. One respondent indicated that invasive *Rubus* species cost him R100/ha of land per annum. This was on a 1 000-ha farm and as such the value could be rounded up to roughly R100 000/year in grazing losses, yield losses, opportunity costs and the cost of control. This respondent did not use any herbicides for control and had indicated that burning was the preferred method. The statement regarding “R100/ ha” was an estimation and one that is not substantiated by any record keeping. One respondent indicated the loss of at least one adult sheep per annum. The value of this sheep according to the respondent was approximately R3 000. These were the sole responses to this question. At this point a value of R3 000 will be attributed to the negative direct impacts of invasive *Rubus* species.

5.1.4.2. Cost of Control

The cost of control can be regarded as a negative impact. The existence of the invasive *Rubus* species infestations generates negative externalities for the landowner. The landowner wants to eliminate or reduce these externalities and thus engages in an action that they believe will do this. This invariably appears to involve some sort of control measure. These control measures incur costs. The cost of control is a negative externality as it detracts from the resources of the individual. Those resources can be both money and time. The implication being that had the plant not been present on the property the respondent could have spent those resources in other ways. If the presence of the plant on the property is not because of the landowners actions the plant has been introduced by a separate party or through natural invasion. This makes the cost of control an externality. A separate section of the questionnaire was directed at establishing the cost of control. This section was titled “Containment” and consisted of seven questions.

The first question sought to establish if the respondent had ever engaged in control procedures regarding the invasive *Rubus* population on their property. Evidently, had a respondent not engaged in said action they would not be able to contribute further to the understanding of the costs of control.

Respondents were asked, “Have you attempted to remove the patches of Rubus/Blackberry from your property?” Sixty-seven percent – a majority – of respondents indicated that they had attempted to remove invasive *Rubus* species from their property.

All respondents from the Eastern Cape and KwaZulu-Natal provinces responded “Yes” to this question.

Respondents were further asked what method of control they utilised. Respondents were provided with responses “Mechanical” and “herbicides” as well as “Other” in which they could include other methods of control employed. The results to this question differed according to region. The Eastern Cape Province saw the greatest variety of methods used. Respondents from the region had engaged in spraying herbicides, mechanical clearance, and other methods. The preferred method of clearing invasive *Rubus* species was mechanical – with sixty percent of respondents using this method. Respondents representing the KwaZulu-Natal Province had all utilised both chemical and mechanical clearing extensively. The Free State Province had a single respondent that asserted that they had unintentionally engaged in ‘clearing’ of invasive *Rubus* species. When questioned further the respondent elucidated that the use of Mob grazing, or high intensity grazing, with their cattle population, and good rotational practices had resulted in a steady control of invasive *Rubus* species populations on their land.

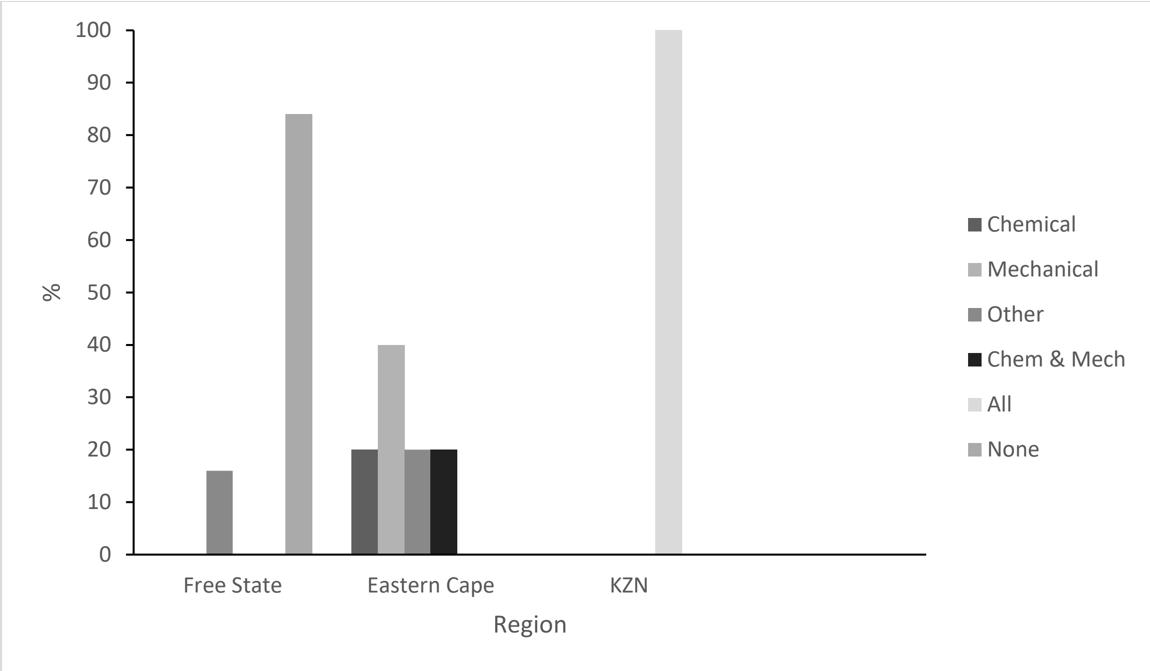


Figure 5. 7: Percentage of control methods employed and applied by the respondents from each region surveyed

Overall, the most popular control methods were a combined method of both chemical and mechanical clearance. This method falls under the term of "integrated control" in invasive alien species management literature (see Figure 5.7).

Questions aimed at determining the success of the control measures implemented – with resultant direct financial implications – and how much these control measures cost the respondent were then posed.

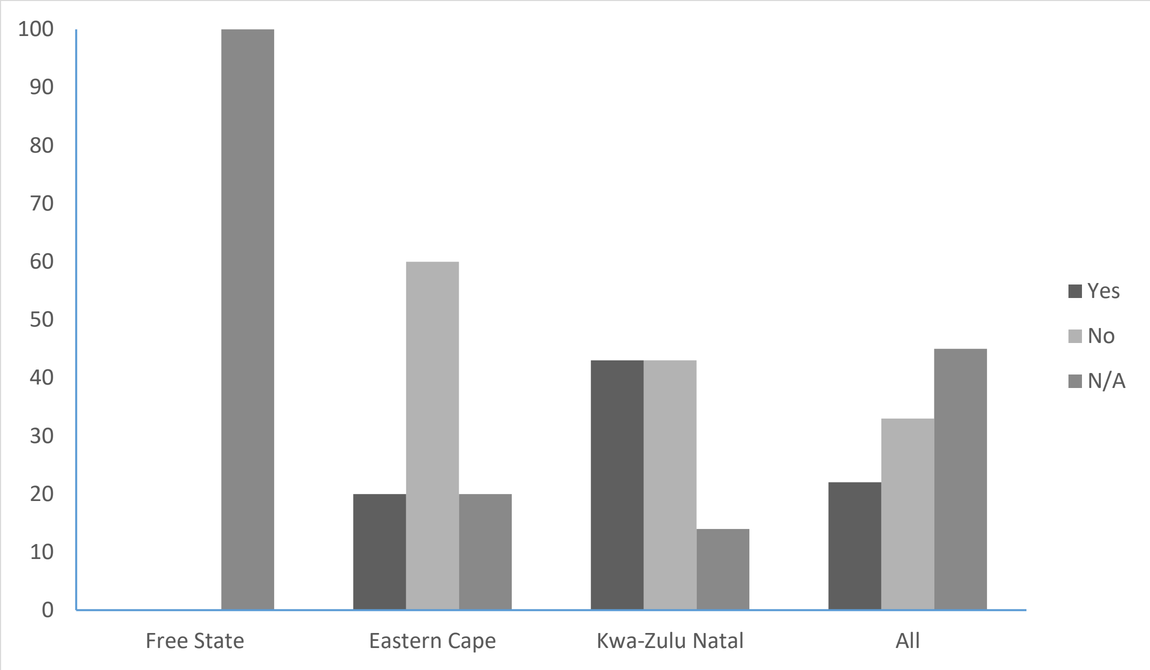


Figure 5. 8: Percentage of respondents who had successful removal attempts

As indicated, respondents in the Free State Province did not engage in measures to control the invasive *Rubus* populations. As such, their responses to this question were not applicable. Sixty percent of respondents in the Eastern Cape Province indicated that the patches of invasive *Rubus* species had been permanently removed, twenty percent reported that they had not, and twenty percent did not have a recorded response. The KwaZulu-Natal region showed a forty-three percent split between patches being permanently removed and those not. It appears that efforts made by respondents to permanently remove invasive *Rubus* species have been more unsuccessful than successful. Thirty-three percent of respondents indicated that the patches were not removed, and twenty-two percent indicated that they were. Upon further engagement with respondents in the KwaZulu-Natal Province it was established that permanent removal of invasive *Rubus* stands was because of bi-yearly application of herbicides and mechanical removal over several years (twenty years in some instances).

In addition, the questions were utilised to ascertain what cost of removal respondents incurred. Every effort was made to request financial records or data from the respondent regarding the cost of control. Wherever possible, respondents were asked if they had a manual entry in a data book, an excel spreadsheet that contained said data or both that could be accessed to ascertain the cost of the control procedures. This information was often not readily available and as such much of the discussion was based on what chemical was used, how many man hours of labour were used, if any equipment was utilised and how frequently the clearing operations were initiated.

Figure 5.9 details the costs of control provided by respondents. These are costs that were either stipulated by respondents or else shown through financial records to be expenditure related to invasive *Rubus* species control. The three regions, Free State, Eastern Cape, and KwaZulu-Natal are present with an additional region added: Government of KwaZulu-Natal Province. This region has been added given the standing of one of the respondents and their specific response to this question. This respondent represents a large conservancy operation charged with the protection and conservation of various conservancy zones across the KwaZulu-Natal province. This respondent indicated that at present R2.5 million per annum of the conservancies budget is spent on invasive *Rubus* species control. The respondent further elaborated that this was an inadequate amount to reduce spread of invasive *Rubus* species. The respondent indicated that to reduce spread R10 million – R12 million would need to be spent over a period of ten years. The respondent indicated that for eradication to be achieved, R15 million per annum for ten years would be necessary. These sums represent government funded clearing operations. Compared to the private respondents consulted in this survey. Of the respondents in the Free State Province, only one respondent spent R2 380 on invasive *Rubus* species control. This was a once off amount as it was the value of the infrastructure required to engage in Mob grazing. In the Eastern Cape Province, a total of R5 000 was noted as being spent by respondents on clearing invasive *Rubus* species. This was predominantly spent on herbicides such as Garland® to kill invasive *Rubus* populations. KwaZulu-Natal reported an expenditure amount of R55 000 per annum. This was the amount spent on herbicides, labour, and farm equipment. All of these are direct costs. The indirect costs of these practices have not been explored in this project.

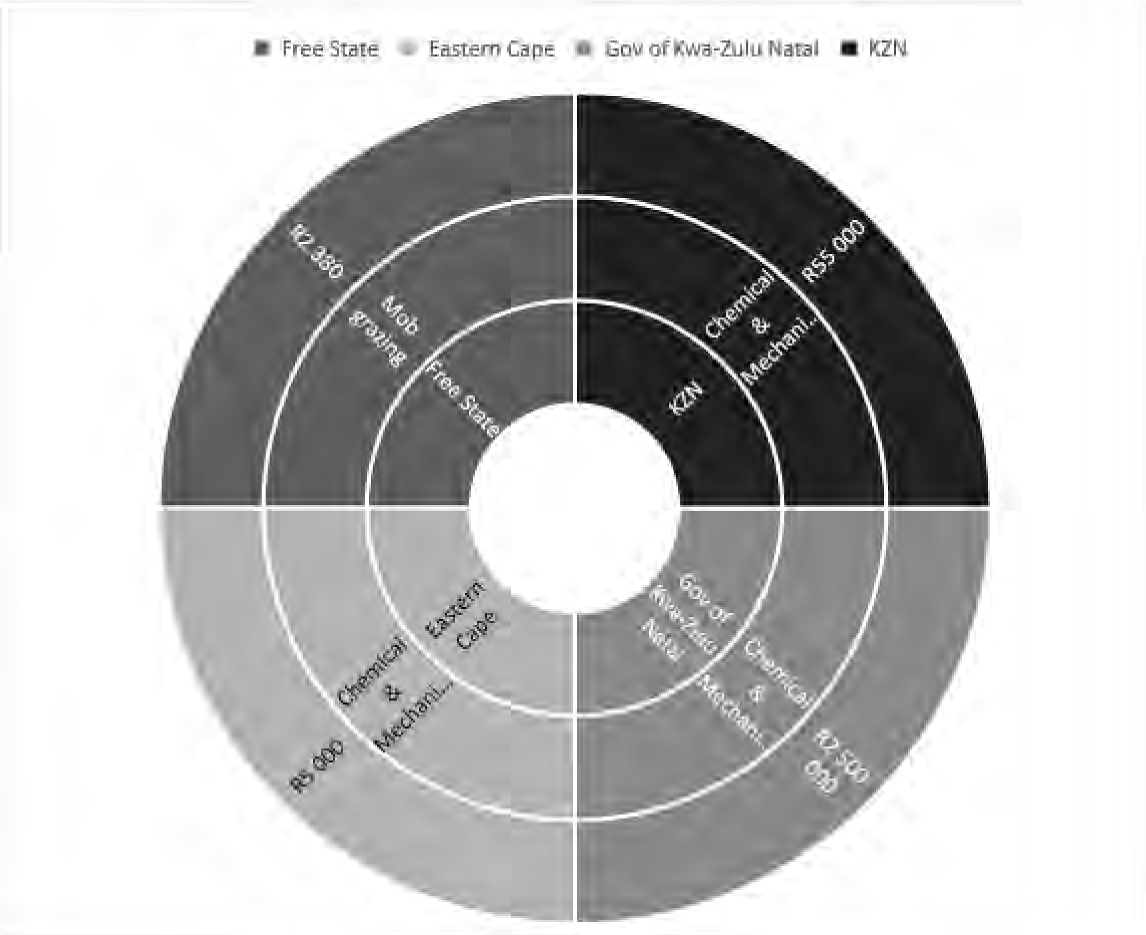


Figure 5. 9: Details of cost of control expenditure by private economic agents over the respondent group. The cost represents total cost in of the impact and not that per any unit of measurement

The total expenditure across eighteen respondents in three selected regions comes to R62 380 for the single year under assessment. This is excluding the figure produced by the government of KwaZulu-Natal Province representative. The respondents that could not produce a response to questions regarding the cost of control still indicated that they believed they incurred costs from invasive *Rubus* species.

5.1.5. Cost-Benefit Analysis

A cost-benefit analysis is a basic economic analysis often associated with environmental economics. The cost-benefit analysis involves comparing two numerical values that represent two opposite ends of the value spectrum. In this way, decisions can be made as to whether the object/entity under consideration can be considered generally more beneficial or costly.

In the case of this study, two separate cost-benefits must be conducted. One that solely compares private costs and benefits – omitting information provided by the conservancy respondent from KwaZulu-Natal, i.e., government funds – and another that includes the latter information.

5.1.5.1. Private cost-benefit

At first, the private costs and benefits derived by the respondent group will be covered. This is a reference to costs and benefits experienced by private landowners or non-government, non-public individuals. In the case of private benefits, this value stands at R189 760 per annum. In the case of private costs, this numerical value stands at R62 380 per annum. The ratio of cost: benefit at these values is: 0,33:1. Or that for every R1 of private benefit enjoyed and recorded by the collective respondent group R0,33 in private cost were incurred and recorded by the same collective. The second iteration can consider figures that did not necessarily meet the criteria of being credible or reliable. This second cost-benefit is calculated to incorporate anecdotal figures provided by landowners to see if these anecdotal figures noticeably change the balance of cost-benefits. In this project's case, this is a reference to the R100/ha estimation made by a Free State respondent. The individual's farm was 1 000 ha. This would increase the cost portion by R100 000 to R162 380. An increase in the cost: benefit ratio to 0,86:1, more than doubling the previous ratio. However, the cost-benefit analysis in this case would still be in favour of the benefits. It must be noted that most of the positive monetary value provided for the cost-benefit accrued to a small group of landowners and as such, the cost-benefit does not provide the most accurate representation of the distribution of the benefits.

5.1.5.2. Public cost-benefit

The information provided by the conservancy respondent from KwaZulu-Natal Province must be treated as standalone figures directly different from those listed above as they represent a contribution of government-based funding. These figures are directly associated with government budgeted funds directed at the control of invasive alien species. This suggests that the cost: benefit ratio for this organisation in the context of invasive *Rubus* species stands at R2 500 000:0. In favour of costs, and without considering all additional externalities not included. This study has not assessed the benefits derived from the control of *Rubus.* If these benefits could be accounted for, they may present a different outcome for the cost-benefit ratio.

5.1.5.3. Costs and Benefits per Hectare Analysis

Having estimated numerical values for the positive impacts, negative impacts, and the cost of control, the costs, and benefits of invasive *Rubus* species could be quantified monetarily. Combining the cost and benefit data with the data acquired on the land coverage of the project enabled ratios to be generated. These ratios represent the costs or benefits per hectare for this project. This combined data was again split into private and then public cost and benefit assessments. The public cost assessment was inclusive of all values derived, i.e., both private and public costs and benefits.

Table 5. 5: Depiction of the costs and benefits spread across hectare and private economic agents

Variables								
Provinces	**Hectares (ha)**	**Costs (R)**	**Benefit (R)**	**No. Economic Agents**	**Cost/ha**	**Benefits/ha**	**Cost/Economic agent (R)**	**Benefit/Economic agent (R)**
Free State	2 362	R2 380	R189 760	6	R1,00	R80,34	R396,67	R31 625,67
Eastern Cape	6 800	R5 000	-	5	R0,74	-	R1 000,00	-
KwaZulu-Natal	5 280	R55 000	-	6	R10,42	-	R9 166,67	-
Total	14 442	R62380	R189 760	18	**R4,32**	**R13,14**	**R3 465.56**	**R11 162,35**

Private costs per hectare of land owned stand at R4,32/ha. Private benefits per hectare of land stand at R13,14/ha. Private benefits are three times as large per hectare as private costs. However, considering the data on a regional level changes this perspective. The costs per hectare in KwaZulu-Natal Province are ten times that of the Free State and the Eastern Cape provinces. Similarly, the benefits per hectare accrue solely to the Free State Province. The cost of invasive *Rubus* species per private economic agent was estimated at R3 465,56. Benefits for these agents stand at R11 162,35. From our current dataset it is evident that the private economic agent at selected sites in South Africa gains from invasive *Rubus* species, when only considering private costs and benefits reported in this study.

When including the value expended by taxpayer funded operations the picture changes drastically. Government expenditure on invasive *Rubus* species takes the value of the cost per hectare from R4,32 to R177,43. The cost per agent is increased dramatically from R3 465,56 to R142 354.44. The *Rubus* species has a complex impact on the South African economy.

There are several pertinent points that must be conveyed:

1. The private cost: benefit is less than one. This is largely due to the influence of the Free State Province which reported high benefits and low costs. The result derived from the Free State Province is because of respondents in that region having sufficient administrative resources to keep appropriate record of the costs and benefits associated with products produced from *Rubus* and does not take into consideration the cost of inputs. As such, the benefits from the Free State Province are inflated.
2. The inclusion of public funding shifts the cost: benefit ratio from less than one to 13,5:1. This is assumed to be, to some extent, because of the government spending being directed at regions or areas that of which are not under private tenure and as such, the costs instituted by *Rubus* in that region or area are not recorded by private landowners but only become apparent because of government intervention. The removal of government spending would not stop these impacts, it would merely remove the metric presently used to ascertain the value of the impact.

Table 5. 6: Depiction of the costs and benefits spread across hectare and both public and private economic agents

Variables								
Provinces	**Hectares (ha)**	**Costs (R)**	**Benefits (R)**	**No. Economic Agents**	**Cost/ha**	**Benefits /ha**	**Cost/Economic agent (R)**	**Benefit/Economic agent (R)**
Free State	2 362	R2 380	R189 760	6	R5,24	R80,34	R396,67	R31 625,67
Eastern Cape	6 800	R5 000	-	5	R0,88	-	R1 000,00	-
KwaZulu-Natal	5 280	R2 555 000	-	7	R484,00	-	R365 000,00	-
Total	14 442	R2 562 380	R189 760	18	**R177,43**	**R13,14**	**R142 354,44**	**R10 542,22**

5.1.6. Conclusion: Economic Agent Questionnaire

Invasive *Rubus* species in South Africa have an impact on economic agents and that these impacts are both positive and negative. It is evident that the positive and negative impacts are not uniformly spread across the selected study sites. They are unevenly distributed with some economic agents experiencing more benefits and others more costs. The invasive *Rubus* species is an appropriate case study for an invasive alien plant externality in South Africa. The plant generates both positive and negative impacts on third parties. Some of these third parties gain from these externalities and others suffer because of them. It is apparent that the government certainly spends the most on *Rubus* control and efforts to mitigate negative impacts. Perhaps this could suggest that the cost of *Rubus* is largely born by the government or at the very least, the government appears to internalise the cost of *Rubus* more prominently than private economic agents. It is evident that economic agents do not know what species of invasive *Rubus* genus they are dealing with. They invariably respond with generic or common names. It is evident that the disposition of respondents towards the invasive *Rubus* species is dependent on their interaction with the species as well as they interaction of the community with the species.

5.2. RESULTS: EXPERT OPINION QUESTIONNAIRE

An expert opinion survey was conducted between 15 to 17 May 2019 at the Waterval Country Lodge, Tulbagh, Western Cape Province, South Africa. The event attracted participants from various invasion science fields. The use of an expert opinion questionnaire (appendix VI) has been discussed in chapter 4. A symposium on biological invasions was thought the most appropriate platform for this form of questionnaire. This is based on the DEA's response to PAIA 172588 (appendix III) and PAIA 180636 (appendix IV). The National Environmental Biodiversity Act informed the study that invasive species legislation was an expert driven process. The legislation mandated the establishment of the Alien Invasive Species lists. These lists are utilised to orchestrate budget allocations and management priorities on National, Provincial and Municipal levels. These lists are constructed based on expert opinion and previous legislation. This was confirmed by the DEA in writing a response to PAIA 172588. Apart from being an expert driven process, new legislation was informed by previous legislation. In this case the Conservation of Agricultural Resources Act of 1989, the preceding legislation. In CARA, *Rubus cuneifolius* and *Rubus fruticosus* agg. are the only species of *Rubus* listed, recalling that *Rubus fruticosus* is not strictly a species. The new AIS (2014) lists – established after CARA (1989) and NEMBA (2008) have six species of *Rubus* listed. The additional species of *Rubus* include: *Rubus ellipticus, Rubus flagellaris, Rubus niveus,* and *Rubus immixtus.* These species could not have been assigned categorisation based on continuity with past legislation as they were not in previous legislation. Therefore, their categorisation must have been informed by expert opinion. The DEA response to PAIA 172588 further stated that preliminary risk assessments were utilised to assist in this endeavour. These risk assessments were requested in PAIA 180636. The DEA responded that only a single risk assessment was available on public record. That assessment was for *Rubus fruticosus* agg. Again, the categorisation of the majority of *Rubus* species must have been based on the opinions of experts engaged at the time. In other words, there are no risk assessments on the other species of *Rubus.* This must mean that the information that informed the decisions was derived from experts involved. The symposium presented an opportunity to engage with experts in the field on invasive *Rubus* species within the economic context. Eleven separate experts were consulted in this questionnaire.

5.2.1. Respondent Awareness and Sentiments: Invasive Rubus species

All respondents indicated that they had an awareness that invasive *Rubus* species were present in South Africa. One invasive *Rubus* species – *Rubus fruticosus* agg. – has been categorised as a category 2 invasive alien species. This category infers that the species can be utilised commercially so long as a permit is issued by DFFE providing permission. At present no permits have been issued for *Rubus* species of any kind in South Africa (Moshobane *et al.,* 2019). This suggests that there is no legal *Rubus fruticosus* agg. operations in South Africa at present. Invasive species can be introduced to an area under the legal mandate of a permit and escape captivity going on to establish wild populations (Moshobane *et al*., 2019). Experts in the survey were asked, "Do you think that having this species as a category 2 plant could contribute to its spread?". Eighty-one percent of respondents indicated that they believed that the commercial utilisation of invasive *Rubus* species results in furthered spread. Nineteen percent of respondents indicated that they were either unsure or else did not agree with the motion. Evidently, most of the respondents have the sentiment that permitting invasive *Rubus* species – using government issued permits - results in furthered spread.

Zengeya *et al.* (2017) undertook an expert, opinion-based, prioritisation exercise with the result being that invasive *Rubus* species were labelled as "Destructive" as opposed to "Inconsequential", "Beneficial", or "Conflict generating species". This categorisation was an independent study that was separate to the AIS list categorisation process mentioned previously (Zengeya *et al.,* 2017). The process involved a set of criteria for which the species were attributed 'points' based on expert opinion and that point system indicated a category for the species when summed. An objective of the expert opinion survey in this research was to uncover whether this categorisation resonated with the experts consulted at the national symposium.

To meet the above objective, this survey asked experts to indicate their level of agreement or disagreement on a scale from 1-10 with the categorisation of invasive *Rubus* species in Zengeya *et al.* (2017). "One" indicating complete disagreement and "ten" indicating complete agreement. Forty-four percent of respondents selected a value greater than "5", Twenty-eight percent selected a value less than "5", and twenty-eight percent selected a value of "5".

Thirty-six percent of respondents selected the number "9". Thereafter, "5" and "3" most accurately reflected respondents' agreement. There appears to be a strong difference amongst experts regarding this categorisation. This dissent points out the volatility of opinion inherent in this categorisation and the need for more information on this genus of plants. The lack of outright agreement or disagreement from the sample group corroborates this statement. The mean response by experts was 6 (+/- SD 2.6). The large standard deviation suggested that there was little agreement between experts about the categorisation of Rubus in South Africa. One expert commented "…they are better off being classed as conflict generating species." They stated, "…the classification as destructive is not necessarily useful and is bound to create conflict on its own."

5.2.2. Understanding of Impacts

The main aim of this study is the determination of what impacts invasive *Rubus* species have on economic agents in South Africa. The impacts of the plant inform all policy, management, sentiment, and general regard of that plant. The categorisation process that occurred regarding invasive *Rubus* species has been discussed and a case presented that this process must have been almost wholly driven by the opinion of experts. The opinion of experts must have been informed by their understanding of impacts. Their understanding of impacts must, therefore, have been a key element to this process and the resulting categorisation. As such, there was a need to ascertain what impacts experts believe exist and the disposition of experts towards those impacts.

Experts were posed similar questions to those questions posed to landowners in the economic agent questionnaire regarding impacts. Impacts that have been associated with invasive *Rubus* species either through literature or the bio-economic model were posed to experts. Experts were asked if they believed this to be an impact experienced in the South African context. This process was conducted for both positive and negative impacts.

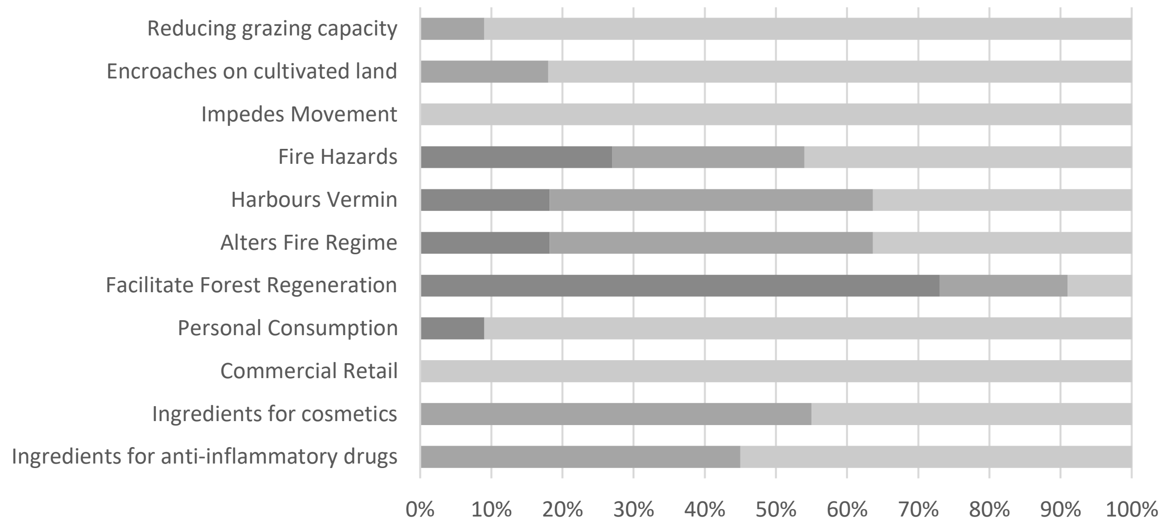
5.2.3. Negative impacts

Three negative impacts were endorsed by most of the expert questioned: Impeding movement (100%)[6], reduced grazing capacity (91%), and encroachment on cultivated land (82%). Whilst three negative impacts were only endorsed by a minority of experts, those being, fire hazards (46%), harbours vermin (45%), and altering fire regime (45%) (Figure 5.10). Experts began, from the inception of the questioning to introduce unique and nuanced information in the open-ended answer platform provided in the questionnaires. Pertinent and insightful comments were noted. One expert indicated, “The negative impacts seem poorly documented. Although I have not given this genus much attention. The fruit are utilised so not entirely negative.” Although a separate expert suggested that invasive *Rubus* species are “… highly invasive and spread over large areas

5.2.4. Positive Impacts

Three positive impacts were endorsed by most of the respondent population: Commercial retail of invasive *Rubus* berries (100%), personal consumption of invasive *Rubus* berries (91%), and ingredients for anti-inflammatory drugs (55%). Using invasive *Rubus* species as an ingredient in cosmetic processes received mostly neutral responses and lastly, the utilisation of invasive *Rubus* species as a forest rehabilitation mechanism was the only positive impact that respondents (73%) mostly disagreed with.

[6] Represents the percentage of respondent group in support of the said impact or notion.



	Ingredients for anti-inflammatory drugs	Ingredients for cosmetics	Commercial Retail	Personal Consumption	Facilitate Forest Regeneration	Alters Fire Regime	Harbours Vermin	Fire Hazards	Impedes Movement	Encroaches on cultivated land	Reducing grazing capacity
Disagree	0	0	0	9	73	18	18	27	0	0	0
Neutral	45	55	0	0	18	45	45	27	0	18	9
Agree	55	45	100	91	9	36	36	46	100	82	91

Figure 5. 10: ***Rubus*** **species impacts from Experts; Endorsement of impacts by experts, as well as what experts thought were the most, and least, valid impacts of invasive** ***Rubus*** **species. (· Black bars represent - disagree, light grey - neutral and · dark grey - agree)**

5.2.4.1. Sentiments regarding use of Rubus

Ascertaining the disposition of experts toward the invasive *Rubus* species is important. The disposition of experts toward invasive *Rubus* species could have previously determined the regulations imposed on the invasive *Rubus* genus in South Africa. To this extent, experts were asked on their disposition towards the use of invasive *Rubus* species in South Africa and what level of management priority the expert would give to invasive *Rubus* species in a general context. The general context referring to the priority experts would give to invasive *Rubus* species considering all the various alien species present in South Africa. Eighty-two percent of respondents responded “No” to promoting the use of invasive *Rubus* species. One respondent’s comment on this question was, “Permitting use can lead to increased demand thus leading to invasion.” Secondly, respondents were asked to rate the need for invasive *Rubus* species to be prioritised on a scale of 1-10, with 10 being an absolute need for prioritisation and 1 being the lowest need for prioritisation. Fifty-five percent of respondents indicated a prioritisation level of over "5". Eighteen percent of respondents indicated a prioritisation level of five and the rest indicated a level below five (Figure 5.11 documents these responses).

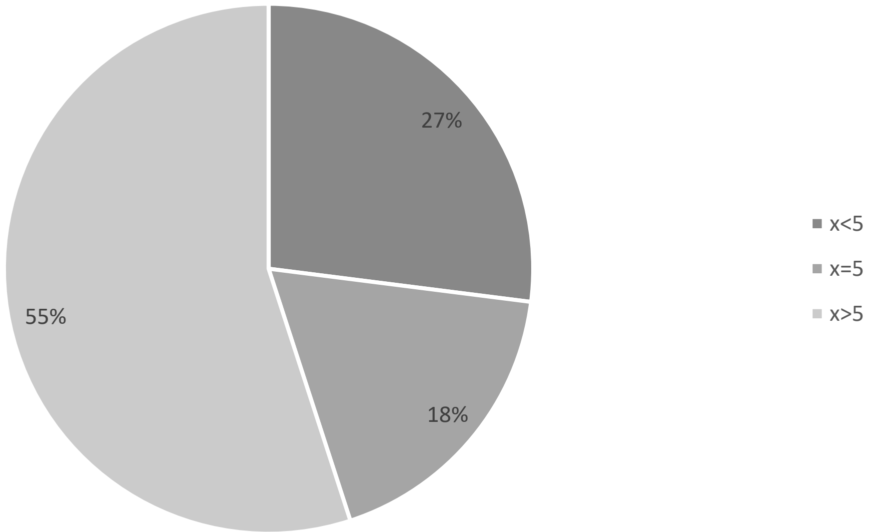


Figure 5. 11: Expert sentiment regarding Prioritisation of invasive *Rubus* species where "x" represents the desire to prioritise invasive *Rubus* for control and eradication.

These responses suggest that experts place a slightly higher than average priority level on invasive *Rubus* or that the need for control is not extremely pressing nor entirely negligible.

5.2.5. Pertinent comments made by respondents

An "Additional notes" component was included in the conclusion section of the questionnaire to allow the experts to elaborate on any ideas, comment on any thoughts or enunciate any information that thought relevant to the study. Several experts did this, and those comments are listed below.

Expert A

One respondent indicated that they found it difficult to answer the questions "… because of the generalisation of the group…" and referred to the "… individual species…" as well as those species being "…ranked/weighted differently on NEMBA…". The respondent suggested, "… list the names of the "invasive *Rubus* sp" you are clumping together as a group so that people can provide more informed/accurate answers."

Expert B

A separate respondent indicated that the "*Rubus* species are bird dispersed and get into inaccessible natural environments spreading and smothering indigenous vegetation." The respondent further commented that the "… spiney nature makes control difficult…" and that "…sprouting…" characteristics of the plant make mechanical and chemical control, "…difficult and expensive."

Expert C

This respondent made extensive comments. The respondent indicated that "This is definitely a plant which I see growing in dense stands in the wild where it can be an obstruction and nuisance." Furthermore, "There is also seldom useful fruit (as in Europe where it is a tasty and useful wild crop), so it seems entirely negative to me in the wild." This respondent ended the survey by stating: "I think of this species as a minor pest.".

Expert D

Similar comments were made by this respondent as those made by Respondent A. The respondent indicated that they did not think it "…useful…" to put all species into one category. Stating, "Instead each species needs to be assessed individually."

5.2.6. Conclusion: Expert Opinion Questionnaire

The aim of the expert opinion-based survey was to determine the opinion on invasive *Rubus* species among invasion scientists as this may have management and legislative implications. There appears to be a sound understanding of the general impacts of invasive *Rubus* species among experts. However, what was apparent was that there was little concurrence on any of the issues posed. No question received unanimous support from the experts. An objective of this expert survey was to understand the disposition of experts towards the AIS list categorisation of invasive *Rubus* species as this is how the initial categorisation was made for the current legislation governing some *Rubus* species in South Africa. It is evident that the experts do not all agree. That they are conflicted regarding the categorisation. Some see it as a clear-cut conflict of interest genus and others as a destructive genus. This appears to be in large part due to a lack of environmental and economic information available for the invasive *Rubus* species in the South African context. This information is essential to informing the process of categorisation. What was also evident was that even though the experts were against promoting the use of invasive *Rubus* species, they did not consider it to be a pressing problem. This can suggest that the experts do not want the species utilised – even if it were through government issued permits – given that this may increase spread. At the same time the experts see other species as more problematic given their disposition towards prioritisation of invasive *Rubus* species. The perception of experts regarding the impacts of invasive *Rubus* species is diverse and rarely unified. It seems that there is a condoning of the invasive *Rubus* species by most of the expert body. Perhaps this is indicative of the bias inherent in dealing with invasive species or perhaps it is a "safe-than-sorry" or "guilty until proven innocent" approach. Either way, the experts acknowledge the need for a deeper understanding of the invasive *Rubus* genus in South Africa. Experts did raise a key conflict that the study has had to address. That the invasive *Rubus* species in South Africa is not a species but rather a genus. Experts are rightly indignant at the generalisation. However, there are few individuals that have the requisite knowledge to give species specific information on *Rubus*. This is primarily due to not knowing how to differentiate species. From the economic standpoint, a consideration of impacts requires an engagement with stakeholders that experience these impacts through their interactions with the species in their activities. However, often the stakeholders do not know what specific species is being dealt with. They simply know it is “Bramble” or “Blackberry”. Hence, although the experts have an appreciation for these differences, the general economic agent does not.

In hindsight, the experts were not asked to elaborate on if impacts could differ across regions within South Africa. There was no mention of the possibility of defining or regulating control procedures or management practices on a regional level. All discussion regarding impacts or regulation was held under the understanding that it would be blanketed across South Africa. The surveys in this study suggested different impacts were experienced in different region and potentially by different Rubus species. In the AIS lists there are several instances where regulations are based on a regional scale. This is often only in relation to island territories held by South Africa – such as Marion Island, or specific cultural spots such as Pretoria, ‘Jacaranda City’. This is an issue that should have been covered in more depth in the survey given the insight from the economic agent questionnaire with the very apparent difference in regional opinions encountered in this study.

5.3. RESULTS OF GROUND PROOFING

As has been mentioned, the study made use of the SAPIA database to locate invasive *Rubus* species localities, or areas were invasive *Rubus* was present. By assessing the SAPIA database, the project was able to ascertain that there were records of invasive *Rubus* species throughout the KwaZulu-Natal Province down into the Eastern Cape Province.

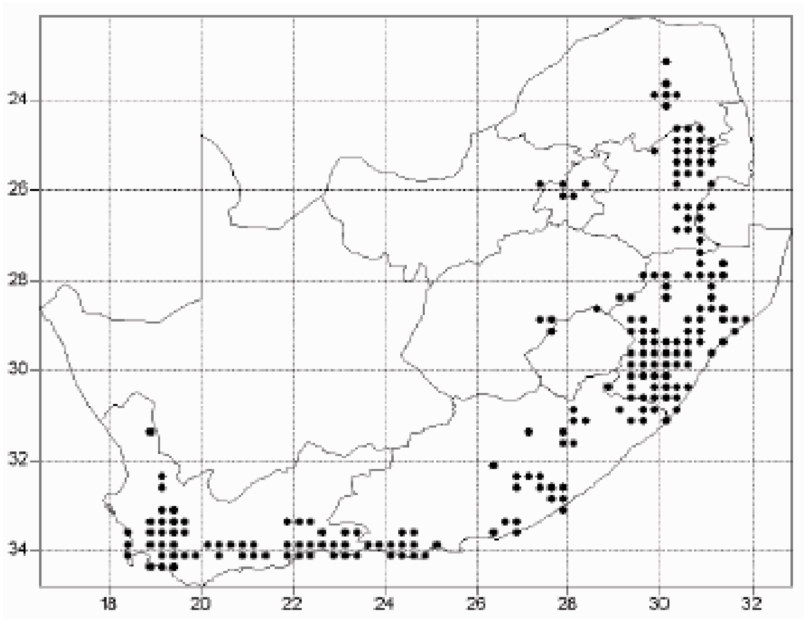


Figure 5. 12: Distribution of invasive Rubus species in South Africa from SAPIA (Henderson, 2001)

The SAPIA record shown in Figure 5.12 is based on four species: *R. cuneifolius, R. fruticosus* agg.*, R. flagellaris* and a hybrid referred to as *R.* X *proteus*. It lacks three of the other invasive species that are listed in AIS lists and gives no indication as to the possible abundance of these species. The ground proofing was necessary to corroborate what was occurring on the ground in terms of *Rubus* species (both indigenous and invasive) from a location and abundance perspective with the regional results of the general questionnaire. It was also required as it was highlighted by the experts in the field that the species are difficult to identify and the species are particularly complex meaning it would be unlikely that any landowner would be able to accurately identify the species on their property. As mentioned earlier these observations were only made possible by the assistance of visiting *Rubus* taxonomist Michal Sochor. The population density of the *Rubus* species was then assessed using the following categories: Rare, sparse, occasional, abundant, and very abundant. These categories of density were allotted on a visual inspection. One to two plants per $10m^2$ were classed as rare, less than 5 plants per $10m^2$ coverage was sparse, 20-30 plants per $10m^2$ occasional, 30-50 plants per $10m^2$ was abundant, and more than 50 plants $10m^2$ deemed very abundant. The total area investigated was primarily based on common sense by investigating the available area infested by *Rubus* species at the site sampled for example on roadside stops 25m above and below the stopping point and 50m into the veld/bush was investigated before making an assessment

In total, thirty-one sites were assessed for *Rubus* species with fifty-one separate observations being made. The sites spanned the Eastern Cape, Free State and KwaZulu-Natal provinces, the same regions where the questionnaires were administered. Eleven different species of *Rubus* were observed. Of this eleven, seven of the species were alien and four indigenous. Figure 5.13 depicts the number of observations made per species. *Rubus* sect. Arguti was the most frequently observed species followed by *Rubus ludwiggi* and then thirdly, *Rubus cuneifolius*. The alien species observed during the ground proofing were *Rubus* sect. Arguti*, Rubus bergii, Rubus cuneifolius, Rubus immixtus, Rubus niveus, Rubus rigidus,* and *Rubus ulmifolius.* The invasive alien species not encountered were *Rubus fruticosus* agg.*, Rubus flagellaris* and *Rubus ellipticus.* By process of logical elimination, it can be suggested that any impacts quantified in this study, as well as the magnitude of those impacts, cannot be attributed to these three species.

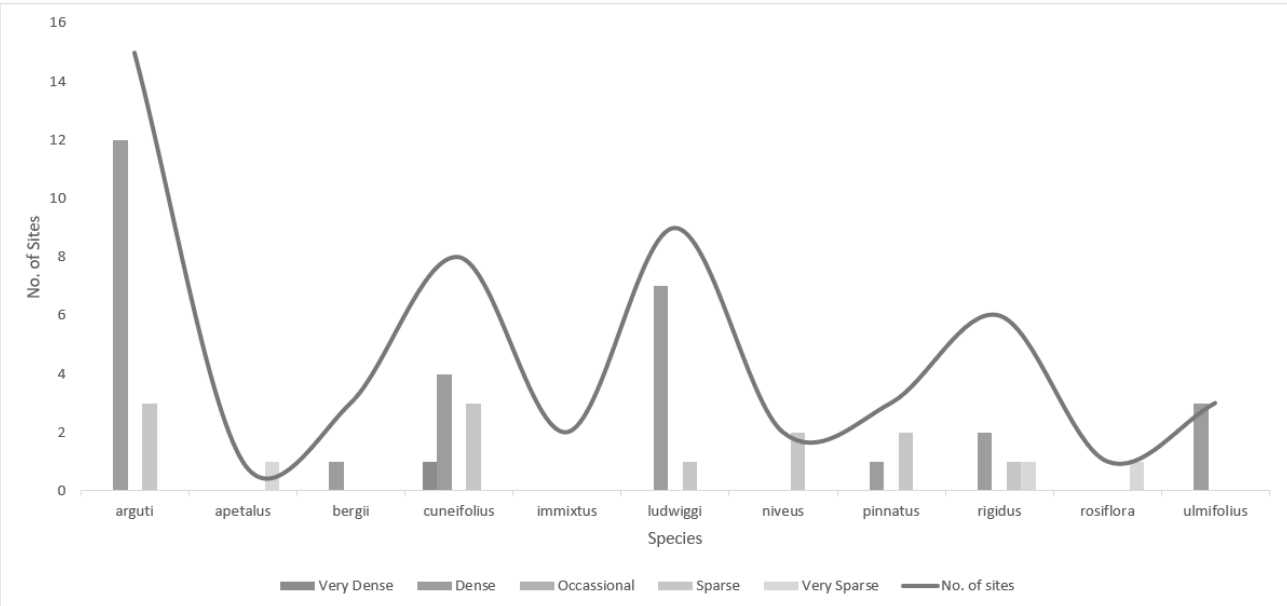


Figure 5. 13: The distribution of alien and indigenous *Rubus* species across sites surveyed in South Africa. *R.* sect. Arguti was the most encountered species, having been observed at fifteen separate sites. *R. apetalus* and *R. rosiflora* were the least encountered species, each was observed at one site only.

Figure 5.14 gives insight into the distribution of *Rubus* species based on the region assessed. KwaZulu-Natal and the Eastern Cape provinces were both found to contain eight *Rubus* species. Of these eight species, five were alien species with one being the invasive alien *R. cuneifolius.* KwaZulu-Natal province was the region in which respondents had the highest control expenditure on invasive *Rubus* species control. It is also the region with the most alien species in the study. There could be a correlation between the cost incurred by both private and public economic agents in KwaZulu-Natal Province and the number of alien species.

The Free State was notable in that only two species of *Rubus* were encountered in this area one indigenous and one alien. The indigenous species, *R. ludwiggi,* was encountered at more sites than the alien species, *R.* sect. Arguti. This is notable given that it has the highest benefit per economic agent and lowest cost per economic agent of the study (Table 5.3). This region had the lowest cost and the lowest number of alien species. The benefits noted in the Free State Province, can only be attributed to either *R. ludwiggi* and/or *R.* sect Arguti*.*

The Eastern Cape Province had eight different species of *Rubus*. It was the only region in which the invasive alien species of *Rubus niveus* was found as well as the indigenous *Rubus apetalus.* Other indigenous species included *Rubus pinnatus* and *Rubus ludwiggi.* The North American invasive alien species of *Rubus cuneifolius* and another invasive, *Rubus immixtus* were both encountered. As were the alien species *Rubus bergii,* and *Rubus rigidus.*

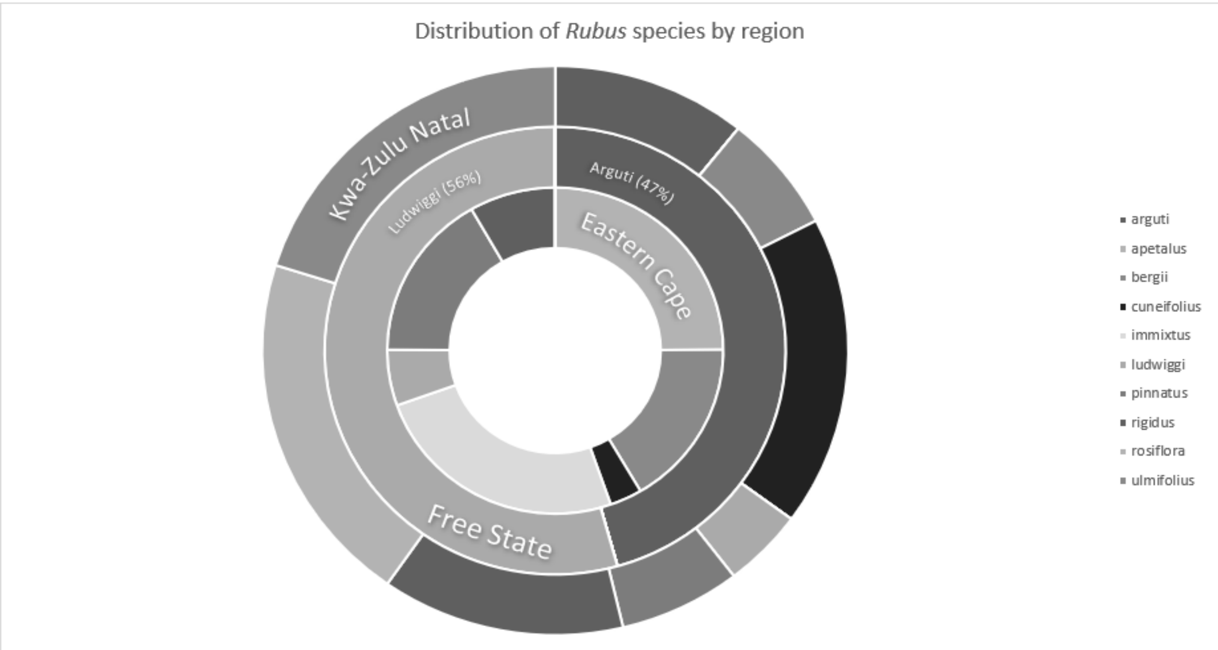


Figure 5. 14**: Distribution of the *Rubus* species according to region. Highlighted are *Rubus ludwiggi* and *R.* sect. Arguti*,* the only species observed in the Free State Province.**

Table 5. 7: Distribution of *Rubus* species

Rubus	*arguti*	*apetalus*	*bergii*	*cuneifolius*	*immixtus*	*ludwiggi*	*niveus*	*pinnatus*	*rigidus*	*rosiflora*	*ulmifolius*
No. of sites	15	1	3	8	2	9	2	3	6	1	3
No of species per site per region											
Eastern Cape	0	1	2	1	1	2	2	2	2	0	0
Free State	7	0	0	0	0	5	0	0	0	0	0
Kwa-Zulu Natal	8	0	1	7	0	2	0	1	4	1	3

Table 5.7 is provided to augment figure 5.14 and shows the distribution of the *Rubus* species across the provinces. This is the same information presented in Figure 5.14, presented in table format.

The morphology of *R. ludwiggi* suggests that the use values derived from *Rubus* in the Free State Province are not from this species*.* This species does not form dense patches and produces very few berries and therefore the capacity to produce berries on the scale required to support the positive benefits seen in the region would simply not be possible. Thus, all positive impacts can be attributed to *R.* sect. Arguti in this region. This plant presents morphological characteristics more indicative of the capacity to support the benefits observed.

On the note of indigenous species, in general these contrasted starkly from invasive species. Indigenous species were always fewer in number, smaller by nature, and never grow in dense, thick infestations. The indigenous species were often found near alien and invasive alien species, often in more natural or pristine areas surrounded by disturbance sites occupied by invasive alien species. The densities of the alien species infestations depended on the site assessed but large infestations were found in the Eastern Cape and KwaZulu-Natal provinces, whilst the areas in the Free State Province surveyed lacked any major infestations.

CHAPTER 6

CONCLUSION

"It's a dangerous business, Frodo, going out your door. You step onto the road, and if you don't keep your feet, there's no knowing where you might be swept off to."

– Tolkien, Bilbo Baggins, (pg. 87, 1991).

This section will conclude the study. The section will take into consideration the externality status of the invasive Rubus species, the epistemology of the invasive Rubus species, the applicability of both the bioeconomic model and mixed-method approach to the invasive *Rubus* species in the study, and lastly, the management and policy implications.

This study was aimed at developing an understanding of the economic impacts of invasive *Rubus* species on economic agents in South Africa. At first, the aim seemed simplistic and relatively straight forward. However, an exploration of the information presented in the first two chapters began to reveal a complex issue. This issue exists across multiple fields, including botany, economics, and invasion science. It became evident that to achieve the aim of the study, a degree of sufficient understanding was required in each field. The mixed-method approach was rooted in the understanding developed by the study and developed to achieve the research aim. In applying this method information pertinent to botany, economics and invasion science was revealed. This understanding will hopefully further the understanding and highlight the difficulties associated with, identifying, prioritisation, utilisation, and control of the invasive *Rubus* genus in South Africa.

The study showed the large differences in impacts and sentiments of economic agents between regions and across invasive *Rubus* species in South Africa. This points to a need for nuanced and complex management strategies as regions are impacted differently and by different species of *Rubus*. In addition, research is required in each of the areas where *Rubus* species are present to determine suitable costs, benefits, and appropriate management in that area.

The invasive *Rubus* species can justifiably be combined into a single, homogeneous threat and treated either as entirely negative or positive in South Africa. Such a combination approach requires a caveat, that this combining be conducted with regional factors in mind. For instance, this study discovered that in the Free State alien *Rubus* species have largely positive economic impacts and are regarded more positively by the limited number of six Free State economic agents that were interviewed compared to the economic agents at other sites. Lumping all alien and invasive *Rubus* into a negative category in the Free State Province would evidently not accurately represent the interaction between *Rubus* species and economic agents in that region. However, to do so in KwaZulu-Natal Province might well be acceptable given that in KwaZulu-Natal alien and invasive *Rubus* species have largely negative impacts and are not regarded positively. This approach should, of course, be broken down into a more thorough regional assessment, i.e., based on municipality or district, rather than province.

Combining all six invasive *Rubus* species into a single, homogenous threat was a necessity to avoid the difficulty of knowing which species is which. What made this project exceedingly difficult is that the taxonomy is and was largely unresolved. This made it challenging to apply a particular method as some species registered as invasive were native and other species found in the field which looked invasive and yet were unrecorded in South Africa. Some species that looked invasive with monocultures infesting large tracks of land are currently regarded as only alien species in the legislation. Fortunately, this is currently being resolved by van Beek *et al.* (Unpublished) and Sochor (unpublished; 2018) and will make this kind of study in the future easier.

The impacts attributable to invasive *Rubus* species are both positive and negative for the small sample of respondents at the selected study sites. Economic agents in this study associated more negative impacts with *Rubus* than positive ones. Several positive impacts noted in international literature are prevalent in South Africa: Personal consumption, retailing on a commercial market and forest regeneration. Use for anti-inflammatory drugs or modern cosmetics are two positive impacts were not recorded as present in South Africa. The six negative impacts cited in the international literature were all endorsed as present and experienced in South Africa. This study determined that invasive *Rubus* species shows impacts on fire regimes, harbours vermin, creates fire hazards, generates impenetrable thickets, affects yield, and encroaches on grazing land. These are all impacts that of which can be further researched to provide a deeper understanding of the environmental cost of these impacts.

To say that the total costs of the invasive *Rubus* species have been captured by this study would be inaccurate. This study has simply accessed the recorded costs available due to cost incursion by either private economic agents or public economic agents. There are two points to be raised here. Firstly, the study sampled a selected group of 18 respondents that incurred economic costs and benefits from invasive *Rubus* species. As such, the entire value of cost and benefit would not have been captured given the fundamental nature of sampling. Secondly, the total cost of the invasive *Rubus* species would require extensive analysis of the environmental impacts and an establishment of *Rubus* hectarage that would potentially cost more than such an assessment was worth. In addition, the problems with identifications and categorisations of species need to be resolved. This study showed the numerical value of benefits, or positive impacts, are noted as being higher than the costs, or negative impacts for private economic agents. Of course, this conclusion depends on how the data is viewed and what figures are considered. However, the results suggest from the perspective of the private landowner, considering all respondents across all regions, the presence of invasive *Rubus* is beneficial with a ratio of cost to benefit at 0,33:1. The benefits per hectare stands at R11 162 and the costs at R3 465,56. This is from the perspective of private landowners without factoring in the benefits derived from the control of invasive *Rubus* species. Introducing any government funds related to control of invasive *Rubus* shifts the ratio strongly in favour of costs, at R142 354 per economic agent. The cost associated with invasive *Rubus* species is in the range of R177/ha. The benefits can be accorded a value of R13/ha. This is a ratio of 13,5:1, costs to benefits. This suggests that the cost per hectare is larger than the benefit by a factor of 13.5. The actual costs of the invasive *Rubus* genus are likely to be greater than this. Given interactions with economic agents, it is unlikely the benefits are much more than what has been noted in this study. However, it has become evident during the study that the benefits and costs of the invasive *Rubus* species must, and can, be categorised according to region and species.

6.1. EXTERNALITY STATUS OF INVASIVE *RUBUS* SPECIES

An academic discussion of invasive alien species as a source of externalities does not appear to be overtly evident. In South Africa it appears that often, invasive alien species are simply referred by impacts with no outright focus on the nature of said impacts. In this regard, the assertion that the impacts faced by economic agents from invasive *Rubus* species in South Africa are externalities is relatively resounding. We can say assuredly that specimens of invasive alien *Rubus* species serve as a source of externalities.

This has practical, and legal implications, such as responsibility of control. Pigou's assertions that the government be responsible for externalities appears to ring true in South Africa. In this study, government funded operations are largely the impetus for control of invasive *Rubus*. However, Pigou existed in a different context and under different socio-economic conditions than we find ourselves. Reliance on government funding to deal with invasive alien species externalities could potentially become unsustainable. As discussed, governments are confronted by a multitude of competing needs, the bureaucratic process makes it difficult to access funds, and private landowners are, to some extent, acting regardless. The law in South Africa requires that private citizens be responsible for the control of alien species on their own properties (Lukey & Hall, 2020). This provision seeks to share the burden of controlling alien species between private enterprises and the government. The government still plays a role in controlling alien species as is evidenced by programs such as Working for Water, but the actions of private individuals are sought to ensure that the effort does not sit solely on the government. This study's finding that respondents are engaged in control measures is promising and indicates an ability to initiate control procedures of invasive *Rubus* species without the need for government intervention. It does need to be pointed out that the region with the least control costs is also the region that presents the most extensive use of invasive *Rubus* species. It could be the case that the use of invasive *Rubus* species berries results in propagule removal from the surrounding environment thereby facilitating the control alien invasive species spread. Of course, methods of control at present are limited to either mechanical or chemical means. The development of a biological control agent could be far more effective and efficient at achieving control that would still enable use by those individuals deriving benefits from the species. Biological control agents could be more efficient as, unlike mechanical means of removal, they act as control agents by their very nature and as such, do not require constant human management to produce control outcomes.

The invasive *Rubus* species do not appear to be used extensively in the study regions. Use factors are limited and appear to be mostly the result of convenience use and, in some instances, cost savings. Particularly when used as a source ingredient for jam. Otherwise, the use of strictly listed invasive *Rubus* species is muted and limited. The most used species is an alien species *R.* sect. Arguti This species is the assumed source of all the benefits experienced by users in the Free State Province. The lack of use of *Rubus* species could be due to lack of community knowledge regarding potential uses. The results suggest that the sentiment among respondents mirrors the extent to which the species is used in a community. Free State respondents had a more favourable disposition toward the invasive *Rubus* species than other regions. This is thought to be because of the known use of the species by the local community. Again, extensive use of the invasive *Rubus* species has direct implications for the control of the species and reduced invasion. This presents an opportunity for community driven control mechanisms in which invasive *Rubus* species are targeted for control through use. This can of course be extended to other invasive species with characteristics that can be used. This could be a potential avenue for economic studies in the invasion science field. In must be noted that rural communities were not surveyed as part of this study and therefore comment on their use of *Rubus* species for consumption would not be appropriate. Future studies should consider the use of *Rubus* species by rural communities. The growth pattern, and locations of *R.* sect. Arguti populations in this study do show invasive tendencies. Indeed, one of the recommendations cited in the field report, produced as a spin-off from this study's ground proofing, is that *R.* sect. Arguti be listed as an invasive. This is because it was previously misidentified as *Rubus cuneifolius* Pursh, commonly known as American bramble (Henderson 2007; Hansen 2015). *R.* sect. Arguti was the most widespread and abundant species uncounted during the surveys and should be listed as an Alien invasive species in South Africa

6.2. EPISTOMOLOGICAL FIT OF INVASIVE *RUBUS* SPECIES TO VENN DIAGRAMS

This study concluded in chapter 1 that scenario 4 most accurately represented the general epistemological relationship between economics and invasion science. Having conducted an economic assessment of a group of invasive alien species the question arises as to whether invasive *Rubus* 'fits' into scenario 4 or, potentially, represents a different scenario? Scenario 4 suggests that a significant portion of invasion science falls into the economic field with aspects of the science falling outside the scope of economics.

It is difficult to make a reliable conclusion in this instance given the grouping of many species into the broad aggregate of "invasive *Rubus* species". Assessed as a group the species certainly seem to be accurately represented by scenario four. For the most part every stage of the invasion science definition, when applied to the general grouping of *Rubus*, appears to link predominantly to economics. It is noted that certain elements are not economic, such as the ecological interaction between indigenous and invasive *Rubus* species, however, these elements are encapsulated by the section of the invasion science Venn diagram existing outside of economic Venn diagram. Not all species of invasive *Rubus* are well represented by scenario four. This speaks to what this study has suggested several times already, that the *Rubus* genus is complex. The introduction of most invasive *Rubus* species was economically incentivised, but not all were. For instance, the introduction of a species such as *Rubus ellipticus* is not economic given the nature of the species and its complete lack of economic use globally. In addition, the hybrid species formed between native and invasive species were not introduced. It would be premature to make suggestions as to the exact epistemological relationship of the *Rubus* species without an in-depth review of each species. What is not premature, is the suggestion that scenario four will not accurately reflect every *Rubus* species in South Africa. It does however, present the most accurate relationship when the alien and invasive *Rubus* species are grouped together.

The Venn diagrams created in chapter 1 are essential in the process of evaluating invasive species. The diagram exposes the underlying relationship between economics and invasion science. This is important as it provides a heuristic to understand two the fields of knowledge, the intersection of which generates a myriad of wicked problems. This means that decisions will be made that will both increase and decrease utility of different economic agents. This will generate social friction between groups. However, so long as a sound rational decision is made, one that is undergirded by heuristics rooted in epistemology then the decision can be justified. Indeed, in a circular way, the decision is because of this heuristic.

Invasive alien species are here to stay. The problem is insurmountable, this is so apparent that the previous statement should be regarded as fact and not opinion. The Venn diagrams have begun to expose the underlying mechanics of invasive alien species and economics. The economics of invasion science is a subject with many contextually relevant factors that are essential to informed decision making. The Venn diagrams provide a heuristic to begin to make the pursuit of this understanding easier than previously. This will potentially aid efforts of economists to participate in invasion science problems.

6.3. THE IMPORTANCE OF USING THE BIOECONOMIC MODEL

It is evident that invasive alien species have a wide array of impacts, however this is not always supported by the literature. The bioeconomic models raised in chapter 4 are invaluable as a credible generation for non-cited impacts of invasive *Rubus* species. Almost none of the impacts raised in the bioeconomic model have been cited as relevant in South Africa. The only impact discussed frequently in South African literature is the impediment of movement. Some grey literature exists around the reduction in yield but as far as credible academic literature in South Africa on the topic – this study could not find any despite extensive searches. Thus, the use of the international literature coupled with the bioeconomic models was invaluable in determining what impacts exist and what impacts do not exist. The results from this study suggest that no cosmetic products or skin products are being produced using any *Rubus* berries in South Africa. We can also suggest that assessment should be conducted on the possible fire related impacts of the species especially in the thickly invaded regions and afforested areas. These impacts would not have been pursued and indeed, may not have been raised at all, had it not been for the bioeconomic model. Of course, the diverse array of impacts often associated with invasive species suggests that there is much research that could be conducted on the topics.

The development of a method of assessment for this study was essential. As stated previously the diversity of fields that the study had to encapsulate to achieve the aim eliminated the use of generic methods of assessment. The understanding derived from the thorough literature review provided a solid base from which to develop the method seen in Figure 4.1. This method successful and generated results that provided more information than required in terms of the aim. This method provided a holistic approach to obtain relevant information, to assess that information and to compare information across fields effectively showing some of the economic implications of invasive *Rubus* species in South Africa as is possible.

6.4. MANAGEMENT & POLICY IMPLICATIONS

The thesis has raised several management and policy implications. These include:

1. **Promotion and Support of Private economic agent control**: Private landowners are presently engaged in the process of control. This should be encouraged and accommodated by officials and policies. These individuals are presently incurring personal costs for this control and producing externalities that are not confined to their own welfare. As such, perhaps a provision could be made to promote this behaviour?
2. **Encourage Public-Private partnerships**: Expenditure on control measures by public entities is larger than private spending. However, private entities must engage in control as there are direct cost implications of not doing so. Public entities do so for the common good and, as individuals, may have no vested interest in the process. Combining the resources of public entities with the motives of private entities could achieve a more efficient and effective outcome.
3. **Education of *Rubus* species:** The *Rubus* genus is problematic as well as complex. Education on the species will facilitate the process of control and data collection of the species from private individuals in the future.
4. **Create policy to deal with alien and indigenous hybrids:** The propensity of the *Rubus* genus to hybridise is evident. Policy makers and the scientific community must be ready to deal with the possibility of an alien-indigenous hybrid and the ramifications of this unique species.

5. **Management approaches must be regional:** The *Rubus* genus has differing impacts in differing regions. The reasons for this are complex and depend on the specific context of a region. As such, a blanket national categorisation approach may not be entirely appropriate to the control of these species. A more regional approach may be better suited to the conditions on the ground.

6.5. CONCLUSION & FURTHER RESEARCH

This study was a first attempt to place a value on Rubus in South Africa it found there is little literature available in South Africa on which to base decisions. The *Rubus* taxonomy is still largely unresolved, however this is currently being addressed. The categorisation of species is/was problematic which might be resolved given SANBI's new SA species risk assessments. Nonetheless the project was able to develop a sound economic method to investigate a complex biological question and has clearly provided insight into the complexity of the *Rubus* genus in South Africa. The small number of landowners at the selected study sites cannot differentiate between species however, the genus has several externalities both positive and negative which vary across regions. Overall, it seems the externalities are mainly negative and with the available data approximately 13,5:1 costs to benefits. The invasive *Rubus* are likely to expand in SA and thus compound the externalities already being experienced. This study scratched the surface but highlighted that more studies are required to put accurate, appropriate numbers to the externalities both positive and negative related to each species for appropriate management to be implemented or the species utilised for its benefits.

Further research can be conducted on the following areas:

1. Effective and appropriate policies on promoting the use of the invasive *Rubus* genus in regions with a positive CBA – such as the Free State Province.
2. The economic and management impacts and implications of hybrids between alien and indigenous species of *Rubus*.
3. The feasibility of bio-control agents for *Rubus* species.
4. The appropriateness of using a regional categorisation system rather than a national one.

The management and control of any invasive species can be difficult and presents problems unique to the species and economic and geographic contexts the species can be found in. This thesis has done its level best to examine the socio-economic context surrounding the invasive species of the Rubus genus in South Africa. In so doing, several impacts have been established, several different stakeholder groups consulted and several numerical values generated to facilitate the understanding of the invasive Rubus genus and role it has to play in the broader South Africa economy and ecosystem. It is hoped that this thesis forms the backbone of more extensive and deliberate research not only directed at the invasive Rubus genus species, but at all invasive species in South Africa and elsewhere.

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APPENDIX I: Description of *Rubus* genus

Rubus cuneifolius (Pursch)

***Rubus cuneifolius* (Taxon A; American Bramble)**:

Description: Erect to sprawling shrub 0.5 - 1.5 m high. Stems: Strongly ridged.

Leaves: Usually 3-foliate; sometimes also 5-foliate (pinnate-palmate) on primocanes, discolours, green, sometimes densely grey-downy beneath, terminal leaflet of primocane leaves usually wedge-shaped (cuneate) and entire at the base.

Flowers: Petals white, rarely pink, few, 2-5 (-10) at the ends of short leafy shoots, either axillary or terminal.

Fruits: Red turning black, fleshy, shiny.

Invades: Grasslands, forest edges, plantations, roadsides, and riverbanks.

Distributions: WC, EC, KZN, FS, Swaziland, and Mpumalanga. (Henderson, 2011)

NEMBA category: 1b.

Cara category: 1.

***Rubus cuneifolius* (Taxon B; Mpumalanga form)**:

Description: Shrub 1-2 m high.

Leaves: 3-foliate on floricane; 5-foliate (pinnate-palmate) (some very large – up to 300 x 330 mm) on primocanes; slightly discolours-not marked as in some specimens of typical R. cuneifolius (Taxon A); dentition slightly different to R. cuneifolius Taxon A- not as deeply incised.

Invades: Grasslands, forest edges, plantations, roadsides, riverbanks.

Distribution: Mpumalanga and Limpopo. (Henderson, 2011)

NEMBA category: 1b.

Rubus cuneifolius was first identified and described by Friedrich Traugott Pursch. The species originates from North America, has edible fruits, and spreads most prominently by seed dispersal as well as vegetative reproduction (SANBI, N.D.). It is known locally as "Sandbraam" or "Amerikaanse braam" in Afrikaans and "ijingijoye" in isiZulu. *R. cuneifolius* is commonly referred to as "Bramble" in South Africa. It is also invasive in Australia (Mabberley, 2017). The species has been under the observation of the Agriculture Resource Council since at least 1984 (Erasmus, 1984). The species is thought to have been introduced into the country in the early 1900's as a source of fruit for jams (Erasmus, 1984). It is one of two species that were listed in the original invasive species legislation Conservation of Agricultural Resources Act (CARA) (Republic of South Africa, 1983). The taxon A form of the species appears more prevalent than taxon B in South Africa.

Figure i: *Rubus cuneifolius*. (Rotate clockwise from top left) Fruits and flowers; A field infested; A close-up of the invaded grassland in the bottom left picture; Flower of population under forest canopy; Grassland invaded by *R. cuneifolius*.

Rubus ellipticus (Smith)

Rubus ellipticus **(Yellow Himalayan Raspberry):**

Description: Achieves a height of up to 7 m, spreads using root suckers and can re-establish itself from an established root system after a fire or being cut.

Stems: Multi-stemmed, arching stems

Leaves: Elliptical to circular, serrated leaflets.

Fruits: Yellow, raspberry like fruit.

Distribution: KZN.

NEMBA category: 1a.

Figure ii: *R. ellipticus*. (Rotate clockwise from left) Stem and Thorns; Flower; Fruit (Photos: CABI, 2020).

Rubus ellipticus was first identified and described by the English Botanist John Smith. The plant originated from Southern Asia specifically: India, Sri-Lanka, Burma, Tropical China, and the Philippines (SANBI, N.D.). The species spreads through both vegetative and seed-based propagation. The fruits are edible and it has been used to produce a purplish-blue dye (SANBI, N.D.). It is known commonly as Yellow Himalayan raspberry or Ceylon blackberry. It does not have any known indigenous South Africa names. It is a known invasive in tropical Africa and Hawaii (Mabberely, 2006). At present, there is only a single known location in the Hillcrest region of Durban with *R. ellipticus* (Lalla *et al.,* 2018).

Rubus flagellaris (Willd)

***Rubus flagellaris* (American Dewberry):**

Description: Prostrate creeper, trailing and rooting at some or all shoot-tips.

Stems: Round, slender, creeping: thorns small slender, straight.

Leaves: Usually 3-foliate, leaflets large, sometimes 5-foliate (pinnate-palmate) on both floricane and primocanes, slightly discolours, straight velvety beneath, margins very coarsely serrated.

Flowers: Petals white, very large (up to 20 mm long and 10 mm wide): flowers few (1-5), in terminal inflorences.

Fruits: Black, shiny; produces very little fruit.

Invades: Forest edges, roadsides.

Distribution: WC, M.

NEMBA category: 1b.

Rubus flagellaris was first identified and described by the German botanist Ludwig Willdenow. The species originated in North America (SANBI, N.D.). The species spreads largely through seeds dispersed by birds. The plant tends to smother indigenous vegetation (SANBI, N.D.). The plant has several uses other than edible fruit: It is used as a remedy for diarrhoea, haemorrhoids,

sore throats, and any arthritic pains (SANBI, N.D.). Mabberley (2017) suggests that there are several commercial cultivars derived from this species.

Figure iii: *R. flagellaris.* (Rotate clockwise from top left) Leaves and berries; Flower; Growth habit (North Carolina State University, 2020).

Rubus fruticosus aggregate (Linnaeus)

***Rubus fruticosus* (European Blackberry):**

Description: Petals are longer than sepals (flowers large and showy).

Leaves: 3-5 or more pinnate-palmate; mature fruits black, shiny. Shrub 1-2m high with strongly arching stems; tip-rooting.

Stems: Round or angled. Leaves: 3-foliate and 5-foliate (pinnate-palmate/lateral leaflets re-divided), the latter on both floricanes and primo-canes, discolours-upper surface green, lower sometimes grey-downy, lower surface strongly veined.

Flowers: Petals white or pink, many in much-branched, very prickly, terminal flowerheads to 200 mm long.

Fruits: Red turning black, fleshy, shiny.

Invades: Grasslands, forest edges, fynbos, plantations, roadsides, riverbanks. **Distribution**: WC, EC, KZN, FS, Swaziland, and Mpumalanga. (Henderson, 2011)

NEMBA category: 2.

Cara category: 2.

Rubus fruticosus was first identified and described by the Swedish botanist Carl Linnaeus. The species originates in the Mediterranean region of Europe (SANBI, N.D.). It spreads predominantly through seed dispersal and tends to compete with indigenous grassland species (SANBI, N.D.). The species produces thick smothering vegetation that prohibits access to certain land, such as water troughs, and affects the grazing capacity of invaded land (SANBI, N.D.). This species is known to have triploids, tetraploids, pentapolids and hexaploids (Mabberley, 2017). The species is regarded as the correct name for two other species of *Rubus* – *Rubus plicatus* (Wiehe & Nees) and the sexual species *Rubus ulmifolius* Schott (Mabberley, 2006). *R. fruticosus* is an aggressive invasive in New Zealand, Australia, and South Africa. In New Zealand, *R. fruticosus* is controlled by the rust fungus *Phragmidium viloceum* (Mabberley, 2017). In Australia *R. fruticosus* is controlled through grazing by goats (Mabberley, 2017). Cultivars of the species are used to produce fruits commercially as well as medicine to treat colds, shingles, acne, and diarrhoea (Mabberley, 2017).

In South Africa, an Australian Weed Risk Assessment (AWRA) was conducted in 2015 by SANBI. This assessment attributed a score of sixteen to *R. fruticosus*. This score is somewhat arbitrary until it can be compared to other scores of *Rubus* species in South Africa. That being said, Pheloung *et al.* (1999, pg. 247) suggest, "We conclude that the weed risk assessment model with explicit scoring of biological, ecological, and geographical attributes is a useful biosecurity tool for detecting potentially invasive weeds in many areas of the world." The establishment of an AWARA score can be compared to other invasive species

Figure iv: *R. fruticosus*. (Rotate clockwise from top left) Fruit and leaves; Flower: Leaves and stem; Stem and thorns; Growth Habit.

in South Africa to facilitate management prioritisation. "Answers to the questions provide a potential total score ranging from -14 (benign taxa) to 29 (maximum weediness) for each taxon" (Pheloung *et al.,* pg. 241, 1999). In the AWRA conducted for "*Rubus fruticosus"* the score determined was 16. This places *R. fruticosus* in the higher categories in accordance with the criteria laid out by Pheloung *et al*. (1999). According to this score, *Rubus fruticosus* would be "rejected" (denied entry into the country) on the grounds of serious weedy characteristics. Pheloung *et al*. (pg. 247, 1999) does go on to warn that differing countries have differing contexts, "Conservationists in Britain, for example, are less inclined than the average to consider a taxon to be a weed, presumably because many weeds have redeeming features…". This brings to the fore the context within which a weed is being assessed. Perhaps, if a weed has certain economic benefits, then those benefits can permit the tolerance of the weed within a country. This is a pertinent point given the difficulties facing the control of IAP's.

Rubus immixtus

Rubus immixtus:

Description: Erect to sprawling shrub.

Stems: Round, purplish with white powder, smooth to weakly armed.

Leaves: 3-5 pinnate, discolours, markedly white-velvety beneath, upper surface deeply veined.

Flowers: Petals pink, about the same length as sepals, flowers large (10-15 mm or more across).

Fruits: Red, downy.

Invades: Grassland, fynbos, forest edges, stream edges and roadsides; the commonest bramble in the Hogsback area of the Eastern Cape.

Distribution: EC, KZN.

AIS listing: 1b.

This is the only species from the subgenus *Rubus* that is not listed in the invasive species South Africa directory.

Figure v: *R. immixtus.* (Rotate clockwise from top left) Fruit and leaves; Leaves and stem; Stem and thorns; Underside of stem and leaves with white colouring; Underside of stem and leaves with darker background.

Rubus niveus (Thunberg)

***Rubus niveus* (Ceylon or Mysore raspberry or Java bramble):**

Description: Scandent shrub up to 2m high, stems arching, tip-rooting.

Stems: Round, rusty brown with white, powdery bloom on primocanes, thorns large, straightish to recurved.

Leaves: 3-5-7 pinnate; mostly 3-5 foliate on floricanes and 7-foliate on primocanes, markedly discolours, dark yellow green above and velvety white below, deeply veined on both surfaces; side veins almost parallel, closely spaced.

Flowers: Petals bright pink, shorter than sepals, numerous carpels.

Fruits: Orange turning red and finally greyish purple, white-downy, small, with many drupelets.

Invades: Grasslands, wooded streambanks and among rocks in tall herb communities; seems to favour higher altitudes between 1000 m and 1 600 m.

Distribution: Swaziland, Mpumalanga, Limpopo (Henderson 2011).

AIS listing: 1b.

Rubus niveus was first identified and described by the Swedish botanist Carl Peter Thunberg. The species originated in Southern Asia, particularly Afghanistan, India, China, Taiwan, and the Philippines (SANBI, N.D.). It is primarily spread by seed dispersal related to predation and excretion. The species has similar impacts to *R. fruticosus* through its dense, impenetrable thickets it often impedes or stops the use of certain land having socio-economic impacts (SANBI, N.D.). The berries are consumed raw or else used to make jams and other condiments. The leaves can be dried to make herbal teas and the roots have been used medicinally (SANBI, N.D.). The common name is Mysore and it is commonly used in Florida, U.S.A (Mabberley, 2017).

Figure vi: *R. niveus.* (Left) Pictures of *R. niveus* in Fort Cunynghame Pass, Stutterheim South Afrika.

APPENDIX II: Unpacking Invasive Alien Species in an Economic context

A strict definition is provided for invasion science (Richardson and Rejmánek, 2011) whereas economics has a broad and diverse array of definitions. As such, the eight core tenets of invasion science, derived from Richardson and Ricciardi (2013), will provide the starting point for this assessment. The best approach to understand the disposition of these two fields to one another would be to conduct thorough literature reviews on the eight tenets of invasion science obtained from the definition. In conducting these literature reviews, any information pertaining to economics or economic activity will be noted and utilised to understand the extent to which that tenet of invasion science is either driven by economics, related to economics, or quantified as a result of economics. In so doing the general disposition of these two fields to each other will be understood and the most appropriate Venn diagram representing that general relationship recommended. As noted previously, several tenets are combined given the study's understanding of the interaction of invasion science's tenets with one another.

1. Introduction *& Transport of Alien Organisms*

The tenets of transportation and introduction of alien species have been combined given that these two tenets often occur in close temporal proximity to one another. The transportation of alien species can be described within two dimensions. The first dimension is the initial transportation of that alien species, often also the introduction of the alien species, be it for the first time or a secondary introduction of new propagules, from its native habitat to the non-native habitat. The second dimension is transportation within the non-native habitat and region, referred to as intra-regional transportation.

i. *Initial Introduction and Transport*

A prior discussion has been had regarding the non-human, or non-economic, alien species introductions that occur across the globe. These natural pathways of introduction have been acknowledged and cited as being less effective, widespread, and problematic than human or economic means (International Species Specialist Group, n.d.). The natural introduction of alien species can be considered as a less prominent issue than the human induced introduction and transport (Solarz *et al.,* 2016).

Humans have historically transported and traded alien species (Hulme, 2007). Three historical periods of time are cited as seeing a marked increase in the amount of alien fauna and flora being moved: At the end of the Middle Ages, at the beginning of the industrial revolution and now, in the period of globalisation (Hulme, 2007). These are, coincidentally, periods of marked economic progress and growth in societies (Rostow, 1959). Alien species are transported either intentionally or unintentionally (Burgiel *et al.,* 2006). Both unintentional and intentional transportation of alien species appears related to economic motives. The intentional transport of alien species appears to largely facilitate certain industries. These industries include but are not limited to, (i) agriculture (Richardson and Rejmánek, 1996; Ewel *et al.,*1999; Reichard and White, 2001; Pickering *et al.,* 2007; van Rensburg *et al.,* 2015), (ii) certain recreational sports (Cambray, 2003), (iii) horticultural activities (Martin and Coetzee, 2011; Ööpik *et al.,* 2013), (iv) illegal plant and animal trade (García-Díaz *et al.,* 2016) and (v) to provide ecosystem services not provided by native biota (Avis, 1989). A good study to understand the diversity of motivations for intentional alien species introductions is Xu *et al.* (2006). According to this study, intentionally introduced alien species into China are used for pasture, feedstuffs, ornamental plants, textile plants, medicinal plants, vegetables, lawn plants, for cultivation or biological control. Each of these reasons for intentional introduction is driven by economic incentives that of which the *Homo economicus*[7] involved is engaged in economically rational, self-serving decision making (Ruiz-Villaverde and Urbina, 2019). Or, as Mill's (1843) suggested, in the pursuit of personal wealth. In Mill's view these introductions would be a consequence of an individual's pursuit of tangible wealth (1843). The term of "individual" could perhaps be replaced by "economic agent" given that economic entities like private businesses are now commonly recognised as legal entities.

The unintentional transport of species appears to be largely driven by economic incentives as well. Unintentional transportation of alien species can be associated with (i) recreational fishing (Niwa and Ohtaka, 2006), (ii) stowaways in equipment, foodstuffs and timber

[7] *Homo economicus* – raised in John Mill's work "On the Definition of Political Economy, and on the Method of Investigation Proper to it." (1836).

(Osyczka, 2010), (iii) hull fouling and ballast waters (Otani, 2006), (iv) canals created to facilitate transport (Otani, 2006; Mavruk and Avsar, 2007), and (v) Hitchhikers on nursery plants, or other imported organic matter (Jenkins, 1996). All the above conduits for alien species transportation stem from an economic incentive utilising the same argument presented by the Mill's classification and Robbins' motive.

Both intentional and unintentional introductions of alien species appear almost entirely underpinned by economic rationale. There is a significant relationship between the density of invasive alien species and absolute size of a nation's GDP (Sharma *et al.,* 2010). United States of America, China, Germany, Japan, and United Kingdom are the top five global importing countries across the globe (Statista, 2019). The United States of America, France, New Zealand, Australia, and the United Kingdom, are recorded as being the top five countries with the most invasive species (Turbelin *et al.,* 2016). There could be several reasons as to why there is a disparity between the top importers and the most invaded nations. Evidently, this basic comparison cannot stand as a rigorous analysis of the relationship between trade and the number of invasive species. What it does suggest, is that this is a complex relationship and that there is not a direct corroboration between those countries that import the most and those that are the most invaded. At least not in a single year period. What does seem apparent is that the motive behind the prominent pathways for alien species introductions and transport are economic. Those pathways and introductory methods that are non-economic are confined to random 'act of god' events (Gewin, 2013) or else only historically relevant (Hoffman and Courchamp, 2016).

ii. *Intra-regional Introduction &Transport*

Alien species are not only introduced from one continent to another but are also introduced within continents between regions and biomes. A country can have multiple biomes or environmentally unique areas within its geo-political borders. South Africa is one of the most diverse nations when considered from a biome perspective, hosting nine uniquely different biomes[8] (Mucina *et al.*, 2006) within its political boundaries. Species introductions into the political boundaries do not necessitate invasions into each of the biomes. Thus, the cross-

[8] Biome - a complex biotic community characterized by distinctive plant and animal species and maintained under the climatic conditions of the region, especially such a community that has developed to climax.

regional transportation of these invasive species is of paramount concern. Once introduced into a nation state's borders, an alien species must be facilitated in spreading through that country (Faulkner *et al.,* 2017). There is a significant relationship between the density of invasive species and the road networks in a nation (Sharma *et al.,* 2010). What this means is that the number of invasive species per kilometre squared is statistically influenced by the road network available in a nation. A road network is provided to facilitate the operations of individuals and entities within a nation state (Malkoc, 2015). The process of building a road as well as the road itself appears to facilitate invasions (Gelbard and Belnap, 2003). The conditions and disturbance of roads, roadsides, construction of roads and road verges provides conditions favourable to establishment and invasion by alien species. Roads provide the economic arteries to a nation and are vital in stimulating growth and providing access to local, regional, and foreign markets as well as employment opportunities. No causal inference can be reasonably generated between the use of roads for economic purposes and the spread of alien species. However, roads are built and maintained predominantly for economic reasons (Malkoc, 2015). Thus, the provision of the vector by which spread is facilitated is economic at its core. The provision of those roads that provide conduits for alien species transport and establishment would not be a factor or would be less of a factor in intraregional spread were it not for economic incentives. A country like South Africa has considerably more land borders than air and sea. The ports of entry into a nation consist of sea, air, and land. The management and understanding of the importance of these pathways has been called into question (Faulkner *et al.,* 2020). The predominant pathway for primary invasions is through sea and air-based imports. However, thereafter secondary invasions are based on intra-regional transportation of those alien species propagules. This process appears to be driven either by economic agents engaged in economic activity or facilitated by economic infrastructure and utilised passively by alien species. Thus, the provision of regional infrastructure in a nation is driven by economic needs. The reasons for use of this infrastructure are largely economic (Malkoc, 2015). This infrastructure and the activities that occur along it facilitate the spread and invasion of alien species. As such, intra-regional transportation of alien species is considerably underpinned by economic factors.

2. ***Establishment & Spread of Alien Species***

The establishment of alien species in non-native countries is subject to both economic and non-economic conditions. Non-economic factors fall into biotic[9] and abiotic[10] factors. Biotic factors such as species richness (Marraffini and Geller, 2015) or the presence or lack of predators, competitors, and parasites (Crawley *et al.,* 2001; Wolfe, 2002) as well as the influence of man, play a role in affecting invasions. The abiotic factors influencing establishment are largely driven by environment matching between the alien species and the conditions in the non-native region (Abellán *et al.,* 2017).

Economic factors affecting alien species establishment are associated with the establishment and cultivation of the alien species during the period in which the species is most vulnerable. The period between introduction and establishment is critical (Richardson *et al.,* 2000). It is the period in which the alien species is most vulnerable to repulsion by the native biota. The influence of man in this process increases the probability that the alien species will establish in that region (Lockwood *et al.,* 2005). The intervention of man in this context fosters alien species establishment by providing favourable conditions that may not have been present without this influence (Alston and Richardson, 2006; Deutschewitz *et al.,* 2003). These favourable conditions assist in overcoming the natural abiotic and biotic factors meant to protect the non-native habitat. At this point the alien species could still be under cultivation conditions and strictly confined to a certain area or region after initial establishment. This is the primary justification of category two in the AIS lists: that these alien species are being cultivated and thus, will be subject to control measures by the cultivator. However, there may come a point in time in which the alien species escapes cultivation (Kowarik, 2005). The escape of alien species from cultivation is a significant contributor to alien species spread. Of course, there is also the possibility that the operation utilising the alien species – and through that utilisation ensuring containment – will cease and the alien species will no longer be regulated or contained and thus escape into the natural environment through these means.

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[9] Biotic – relating to or resulting from living organisms.
[10] Abiotic – Not used in the strict sense of "non-biological" i.e. weather, climate non-living factors intervening. Abiotic used to suggest a divorce from strictly natural non-made mediated factors.

The investigative core of this segment is to understand why economic agents would diligently aid in the establishment of alien species. This study posits that this is largely because of economic incentives. These economic incentives are a result of the economic agents valuing the alien species or a product of the alien species. This value can be divided along industry lines, (i) horticultural, (ii) agricultural, (iii) pet keeping, (iv) environmental protection, (v) recreational sport and (vi) unknown.

The most significant reason for establishment of alien plant species in Europe was due to horticultural use[11] (Kowarik, 2005). Horticulture as a predominate reason for the introduction of alien species is a common phenomenon across Australia, southern Africa, North America, the Pacific Islands, and New Zealand (Richardson and Rejmánek, 2011). Knowing that horticulture is the predominate reason for alien plant species introductions, the next question in this assessment is whether the keeping of alien plants has an economic incentive? It is evident that for the economic agents retailing the alien species there is an economic incentive to obtain and retail alien species in their non-native environments. This is a reference to any economic agent importing those alien species – legally or otherwise. A British study cited market presence and market prices as significant variables determining alien species escaping captivity (Dehnen-Schmutz *et al.,* 2007). Economic market variables not only incentivise the introduction of alien plant species but, determine the probability of their introduction and establishment in the broader community. There is no need to explore the demand side determinants of alien species purchase for horticultural reasons. It is suitable to understand that the supply side – i.e., establishment of alien species in non-native habitats by agents such as nurseries or farms – undertakes the process of care and provisioning of sustenance for alien species in order to satisfy demand for those species in the local market. The process of establishment and care is undertaken by these economic agents not as a charitable endeavour but given economic incentives provided for by the market demand. In other words, there is no need to understand whether a horticultural hobbyist using alien species in their garden does so for economic reasons. This is because the importation and care – in some cases establishment – of those alien species is undertaken by the supply side – nurseries etc - to meet that demand. This relationship is an economic one, driven by economic incentive

[11] Horticultural -

and thus the justification provided for citing economics as a prominent driver of alien species establishment has been made.

Agriculture, pet keeping, environmental protection and recreational sport are all facets of establishment and spread of alien species that are justifiable through the same economic lens as horticulture. A detailed analysis is not going to be pursued. However, a similar analysis of recreational hunting provides the same justification as that obtained for horticultural reasons.

Recreational hunting in the United States of America supports a US$12 billion an annum industry (National Shooting Sports Foundation, 2013). An aspect of this industry is non-native species hunting. There is substantial evidence that many of these species are introduced and established under the premise of economic incentive related to the purchasing of hunting 'bags' including the non-native species (Main, 2020). There is evidently an economic incentive to foster and promote the establishment of alien species in the United States by landowners who are in the hunting industry. Non-native species that are introduced and looked after by *Homo economicus* include *Oryx leucoryx* Pallas (Bovidae) (Arabian oryx), *Axis axis* Erxleben (Cervidae) (Axis deer), *Cervus canadensis* Erxleben (Cervidae) (Elk), *Giraffa camelopardalis* Linnaeus (Giraffidae) (Giraffe), *Hippotragus niger* Harris (Bovidae) (Sable), *Ovis orientalis vignei* Blyth (Bovidae) (Transcaspian Urials), *Connochaetes gnou* Lichtenstein (Bovidae) (Wildebeest), and *Equus capensis* Smith (Equidae) (Zebra) (Main, 2020). Of course, these same introductory pathways seem to serve as conservation hotspots for species threatened in their native habitats, a double-edged sword.

3. *Interactions with surrounding environment and Causes and Consequences*

Alien species interact with the non-native ecosystems and socio-economic environment that they are introduced into. These interactions generate both positive and negative impacts. Alien invasive species are more prominent in their impacts than alien species (Richardson *et al*., 2000). These impacts differ according to a specie's range, abundance, and per capita effects (Nel *et al*., 2004) and could only be felt after a lag phase of introduction (Moran *et al*., 2013).

Impacts can be accorded along the lines of:

i. Allelopathic,
ii. Biodiversity,
iii. Cultural services.
iv. Disease facilitation,
v. Fire and regime,
vi. Physical impediments,
vii. Provisioning services,
viii. Water.

The impacts, and the relationship to economics, are discussed below.

3.1. *Allelopathic Impacts*

IAPs have the impact of altering soil legacies (Nsikani *et al*., 2018). The altering of soil conditions is known to be a bio-chemical tool utilised by certain IAPs to ecosystem engineer the surrounding region making it uninhabitable for the local indigenous species – the process is known as allelopathy (Kholi *et al*., 2008). Altering the soil legacy has the knock-on effect of altering the biological hierarchy of the native system this has several spinoff effects that can be deleterious to the ecosystem (Scalera and Zaghi, 2004). Not all IAPs are allelopathic, but those that are include *Parthenium hysterophorus* Linnaeus (Asteraceae) (Bitter weed) (Tamado and Milberg, 2000), *Acacia dealbata* Link (Fabaceae) (Silver wattle) (Lorenzo *et al*., 2010; Gouws and Shackleton, 2019), *Acacia mearnsii* De Wildeman (Fabaceae) (Black wattle) (Gwate *et al*., 2016) and *Ageratina adenophora* King and Robinson (Asteraceae) (Crofton weed) (Tererai and Wood, 2014). The ability to transform the local soil conditions is one that makes AIPs particularly damaging to the local ecosystem and destabilises those regions making them more prone to successful invasions. A debate has been ongoing as to the difference between allelopathic impacts and plant-based competition (Qasem and Foy, 2001). In competitive settings organisms compete over a fixed resource by hoarding or gaining control over as much of that resource as is possible. In allelopathy, the aim is the same as in competition: to gain control of as much of a resource as possible. However, allelopathic interactions are underpinned by the introduction of herbicides by one of the organisms aimed at creating an advantage in gaining control of the fixed resource. Perhaps allelopathy is an advanced form of plant-based competition (Qasem and Foy, 2001).

Allelopathic impacts have been linked to crop systems. The impact on commercial, crop-based operations by allelopathy has been produced by no less than 225 species on crops as prominent as barley, corn, lettuce, rice, sorghum, soybean, and wheat as diverse as Bajra, cluster bean, cucumber, flax, mustard, and radish (Qasem and Foy, 2001). This appears to be the most prominent economic interaction associated with allelopathy.

3.2. *Biodiversity*

The loss of biodiversity is often cited as one the most prominent impact of alien species (Scalera and Zaghi, 2004; Hooper *et al*., 2005; Ward and Shackleton 2016). Biodiversity is important as it ensures the integrity and resilience of the ecosystem (Chapin *et al*., 2000). The loss of biodiversity leads to disintegration of ecosystems. This results in the erosion of the "invaluable safety net" of natural resources present in an ecosystem (Ward and Shackleton, pg. 81, 2016) and a loss of ecosystem services on which communities are reliant for livelihoods (Fisher *et al*., 2009). A removal of biodiversity prompts ecosystem shifts that alter, transform, and affect local, natural cycles such as environmental productivity, carbon sequestration, hydrology, and nutrient cycles (Hooper *et al*., 2005). These alterations have serious implications for human populations and settlements: The destruction of habitat is one of the key indicators of societal failure (Diamond, 2005). The erosion of the ecosystems and services that are provided by that ecosystem often result in conditions favourable to conflict and divisiveness (Diamond, 2005). AIS threaten three distinct levels of biodiversity: Species richness, species abundance and species composition (Clusella-Trullas and Garcia, 2017). South Africa has experienced a 75% reduction in species composition, 56% loss of species richness and 41% reduced species abundance in certain regions (Clusella-Trullas and Garcia, 2017). In South Africa's case certain IAS were identified as contributing significantly to the erosion of biodiversity. Some species of IAS have more prominent impacts than others. This is evident with species such as *Acacia dealbata* (Silver wattle) having a more prominent impact than other species such as *Solanum mauritianum* Scopoli (Solanaceae) (Earleaf).

One of the means of undercutting biodiversity is the dilution of indigenous genetic lineages with alien species genes through hybridisation (Scalera and Zaghi, 2004). The dilution of these genetic pools can reduce the resilience of local populations and result in the loss of unique genetic code that of which cannot be recovered.

The loss of biodiversity is at its root an economic problem (The Economics of Ecosystems and Biodiversity (TEEB), 2010). The economic paradigm considers nature and the natural environment to be an asset (Tietenberg and Lewis, 2012; van Rensburg *et al.,* 2015). This asset is meant for use by man to provide goods and services that facilitate the quality of life of economic agents. Economics is traditionally compartmentalised into land, labour, capital, and entrepreneurship (Parkin, 2016). Land and capital comprise assets. Capital is often regarded as assets that have been constructed or created by the confluence of labour, entrepreneurship, and land. Land is the base element that supplies the initial raw materials required for all other subsequent economic processes to occur. The category of land encapsulates the elements of nature that are essential to the production of raw materials. The production of these 'raw materials' is often predicated upon the confluence of biotic and abiotic factors. An essential biotic factor is biodiversity. Thus, the erosion of biodiversity is at its core an economic issue.

3.3. Cultural *services*

Cultural services are non-consumptive[12] uses of alien species by economic agents. Cultural services refer to the use of alien species for shade, generating aesthetically pleasing vistas or those species that have historical associations (Potgieter *et al*., 2019). *Jacaranda mimosifolia* Don (Bignoniaceae) (Jacaranda) is an IAP that is to be eradicated on sight unless it is in the Gauteng region or within 200 meters of a farmhouse that predates 1920 (The Republic of South Africa, 2016). There is no mention of environmental benefits provided by Jacarandas. However, the species has cultural associations and provides cultural services that economic

[12] Non-Consumptive uses – a categorisation of use value commonly used in environmental economics. It implies that the object is not consumed when utility (enjoyment) is derived by an economic agent from that object.

agents enjoy. As recently as 2019 the species has caused consternation and dissent among certain societal members given its cultural services and its perceived negative impacts (Koning and Mackenzie, 2019). Evidently, a species' historical associations play a role in determining its management. This species, and the management directive associated with it are evident indications of use values, or cultural services, playing a role in determining the approach to AIS control.

Twenty-one different species of IAPs across 15 genetic families were utilised by rural inhabitants in the Limpopo region of South Africa (Semenya *et al*., 2012). These AIPs can provide alternatives to overexploited indigenous vegetation as well as providing native vegetation with time to recover given reduced harvesting pressure (Semenya *et al*., 2012), and for cultural services such as providing shade, generating aesthetically pleasing vistas, and generating historic or cultural utility (Dickie *et al*., 2014; Potgieter *et al*., 2019).

3.4. *Disease and Disease Facilitation*

AIS can harbour diseases or else be a disease in and of themselves (Hesketh and Roy, 2015). *Rana catesbeiana* Shaw (Ranidae) (the American bullfrog) is a widespread AIS in many regions of the world (Ficetola *et al*., 2007) causing declines in local biodiversity due to its interaction with surrounding amphibian species as well as serving as a vector for *Batrachochytrium dendrobatidis* Pessier and Nichols (Rhizophydiales) (Bd) (Garner *et al*., 2006; Bai *et al*., 2010). Bd being an AIS in and of itself falling into the category of pathogens that Hesketh and Roy (2015) point out as being deleterious. IAS have the capacity to act as a vector for other IAS such that they not only effect local ecosystems through their own interactions, but they act as a vector of introduction and a host for establishment for a separate IAS. IAPs play a role in facilitating the spread of disease vectors by providing them with suitable habitats where none existed prior to their establishment (Scalera & Zaghi, 2004; Stone *et al*., 2018). This is true for the Anopheles mosquito, a vector of malaria, that has seen to utilise IAPs in certain regions previously inaccessible (Stone *et al*., 2018). The spread of invasive species and disease has been noted for correlation (Crowl *et al.,* 2008). Both have deleterious impacts on ecosystems and by association the economy (Crowl *et al.,* 2008).

3.5. *Fire and Fire Regime*

IAPs have detrimental impacts on the fire regimes of areas (James and Lockwood, 1998). Fire has been considered as analogous to herbivores in their effects on ecosystems and ecosystem evolutions (Bond & Keeley, 2005). Fire can impact ecosystems in such a way that they affect the species composition of those ecosystems and have been noted to remove up to two-thirds of some species when introduced to non-fire-adapted regions (Bond and Keeley, 2005). Certain IAP species produce large amounts of biomass that significantly alter the fuel load of a region (Gwate *et al*., 2016; Gouws and Shackleton, 2019). Changing the fuel load of a region can alter the frequency, intensity, extent, type, and seasonality of fires (Brooks *et al*., 2004). A shift in these variables can have the knock-on effect of altering the vegetation type and suppressing the regrowth of indigenous vegetation as well as aiding in the establishment of IAPs. There is evidence that higher fire intensity can also negatively impact on IAPs by disrupting seed banks (Vermeire and Rinella, 2009). However, these effects would be species specific and there is certainly evidence of IAPs being fire adapted (Bond and Keeley, 2005). The *Pinus* genus species is particularly pertinent in this regard having developed a number of fire centric traits not least of which is the trait of serotiny – whereby seeds are stored in cones that open post fire (Bond and Keeley, 2005). Again, these fire adaptive traits are species specific. Turpie *et al*. (2003) estimated that the Cape Floristic region (CFR) contributed R10 billion to the gross geographic product of the region. This includes terrestrial and marine resources as well as tangible and intangible resources such as water supply and the value contributed by bee keeping activities. Much of this value is dependent on the local biodiversity of the region and the erosion of this biodiversity places the ecosystems services provided by the region under threat. The CFR is under pressure from fire related impacts. Heeleman *et al*. (2008) evaluated that indigenous species of *Proteaceae* were particularly impacted by AIP related fire impacts. The recruitment of species is affected by the seasonality of fires which in turn is impacted by the presence of IAPs. IAPs are often prone to fire (James and Lockwood, 1998) and can alter the fire regime of an area by having fire of increased severity (Brooks *et al.*, 2004). This is particularly pervasive in those biomes that are fire dependent such as the Fynbos biome (Brooks *et al.,* 2004).

Fire and invasive species are frequently linked. The 2017 Knysna forest fires serve as recent reminder of the role of alien invasive plants in facilitating what can be a disastrous outcome. The Knysna forest fire cost R3 billion (Forsyth *et al.*, 2019). A significant contribution to the fuel load necessary for the fire was derived from the abundant invasive alien species in the area (Kraaij *et al.,* 2018). This serves as basic and shallow example of the potential economic impact of AIP related fires.

3.6. *Provisioning services*

Provisioning services are the consumptive use component of invasive alien species. Provisioning services include use for firewood (Dickie *et al*., 2014; Ward and Shackleton, 2016; Ngorima and Shackleton, 2019; Potgieter *et al*., 2019; Gouws & Shackleton, 2019), to build either tools or as a construction material (Ngorima and Shackleton, 2019) or as a dune stabiliser or erosion control provider (Cronk and Fuller, 2001; Dickie *et al*., 2014). IAP services such as firewood provision are particularly important to poor communities (Ngorima and Shackleton, 2019). In the Eastern Cape (EC) region 100% of households surveyed were utilising Silver wattle with an estimated 1800kgs being used per household on an annual basis (Ngorima and Shackleton, 2019). 100% of households used Silver wattle as a source of firewood, 77% to construct tools and 73% as construction timber. Even with the apparent extensive use of an IAP in the community, 84% of that community did not want increased spread or density of strands of Silver wattle. This would suggest a certain mindfulness of the community regarding the costs and benefits associated with this IAP. This is not an isolated case with Black wattle also being utilised by a rural community in the Drakensburg region (de Neergaard *et al*., 2005). All the households in this region made use of the tree as a construction material, 90% as a primary source of heat, 45% as a source of traditional medicine and 19% as a source of income (de Neergaard *et al*., 2005). The use of various species of *Acacia* across SA is extensive with example of use in Mpumalanga, KwaZulu-Natal, the Western Cape, and Eastern Cape being available (Kull *et al*., 2011). The use of these plants in these areas is often by rural communities thus any efforts at removal will have to take into consideration that the impacts could be disproportionately shared by the rural communities (Kull *et al*., 2011).

3.7. *Physical Impediments*

In some instances, IAPs are responsible for restricting human and livestock access to certain areas (James & Lockwood, 1998). This can result in the entanglement of livestock and reduce the productive capacity of that land area (James & Lockwood, 1998). IAS can also physically impede indigenous populations (Kholi *et al.,* 2018). This often occurs post seasonal events, such as veldt fires, with alien species regenerating populations at a faster rate and therefore, outcompeting and impeding indigenous populations from re-establishing (James & Lockwood, 1998; Kholi *et al*., 2008). This has direct consequences for biodiversity, cultural services, provisioning services and a host of other impacts mentioned already.

3.8. *Water Impacts*

IAPs have severe impacts on the water resources of a country and often invade riparian zones that are paramount to the hydrological cycle of the country (Le Maitre *et al*., 2000; Milton, 2004; van Wilgen *et al*., 2008). South Africa is a semi-arid country and falls in the top 30 driest countries on Earth making the preservation of water resources a top priority (Donnenfeld *et al*., 2018; Department of Water & Sanitation, 2019). Estimates suggest that to 1 444 million m^3 to 2 444 million m^3 per year are lost to IAPs – this amounts to 5% of annual runoff (van Wilgen *et al*., 2017). With no remedial action taken, the figure of water loss could rise to 2 589 to 3 153 million m^3 per year. These water losses are region specific but tend to impact those regions that are most water deficient, such as the Western Cape (Department of Water & Sanitation, 2019). On a regional scale the losses can be extensive with assessments in the De Hoop and Berg River systems suggesting that if no remedial action is taken up to 44% and 51% of the mean annual run off could be lost over a 45-year period (Preston *et al*., 2018). The impact of IAPs on water coupled with the South Africa public works economic regime led to the formation of the Working for Water programme in 1995 tasked with taking said remedial action (Hobbs, 2004). Management focused on water preservation needs to be informed of the species-specific impacts. Certain species, such as *Populus canescens* Smith (Salicaceae) (Grey Poplar), are noted as not being water intensive users (Ntshidi *et al*., 2018) others, such as Black Wattle, are noted as being water intensive users (Clulow *et al*., 2011). For some, such as *Pinus radiata* Don (Pinaceae) (Monterey Pine) and *Eucalyptus grandis* Hill (Myrtaceae)

(Flooded gum) they have extensive impacts on water resources in the short run (Jackson *et al*., 2005) whilst longer run effects are being called into question (Scott and Prinsloo, 2008). The management of water resources is a complex and involved process requiring extensive local, contextual, and species-specific information.

Water resources provide the basic inputs for energy production, food production, and water supply. Almost all other economic activity is based directly, or indirectly on these three industries. Any factor that impedes or increases the cost of energy, food or water supply is having a direct or indirect effect on the economy.

APPENDIX III: Reason for listing *Rubus* in NEMBA

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Private Bag X 447- PRETORIA - 0001 473 STEVE BIKO ARCADIA PRETORIA 0083- Tel (+ 27 12) 399 9497 -
Private Bag X 4390 CAPE TOWN 8002 2 EAST PIER BUILDING, EAST PIER ROAD, V & A WATERFRONT CAPE TOWN 8001
Tel (+ 27 21) 819 2410

Ref: PAIA 172698 **Enquiries:** Ms. Nomanduli Geja
Tel: (021) 441 2791 **Email:** [illegible]

Mr. Brett Anthony Mason
Worcester Mews,
Unit 10
GRAHAMSTOWN
6139

Email: [illegible]
Cell: 071 998 6403

Dear Mr. Mason

REQUEST IN TERMS OF THE PROMOTION OF ACCESS TO INFORMATION ACT, 2000 (ACT NO. 2 OF 2000) ("PAIA") FOR ACCESS TO INFORMATION PERTAINING TO THE REASONS FOR LISTING *RUBUS GENUS* UNDER THE 2014 ALIEN AND INVASIVE SPECIES REGULATIONS ("RECORD")

1. Your request for access to certain records in terms of Promotion of Access to Information Act, 2000 (Act No. 2 of 2000) (PAIA), dated 09 May 2018, for which payment was made on 11 May 2018, has reference.

2. Subsequent to the above mentioned request, you provided further clarity in an email dated 4 June 2018, where you stated that you specifically request the following:-

   "information pertaining to the reasons for listing Rubus genus under the 2014 Alien and Invasive Species Regulations (AIS Regulations) that were published in terms of the National Environmental Management Act, 2004 (Act No. 10 of 2004)".

3. Kindly be advised that the Department listed *Rubus* genus under the 2014 AIS Regulations because it was important to align the species listed in Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983) (CARA) with the newly formulated AIS Regulations.

4. The alignment of the abovementioned legislations (CARA and AIS Regulations) was an expert driven process which considered the invasiveness of the species. A preliminary risk assessment was also conducted and is attached hereto.

5. Should you wish to appeal this decision you are kindly referred to Sections 74 and 75 of PAIA which allows you to lodge an internal appeal in the prescribed form to the Information Officer of the Department of Environmental Affairs within sixty (60) days. The subject and reasons for the internal appeal must be clearly indicated.

APPENDIX IV: Risk assessments for *Rubus* species

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Private Bag X 447 · PRETORIA · 0001·473 STEVE BIKO-ARCADIA-PRETORIA 0083 · Tel (+27 12) 399 9467 ·
Private Bag X 4390 CAPE TOWN 8002 2 EAST PIER BUILDING, EAST PIER ROAD, V & A WATERFRONT CAPE TOWN 8001
Tel (+27 21) 819 2410

Ref: PAIA180636 **Enquiries:** Mr. K Netukalo
Tel: (021) 441 2812 **Email:** [illegible]

Mr. Brett Anthony Mason
Worcester Mews
Unit 10
GRAHAMSTOWN
6139

Email: brett_mason@rocketmail.com
Cell: 0719986403

Dear Mr. Mason

REQUEST IN TERMS OF THE PROMOTION OF ACCESS TO INFORMATION ACT, 2000 (ACT NO. 2 OF 2000) ("PAIA") FOR ACCESS TO RISK ASSESSMENTS CONDUCTED IN SOUTH AFRICA ON THE *RUBUS* (*SUBGENUS RUBUS*) *GENUS* ("RECORD")

1. Your request for access to certain information in terms of Promotion of Access to Information Act, 2000 (Act No. 2 of 2000) (PAIA), dated 09 May 2018, but was received by the Department on 14 February 2019 and for which payment was made on 18 February 2019, has reference.

2. You specifically made the following request:

   "…. any risk assessments conducted in South Africa on the Rubus (Subgenus Rubus) genus of plants. I am specifically interested in risk assessments pertaining to the following:
   Rubus cunefolia;
   Rubus fruticosus;
   Rubus niveus,
   Rubus flagellaris,
   Rubus ellipticus,
   Rubus immixtus."

3. Kindly be advised that after conducting a thorough search for the records mentioned in paragraph 2 above, all the requested records could not be retrieved by the Department except for the preliminary risk assessment for the *Rubus fruticousus* species. I have decided to grant you access to this available record.

4. The access fee for the information requested is hereby waived. The documents will be sent to you in electronic format.

5. Section 23(1) of PAIA states that:
   "(1) If-
   (a) all reasonable steps have been taken to find a record requested; and
   (b) there are reasonable grounds for believing that the record-
   (i) is in the public body's possession but cannot be found; or
   (ii) does not exist,

the information officer of a public body must, by way of affidavit or affirmation, notify the requester that it is not possible to give access to that record."

6. The Department is not in possession of the risk assessments for *Rubus cunefolis*, *Rubus niveus*, *Rubus flagellaris*, *Rubus ellipticus and Rubus immixtus* as these documents/records do not exist. An affidavit prepared in terms of section 23(1)(b)(ii) of the PAIA is attached for your attention.

7. Should you wish to appeal this decision you are kindly referred to Sections 74 and 75 of PAIA which allows you to lodge an internal appeal, together with the prescribed appeal fee, in the prescribed form to the Information Officer of the Department of Environmental Affairs within sixty (60) days. The subject and reasons for the internal appeal must be clearly indicated.

Yours faithfully

DEPUTY INFORMATION OFFICER
DEPUTY DIRECTOR-GENERAL: ENVIRONMENTAL PROGRAMMES
DEPARTMENT OF ENVIRONMENTAL AFFAIRS
14 LOOP STREET
CAPE TOWN
DATE: 2019 -03- 15

APPENDIX V: *Rubus* control plan Request

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Private Bag X 447· PRETORIA · 0001·473 STEVE BIKO·ARCADIA·PRETORIA·0083· Tel (+ 27 12) 399 9587 ·
Private Bag X 4390 CAPE TOWN 8000 2 EAST PIER BUILDING, EAST PIER ROAD, V & A WATERFRONT CAPE TOWN 8001
Tel (+ 27 21) 819 2410

Ref: PAIA 173871 Enquiries: Ms. Nomatubi Gaja
Tel: (021) 441 2791 Email: NGaja@environment.gov.za

Mr. Brett Anthony Mason
Worcester Mews,
Unit 10
GRAHAMSTOWN
6139

Email: brett_mason@rocketmail.com
Cell: 071 398 6403

Dear Mr. Mason

REQUEST FOR ACCESS TO INVASIVE SPECIES CONTROL PLANS AVAILABLE IN THE DATABASE WHICH EVERY ORGAN OF THE STATE WAS REQUIRED TO HAVE IN PLACE BY 1 OCTOBER, 2016 INSTITUTED BY THE EC AND KZN IN TERMS OF THE PROMOTION OF ACCESS TO INFORMATION ACT, 2000 (ACT NO. 2 OF 2000) ("PAIA")

1. Your request for access to information received by the Department on 21 June 2018 in terms of the Promotion of Access to Information Act, 2000 (Act No. 2 of 2000) has reference.

2. After careful consideration of your request, I, in my capacity as the Deputy Information Officer, have decided to grant you access to 12 Invasive Species Control Plans received by the Department from Eastern Cape and KwaZulu-Natal provinces. The Eastern Cape Province submitted 4 plans whilst the KwaZulu-Natal Province managed to submit 8 plans.

3. The access fee for the information requested has been waived and copies of the requested information will be forwarded to you by email as indicated in your PAIA Form A.

4. Should you wish to appeal against this decision, you are referred to Sections 74 and 75 of the Promotion of Access to Information Act, 2000 which allows you to lodge an internal appeal together with the prescribed appeal fee, in the prescribed form to the Information Officer of the Department. The subject and reasons for the internal appeal must be clearly indicated.

Yours faithfully

DEPUTY INFORMATION OFFICER
DEPUTY DIRECTOR-GENERAL: ENVIRONMENTAL PROGRAMMES
14 LOOP STREET
CAPE TOWN
DATE: 2018 -07- 03

Appendix VI: Expert Opinion Questionnaire

RHODES UNIVERSITY
Where leaders learn

INFORMED CONSENT DECLARATION

Expert Opinion Questionnaire

Project Title: **An evaluation of the economic costs and benefits of a selected geographical distribution of invasive *Rubus* genus in South Africa.**

Brett Mason 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 *Rubus* genus species in South Africa from the perspective of farmers, landowners and other stakeholders in the relevant geographical areas.

2. 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 genus of plants occupying category 1a, 1b & 2 in the National Environmental Management: Biodiversity Act. This research will aid in understanding the impacts of a little researched genus of IAP, provide much needed knowledge on the species of that genus, 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 provide informed opinions on the invasive statues and characteristics of *Rubus* genus species.

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 stored without the personal details of the participants being included.
    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 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 Brett Mason – brett_mason@rocketmail.com ; 0719986403.

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 Brett Mason, available at brett_mason@rocketmail.com or on 0719986403.
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. Positive & Negative Impacts as well as Conflict Generating Species

1. **Are you aware of *Rubus* species as invasives in South Africa?**

• - Yes • - No

2. **Rubus fruticosus (European Blackberry) is a category 2 plant in the Alien Species List of SA. Plants within this category of invasive species are permitted to be cultivated and used. Therefore, it is grown for commercial use in SA. Do you think that having this species as a category 2 plant could contribute to its spread?**

☐ - Yes ☐ - No ☐- Unsure

3. **All invasive Rubus genus species are declared as "Destructive" (As opposed to "inconsequential", "beneficial" or "conflict generating species"). Do you agree with this categorisation? Scale of 1-10 (where 1 is low and 10 is high).**

• - 1 • - 2 • - 3 • - 4 • - 5 • - 6 • - 7 • - 8 • - 9 • - 10

Please detail your thoughts on the topic:

____
____
____
____
____
____
____
____

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

a. International studies have suggested that this plant has the following positive impacts: 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
a. The Berries can be processed to provide basic constituents of anti-inflammatory drugs. (Medicinal)					
b. The Berries can be processed to deliver ingredients that are used to develop modern cosmetics.					
c. The Berries can be harvested to be sold on a commercial market.					
d. The Berries can be harvested for personal consumption.					
e. The plant can be used to facilitate natural forest regeneration.					

b. Did you know that invasive Rubus species has a significant related industry in SA?

• - Yes **• - No**

5. 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, N = Neutral, A = Agree & SA = Strongly agree**]**

	SD*	D	N	A	SA
a. The plant alters the fire regime of the natural vegetation (changes the fire season).					
b. The plant harbours vermin (rats, mice, snakes etc).					

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.

6. Do you think we should promote the use of invasive Rubus genus species in SA?

• - Yes **• - No**

7. How would you rate the priority of managing invasive *Rubus* genus species to you? Scale of 1-10 (where 1 is low and 10 is high; 8 = important target for management efforts).

• - 1 • - 2 • - 3 • - 4 • - 5 • - 6 • - 7 • - 8 • - 9 • - 10

C. 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 brett_mason@rocketmail.com and I am available on 0719986403.

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

Additional Notes:

____
____
____
____
____
____

Appendix VII: Economic Agent Questionnaire

RHODES UNIVERSITY

Where leaders learn

INFORMED CONSENT DECLARATION

Economic Agent Questionnaire

Project Title: **An evaluation of the economic costs and benefits of a selected geographical distribution of invasive *Rubus* genus in South Africa.**

Brett Mason 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 *Rubus* genus species in South Africa from the perspective of farmers, landowners and other stakeholders in the relevant geographical areas.

14. 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 genus of plants occupying category 1a, 1b & 2 in the National Environmental Management: Biodiversity Act. This research will aid in understanding the impacts of a little researched genus of IAP, provide much needed knowledge on the species of that genus, 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 provide informed opinions on the invasive statues and characteristics of *Rubus* genus species.

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 stored without the personal details of the participants being included.
    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 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 Brett Mason – brett_mason@rocketmail.com ; 0719986403.

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**

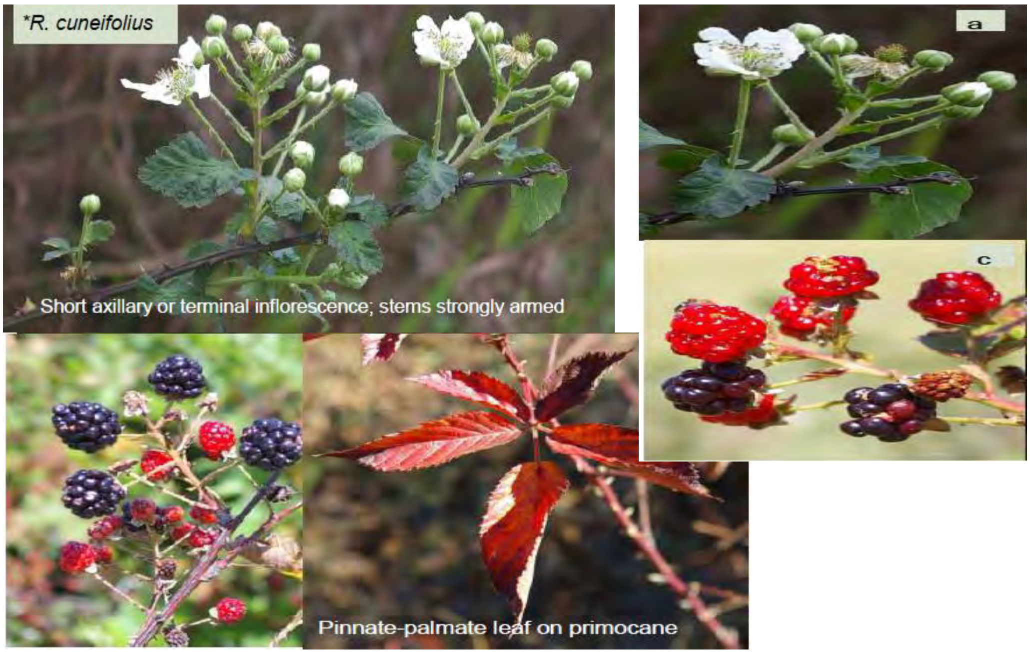
Any queries should be directed to Brett Mason, available at brett_mason@rocketmail.com or on 0719986403.
Any complaints should be directed to the Chair of the Human Ethics Sub-Committee Prof Jo Dames, available at j.dames@ru.ac.za

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

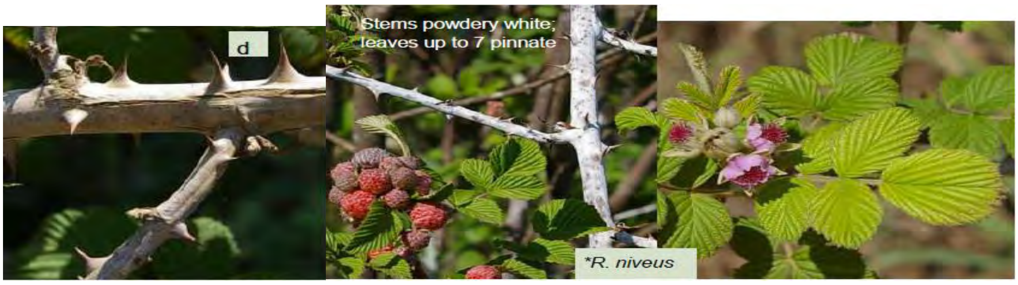
NAME (first and surname)	
CONTACT DETAILS (optional)	Number: ____________________________
PREFERRED NAME OF PROPERTY	
DISTRICT PROPERTY LIES WITHIN	
YEARS UNDER YOUR OWNERSHIP/LEASE	
SIZE OF PROPERTY (HA)	
OPERATIONS ON PROPERTY (e.g. farming, forestry, private property, private homestead, etc)	

B. Plant Identification

There are six different plants under consideration in this study. They are taxonomically very similar and morphologically difficult to distinguish. As such, the images below are an assortment of the main features of the plants.

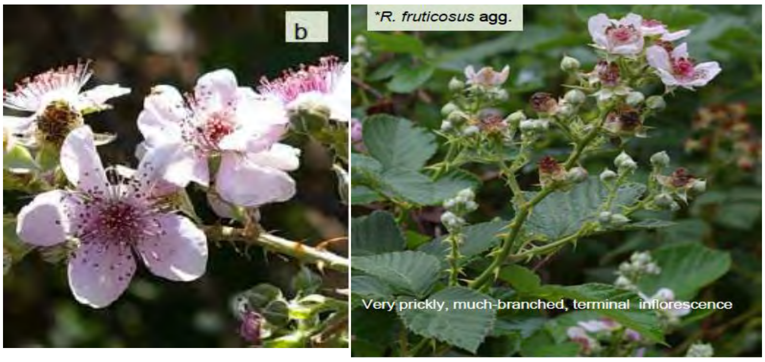


Rubus cuneifolius



Rubus niveus

Rubus flagellaris



Rubus fruticosus

5. **Do you feel confident you can identify an invasive species of *Rubus* given the above pictures?**

____

C. Perceptions

1. **Have you noticed any species of Rubus on your land? (Please tick the box that best reflects you answer)**

☐ - Yes ☐ - No ☐ - Possibly

2. **If yes, please indicate which species you believe this to be.**

☐ - *R. ellipticus*	☐ - *R. cuneifolius*	☐ - *R. niveus*
☐ - *R. flagellaris*	☐ - *R. immixtus*	☐ - *R. fruticosus*
☐ - Other	☐ - Not sure	

Other (please elaborate):____

3. **Since you noticed the plant, has the area occupied by the plant increased or decreased?**

☐ - Increased ☐ - Decreased ☐ - I have not noticed a change

4. **Did you plant this plant on your property?**

☐ - Yes ☐ - No

4.1. If "Yes", what was the source of the seeds?

☐ - Nursery ☐ - Wild cuttings ☐ - Friend
☐ - Supermarket seeds

Other (please elaborate):____

5. **Are you aware of the National Environmental Management: Biodiversity Act of 2004 and the Alien Invasive Lists of 2014?**

 - Yes - No

6. **Are you aware of invasive alien plants and the impacts that they pose (a good example of an alien invasive plant is *Opuntia:* Prickly Pear)?**

 - Yes - No

D. Benefits

7. **What is your feeling towards the statement: "This plant (invasive *Rubus* plants specifically) is beneficial and should be allowed to propagate and expand over new areas."?**

• - Strongly disagree • - Disagree • - Indifferent • - Agree • - Strongly Agree

8. **Do you personally make use of this plant/s in any way?**

 - Yes - No

8.1. If yes, please describe in what way do you make use of this plant? (e.g. I harvest the berries for personal consumption or I use the plant as a hedge)

____

____

____

____

8.2. Would you please estimate the Rand value, per year, of these benefits to yourself and your household?

Rand value: | R /year |

9

a. International studies have suggested that this plant and its berries have the following positive impacts: please indicate whether you make use of/believe you make use of the plant/berries in this/these ways.

[*D = Disagree, N = Neutral/Unsure, A = Agree]

	D*	N	A
f. The berries can be processed to provide basic constituents of anti-inflammatory drugs. (Medicinal)			
g. The berries can be processed to deliver ingredients that are used to develop modern cosmetics.			
h. The berries can be harvested to be sold on a commercial market.			
i. The berries can be harvested for personal consumption.			
j. The plant can be used to facilitate natural forest regeneration.			

9. Can you think of any other benefits derived from the plant that are not covered by the above statements? If so, please detail those benefits below.

____

____

____

____

E. Costs

10. What is your feeling toward the statement: "This plant (invasive *Rubus* plants specifically) is a menace and should be eradicated."?

• - Strongly disagree • - Disagree • - Indifferent • - Agree • - Strongly Agree

11. Do you personally feel that you incur any costs from this plant?

- - Yes
- - No

11.1. If yes, please describe in what way you incur costs from the plant? (e.g. I spend my leisure time on clearing thickets of the plant or I regularly buy chemicals to administer to the plant)

11.2. Would you please estimate the Rand value, per year, of these costs to you and your household?

Rand value: R /year

12. International studies have suggested that this plant has the following negative impacts: please indicate whether you experience/believe you experience the underlying effects of the plant/berries.

[*D = Disagree, N = Neutral/Unsure, A = Agree]

	D*	N/A	A
g. The plant alters the fire regime of the natural vegetation (changes the fire season).			
h. The plant harbours vermin (rats, mice, snakes etc).			
i. The plant creates fire hazards.			
j. The plant creates impenetrable thickets that impede human and animal movement.			
k. The plant reduces the yields of farming land by encroaching on cultivated land.			
l. The plants reduce the grazing land available to livestock.			

12.1. 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.

F. Containment:

13. **Have you attempted to remove the patches of Rubus/Blackberry from your property?**

 - Yes - No

14. Are you aware of the method of control known as "biological control"? (The use of natural predators, such as insects, to control the weedy species?)

• - Yes • - No

15. What method of removal did you use?

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

 - **Chemical** (Use of herbicides)

Other method (please elaborate):

____

16. Would you support the release of biological control agents, such as a rust fungus, to control the current populations of invasive *Rubus* species?

• - Yes • - No • - Maybe

17. Have the patches been permanently removed?

 - Yes - No - N/A

18. If yes, could you please provide a rough estimation of the total expense of clearing these thickets over the time it took to clear them?

R

Alternatively:

a. Please provide details of amount of chemicals purchased, type and price paid:

____

b. Please provide details of man-hours spent on removal:

____

c. Please provide details of the cost of acquiring the animal/insect (agent), the hours spent releasing the agent and the hours spent on monitoring the agent:

____

19. If no, could you please provide a rough estimation of the annual cost incurred in the current year to clear the thickets?

R /year

Alternatively:

a. Please provide details of the average annual amount of chemicals purchased, type and price paid per year:

b. Please provide details of the average number of man-hours spent on removal per year:

c. Please provide details of the cost of acquiring the animal/insect (agent), the hours spent releasing the agent and the hours spent on monitoring the agent per year:

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 brett_mason@rocketmail.com and I am available on 0719986403.

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

Additional Notes: