BIODIVERSITY STEWARDSHIP IN SOUTH AFRICA - AN ASSESSMENT OF THE KLIPKRAAL BIODIVERSITY STEWARDSHIP PROGRAMME AND ITS POTENTIAL FOR CONSERVATION

by

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Declaration

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

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Abstract

The importance of conservation in agriculture has become more apparent over the last couple of years, however it involves complex social-ecological relationships and as agriculture is a critical industry for human survival, biodiversity conservation in the industry is a major challenge worldwide. In South Africa, biodiversity stewardship programmes, which involve agreements between landowners and conservation authorities to secure land in biodiversity priority areas, are becoming a prominent method of conservation in agriculture. Yet there is a lack of research on the conservation benefits and whether they show improvements in the area's biodiversity. This study focussed on the Klipkraal biodiversity stewardship programme which consists of two privately owned functional cattle farms in a peri-urban area of the southern grasslands of Gauteng making up 2 656 hectares of land of which 1 600 hectares are natural vegetation, and the remaining area is cultivated land used for farming maize and soya. The study sought to answer the question: what is the ecological state of the area and does this programme have potential for conservation in the long-term?

The aim of this study was to assess the potential conservation benefits and sustainability of the Klipkraal biodiversity stewardship programme. The study involved both qualitative and quantitative data collection, including landcover mapping, field surveying to assess the vegetation state and mammal diversity and distribution of the site, and interviews with key stakeholders. The landcover mapping allowed for a visual representation of the various landcover types and percentage coverage of each of the six landcover types found in the study area. Vegetation assessments at five different sites resulted in an understanding of the vegetation structure, composition and cover across the two farms and from this it was established that the vegetation structure and species diversity differ, but the species composition is similar throughout the study site. An anthropogenic disturbance score was allocated to each site and the highest rated anthropogenic scores correlated with the sites consisting of the highest exotic species. The mammal assessments showed that the varying vegetation structure allows for specialist species to occupy a range of habitats within the site and also indicated that there are barriers to the movement of large mammals within the site. The results of the vegetation and mammal assessment which suggest a diverse range of vegetation units, habitats, and mammal diversity, emphasise that the area is important for conservation. The interviews revealed the multiple challenges involved in the Klipkraal Biodiversity Stewardship Programme and requirements in order for the programme to be

successful in the long term. These include a need for willingness of landowners to put their time and resources into conservation efforts on their properties, a need for constant monitoring of management strategies, the importance of expanding the stewardship areas to ensure conservation of the entire area and not just isolated fragments of the area. However, key challenges in expanding the programme were also revealed, such as scepticism by landowners in entering land agreements with the government and in Gauteng, many areas of conservation interest are made of multiple small properties that are owned by different landowners which means a lot of effort is required in getting each landowner to sign up. Insight was also given into the roles of the various stakeholders and the relationship between the Gauteng Department of Agriculture and Rural Development (GDARD) and the landowners, and it was indicated that GDARD's role is to provide guidance, education and resources when available to the landowners in order to manage their protected area. This study can be used as a baseline study for GDARD to measure the progress in conservation in terms of the landcover and ecological aspects at the site and to monitor any changes in landowner-GDARD dynamics.

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CHAPTER 1: INTRODUCTION

1.1 Background to the Study

With a growing human population, cities and urban areas are expanding, resulting in the alteration of natural land to artificial structures such as buildings and roads in the process of urbanisation (Fraser *et al*., 2016; Pauchard *et al*., 2006). Land-use activities correlated with urbanisation have resulted in the transformation of a large percentage of the earth's land surface from its natural state (Venter *et al*., 2016; Foley *et al*., 2005). There are many effects of land-use change, ranging from variations in the planet's atmospheric composition to the widespread alterations of ecosystems (Steffen *et al*., 2015; Wackernagel *et al*., 2002). Included in these effects are declines in biodiversity through the destruction, alteration and fragmentation of habitats, water and soil degradation and the overexploitation of indigenous species (Habitat, 2020; Kattel *et al*., 2013; Pimm and Raven, 2000). A major challenge faced by society is thus how to decrease the rate at which global biodiversity is being lost (Cardinale *et al*., 2012).

Many species that are harmed as a result of urbanisation are also likely to be threatened by many other human activities such as agriculture, recreational exploitation and forestry, highlighting the extensive transformations that coincide with urban sprawl (Krausmann *et al*., 2013; Mckinney, 2002). Urban sprawl has also been linked with damage to and fragmentation of ecosystems, decreased species diversity (Dadashpoor *et al.*, 2019; Da Gamma Torres, 2011) and the expansion and intensification of agricultural practices which are key drivers of biodiversity loss. With the ever-growing worldwide demand for the production of food through agriculture, further stress on species within close proximity to agricultural areas is inevitable (Cardinale *et al*., 2012). Although the importance of conserving biodiversity in agricultural areas is beginning to become more evident in conservation policies, finding the best methods to effectively conserve biodiversity in agriculture is still a major challenge worldwide (Gonthier *et al.*, 2014). As farming is a key source of food and an important aspect of the economy throughout the world (Wheeler and von Braun, 2013; Tscharntke *et al*., 2012), biodiversity conservation cannot occur at the cost of agriculture. Additionally, conservation in agriculture is a consistent human-nature relationship forming a social-ecological system with many complex components (Lescourret *et al*., 2015; Ogden *et al*., 2013). Therefore, because of the importance of agriculture and the complex social-ecological relationships in conservation, biodiversity conservation in agriculture is a major challenge all over the world (Lipper *et al*., 2014). Thus, in order for biodiversity conservation to be effective and sustainable, a balance between productive agriculture to meet the needs of people and biodiversity conservation needs to be established (Cockburn *et al*., 2018; Lipper *et al*., 2014).

One conservation method that is becoming more prominent in biodiversity conservation in agriculture is the establishment of biodiversity stewardship programmes. Biodiversity stewardship in South Africa is defined as "an approach to securing land in biodiversity priority areas through entering into agreements with private and communal landowners, led by conservation authorities" (SANBI, 2016, p. 11). The challenges around biodiversity stewardship are that there are varying interpretations of what biodiversity stewardship means (Cockburn *et al*., 2019) as well as difficulties in how to put the stewardship concept into practice, as the connections between the theory of the stewardship and the practice of the stewardship are insufficiently developed (Bennett *et al*., 2018). Biodiversity stewardship programmes in South Africa have the potential to improve biodiversity conservation in agriculture if the theory of the stewardship is translated into practice (Cockburn *et al*., 2019). Additionally, biodiversity stewardship is a highly cost-effective method of conserving land and expanding protected areas in South Africa as the constant costs of assisting the landowners in conserving the land is much cheaper for the authorities than purchasing and maintaining the land themselves (SANBI, 2015). This means that sufficient resources and time should be put into developing and expanding biodiversity stewardship in South Africa into agricultural landscapes, to ensure that agricultural practices are performed with a stronger focus on biodiversity conservation in a cost-effective way.

It appears that the success of biodiversity stewardship programmes has been noted by the successful expansion of the areas conserved and by ensuring collaboration between government and landowners (Cockburn *et al*., 2019; Cockburn *et al*., 2018; Rawat, 2017; SANBI, 2017; Boon *et al.,* 2016; McCann *et al.,* 2015; van Noie, 2009), however there is a lack of research on the conservation benefits and whether the programmes have been measured to improve the biodiversity of the conserved areas. The question remains whether biodiversity stewardship programmes are sustainable, adding value to both conservation and the landowners. This study focussed on an established biodiversity stewardship programme and sought to answer the question: what is the ecological state of the area and does this programme have potential for conservation in the long-term? To answer this question, this study investigated the Klipkraal biodiversity stewardship programme to determine a) the ecological state (functionality) of the area; b) the biodiversity stewardship programme's potential in terms of conservation, and c) the programme's sustainability in the long term in terms of the relationship between landowners and conservation authorities.

1.2 Aim and Objectives

The aim of this study was to assess the potential conservation value and sustainability of the Klipkraal biodiversity stewardship programme.

The objectives of this study were:

1. to assess the vegetation species richness and composition of the two farms that form part of the Klipkraal biodiversity stewardship programme;
2. to assess the mammal diversity, distribution and space use across the two farms;
3. to understand the perceptions of participating and non-participating farmers of the ecological and economic benefits and challenges of the Klipkraal biodiversity stewardship programme;
4. to understand the perceptions of the project managers from the Gauteng Department of Agriculture and Rural Development (GDARD) in using this biodiversity stewardship programme for conservation purposes.

1.3 Layout of Dissertation

The findings of the study have been written up as a dissertation that comprises of five different chapters. The introduction chapter (Chapter 1) includes the research gap and the aim and objectives. Chapter 2 provides a detailed literature review related to urbanisation and biodiversity, the impacts of urbanisation and agricultural expansion on biodiversity and wildlife, conservation within urbanised areas and agricultural areas and biodiversity stewardship in South Africa. Chapter 3 presents the study site and methodology for the study. Chapter 4 summarises the results of the study and Chapter 5 closes with the discussion of the results as well as the conclusion of the study. The references and appendices can be found at the end of the dissertation.

CHAPTER 2: LITERATURE REVIEW

The human population is growing at a rapid rate and as a result urban areas, cities and industries are expanding quickly to accommodate the rapid growth (Fraser *et al*., 2016). The expansion of the human impacted areas is resulting in the disturbance of natural areas, fragmentation of ecosystems and decreased species diversity (Dadashpoor *et al.,* 2019; Venter *et al*., 2016) and pressure is put on the natural environment to adapt to this change (Barendse *et al*., 2016). A major challenge faced by society is how to decrease the rate at which natural areas and global biodiversity is being lost because of urbanisation and urban sprawl (Cardinale *et al*., 2012) whilst still meeting economic development needs (Izzatulloev, 2023).

2.1 Urbanisation and Urban Sprawl

Urbanisation is a gradual growth in the number of people occupying cities or urban areas and is found to be occurring throughout the world (Bodo, 2019). Urban sprawl is a result of urbanisation where urban areas physically grow in size in different spatial patterns as a result of many different drivers, for example, an increase in population density (Artmann *et al*., 2019). At the current rate of urbanisation, it is expected that by 2050 the percentage of the population living in urban areas will increase to 66% from 54% in 2014 (UNDESA, 2019; Gómez-Baggethun and Barton, 2013), and that 90% of urban growth will occur in the lesser developed regions of Africa and Asia. Low-income countries are expected to show the quickest rate of urbanisation in the coming decades (United Nations, 2019). It is expected that by the year 2030, cities will triple the area they occupy from the year 2000 and the majority of this increase will occur in fairly untouched biodiversity-rich areas (Seto *et al*, 2012).

Natural land is being replaced with artificial structures in the process of urbanisation and urban sprawl because of the growing human population (Fraser *et al*., 2016; Pauchard *et al*., 2006). This results in the conversion of natural land to areas for human use or a shift in management methods on current land that is already converted for current-day human activities (Venter *et al*., 2016; Foley *et al*., 2005). The effects of land-use change vary, from changes in ecosystem structure and function to changes in atmospheric composition (Steffen *et al*., 2015; Wackernagel *et al*., 2002). Included in these effects is the destruction, alteration and fragmentation of habitats, water and soil degradation, the overexploitation of indigenous species and, on a larger scale, a significant contribution to climate change (Habitat, 2020; Kattel *et al*., 2013; Bryant, 2006; Pimm and Raven, 2000). Urbanisation is thought to be the most extreme and long-term form of change in terms of the alteration of ecosystems and landscapes (Gómez-Baggethun and Barton, 2013) and also results in the loss of many indigenous plant and animal species. The fragmentation of ecosystems and habitats, as well as the replacement of native species by exotic species all have a negative effect on the biodiversity in the area (Steffen *et al*., 2015; Bryant, 2006).

Urbanisation has resulted in some of the highest local species extinction rates (Mckinney, 2002), posing a severe threat to the natural environment and its biodiversity, and that environmental protection should be enhanced in urban areas (Cilliers *et al*., 2004). Species loss negatively affects the ecosystem services provided by the natural environment which have great economic value, such as food and fuel production, soil nutrition and water purification/provision (IPBES, 2018; Perrings *et al*., 2006). If the fragmentation levels as a result of urbanisation and urban sprawl are high, a region can move past connectivity thresholds, making restoration challenging and costly. To prevent this and to protect the biodiversity in an area, policies that enable the restoration and protection of heterogeneous and connected ecosystems need to urgently be put in place (Dupras *et al*., 2016) and suitable, well researched strategies for managing urban growth need to be developed (Habitat, 2020). Additionally, a deeper understanding of the relationship between the natural ecosystems and society as well as how to manage this relationship has become key in moving towards sustainable development (Qiu *et al*., 2021).

2.2 The Importance of Biodiversity Conservation

Biodiversity is the foundation of functioning ecosystems (Reid *et al*., 2005; Noss, 1990) and as a result, a loss of species influences ecosystem functioning which affects the services provided by those ecosystems (Cardinale *et al*., 2012; Reid *et al*., 2005). Biodiversity is known to ensure the stability of an ecosystem in order for that system to function optimally, which means that an ecosystem can continue providing ecosystem services (Loreau *et al.*, 2021; Cardinale *et al*., 2012). Ecosystem services are the benefits that humans gain from a functional ecosystem (Gómez-Baggethun and Barton, 2013), including the natural advantages that occur for social and economic structures (Atif *et al*., 2018). These services include, for example, the physical resources people obtain from ecosystems such as food and water (Martínez-Harms and Balvanera, 2012; Millennium Ecosystem Assessment, 2005), services that control environmental conditions such as temperature and flood regulation, cultural services such as recreation (Cilliers *et al.*, 2013) and services that indirectly benefit humans such as nutrient cycling, which supports the production of other ecosystem services (Cilliers *et al.*, 2013; Martínez-Harms and Balvanera, 2012; Millennium Ecosystem Assessment, 2005). Studies suggest that biodiversity also plays an important role in increasing ecosystem resilience to many different disturbances (Sasaki *et al*., 2015; Cardinale *et al*., 2012), including changes in rainfall patterns and other environmental changes (Isbell *et al*., 2015).

Urbanised areas are known to support more exotic species at the cost indigenous species (Johnson and Munshi-South, 2017). Exotic species have been acknowledged as one of the top five causes of biodiversity declines worldwide by the Millennium Ecosystem Assessment (Stelter, 2005) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (IPBES, 2018) and are especially prominent in human-impacted areas such as cities. The exclusion of naturally occurring species by exotic species has a negative effect on the biodiversity in an area and can alter the structure or functioning of an ecosystem (Gentili *et al.,* 2021; Pyšek and Richardson, 2010; Bryant, 2006). For example, exotic insects can alter ecosystem functioning by varying the nutrient, carbon and hydrological cycles of an area (Clark *et al*., 2010) and exotic grasses can invade an area, transforming the ecosystem which results in drastic changes to the area's fire regime (Brooks *et al*., 2004). This has been proven in a study by Fusco *et al.* (2019) who showed that exotic grasses increase the frequencies of fire across many different biomes in the United States. Additionally, a study by Kraaij *et al.* (2018) suggests that a major cause of the disastrous 2017 wildfires in Knysna, South Africa is the abundance of invasive plants and trees in that area. A change in vegetation structure through the introduction of exotic plants also tends to result in loss of native biodiversity, increased habitat degradation and decreased diversity and species richness of birds and some mammals in the area (Marzluff and Ewing, 2008). Godfrey *et al*. (2017) found that invasive grasses in Australia caused a transformation of landscapes and a loss of biodiversity through habitat fragmentation and by creating an unfavourable environment for native plants. It is however suggested that mammals may be more affected by changes in land use as a result of urbanisation and urban sprawl than plants and birds. This is because they need a larger area to ensure successful survival of the population, whereas plants can thrive in a relatively small area and many birds are attracted to small spaces with varying vegetation, regardless of whether the plant species are exotic species or not (Visconti *et al*., 2016; Mckinney, 2008). Additionally, different mammals will be affected differently by urbanisation as a result of the vast range in the size, ecology and structure of mammals, making the effects of land use change and urbanisation on mammals complex (Santini *et al*., 2019). For example, a study in Bangkok, Thailand by Thaweepworadej and Evans (2023) found that an increase in urbanisation has resulted in a decline in squirrel abundance and diversity. In turn, Ancillotto *et al.* (2015) found that a species of bat (*Pipistrellus kuhlii*) benefits from urbanisation and produces more pups in urbanised areas than in rural areas. A study by Magle *et al.* (2021) indicated that, from an assessment of multiple different mammals across North America, urbanisation had a negative effect on the species richness and diversity of medium to large mammals. The study also indicated that racoons were not as negatively affected by urbanisation. As a result of the many different responses to urbanisation, animals have been classified into three main categories based on their response to the effects of urbanisation. The three categories are dwellers, which establish stable populations in the urbanised areas and can eventually thrive in this area; utilisers, which can make use of urbanised areas occasionally, and avoiders, for which the species abundance declines and could eventually disappear with greater urbanisation (Fischer *et al*., 2015).

In South Africa, biodiversity conservation is important for several reasons (Barendse *et al*., 2016). Firstly, ecosystem services contribute a service value equal to approximately seven percent of the country's Gross Domestic Product (GDP) (Cadman *et al*., 2010) and Scholes *et al.* (2023) pointed out that conserving biodiversity is an economic imperative as biodiversity rich ecosystems provide the population with the necessary goods and services for survival. Tourism, horticulture, traditional medicine use, fisheries, wild game farming and wildflower harvesting are all examples of industries that are vulnerable to biodiversity loss. Secondly, the conservation and rehabilitation of the country's natural landscapes is an important part of climate change adaptation strategies, as recognised by South Africa's National Development Plan 2030 (Barendse *et al*., 2016). For example, the Cape Floristic Region's vegetation has evolved through conditions of hot and cool periods, droughts and fires, making its vegetation suitable to cope with the conditions associated with climate change (Barendse *et al*., 2016). Thirdly, because of the richness and uniqueness of the biodiversity of the country, South Africa has a responsibility globally to ensure conservation of its biodiversity. For example, the Cape Floristic Region has more than 9600 species of plants, of which 69 percent do not occur anywhere else on Earth (Ashwell *et al*., 2006). Fourthly, South Africa's rich biodiversity, wildlife abundance and natural landscapes are a fundamental part of its tourism sector, which contributes greatly to the country's GDP and supports employment (Barendse *et al*., 2016). Activities which have an impact on the biodiversity of an area can greatly change the quality and functionality of its ecosystems, in turn affecting the ecosystem services provided (Loreau *et al.*, 2021; Cardinale *et al*., 2012; Reid *et al*., 2005). This could have financial, social and cultural implications (Cardinale *et al*., 2012) and affect many people differently, as people have varying views of and uses for biodiversity and ecosystem services (Dallimer *et al*., 2012).

2.3 Biodiversity Conservation in Urban and Peri-Urban Areas

Urbanisation and the development of cities has contributed to the alteration of ecosystems all over the world, pushing biodiversity to the edge of a sixth mass extinction (IPCC, 2021). Little progress has been made toward achieving the objectives set out in the Convention on Biological Diversity (United Nations, 2015) to mitigates the rapid loss of biodiversity occurring globally (Rega-Brodsky *et al.*, 2022). The study of urban ecology has become an important focus in modern environmental science (Cressey 2015), but there is still only limited knowledge about the species found in cities and what allows them to adapt and persist in urban areas (Rivkin *et al*., 2019; Kowarik and von der Lippe, 2018). Multiple studies have found that the state of natural ecosystems has been negatively affected in multiple ways as a result of the continuing development of cities (Aronson *et al.*, 2014; Güneralp and Seto, 2013; Grimm *et al.*, 2008), highlighting the need for a focus on conservation practices in cities. There are however a few challenges involved in conserving biodiversity in cities. For example, a major issue is that decision makers in cities and occupants of the city often perceive other issues as more urgent and important than biodiversity conservation in the city. Often, biodiversity conservation in cities is seen as an expense, whereas development and income generation are a priority (Yang and Taufen, 2022).

Multiple models and frameworks have been considered to ensure the protection of biodiversity in urban areas, but due to the complex nature of urban systems and the numerous impacts that humans have on natural landscapes need to be considered, these are difficult to develop (Kattel *et al*., 2013). Through the development and management of urban green spaces (patches of natural, semi-natural and artificial biological systems), cities have been found to play an essential role in biodiversity conservation (Aronson *et al.*, 2017). Although these spaces can often be "patchy", they provide habitats for many pollinators, birds, insects and many other species (Andersson and Colding, 2014) and therefore play a significant role in the conservation of biodiversity at varying scales (Anderson *et al.*, 2014). On the other hand, they are known to be fragmented as a result of development, intensive agricultural practices and industrialisation (Ferretti and Pomarico, 2013). The fragmented and isolated patches can limit species migration, altering the interactions amongst species, modifying or prohibiting wildlife dispersal (Massol *et al*., 2011; Rico *et al*., 2007). This results in patch isolation as well as the isolation of species occupying these spaces and hinders species' ability to persist in the area as their gene flow is limited (Closset-Kopp *et al*., 2016), resulting in decreasing animal and plant diversity within these isolated patches (Nor *et al*., 2017). The larger the area of natural or semi-natural areas kept, the greater the resources and range provided for species to survive and populate resulting in more genetic diversity, a key component in ensuring ecosystem resilience (Mouillot *et al.*, 2014; Hodgson *et al*., 2011).

2.4 Ecological Corridors and Connectivity

As habitat fragmentation causes animal species to be isolated and decreases the system's resilience to environmental pressures, maintaining habitat connectivity has become a critical concern and priority in conservation ecology (Thompson *et al*., 2017; Ferretti and Pomarico, 2013). Habitat corridors or ecological corridors are a widely used approach to enhance landscape connectivity (Hobbs, 1992). These are structures or areas that allow for the migration, spreading and exchange of animal species amongst core areas in an ecological network which consists of corridors linking hubs (areas with a known ecological value) to one another (Ferretti and Pomarico, 2013). By connecting patches within landscapes, animal species have a way of travelling between these natural areas, which results in a decrease in genetic isolation and also means that, if a species' habitat is affected by pollution or development, it is able to relocate to a new habitat (Closset-Kopp *et al.*, 2016). Ecological corridors and connectivity are known to enhance species richness and the viability of populations at both local and regional levels (Thiele *et al*., 2018; Gilbert-Norton *et al*., 2010), and hence the importance of protecting these ecological links has become apparent (Nor *et al.*, 2017). The importance of mitigating the consequences of ecosystem fragmentation makes clear that simply ensuring the protection of many isolated patches is insufficient to ensure the ecological integrity of an area (Pino and Marull, 2012). It has been acknowledged in scientific studies that larger, undamaged patches of natural land are favourable for biodiversity conservation as these can sustain a greater number of species and larger populations as there are more resources and niches available (Kremen and Merenlender, 2018; Connor, 2000). A study by Mendez *et al.* (2014) in Spain found that populations of Dupont's larks (*Chersophilus duponti*) showed a lower genetic diversity in small, isolated patches than the larger less isolated populations. Another study by Habibzadeh and Ashrafzadeh (2018) performed in Iran on an endangered brown bear found that some populations were not able to survive without connectivity between the habitat patches and only a small percentage of the isolated patches were suitable for the bear to breed. A study by Zungu *et al.* (2020) in the Durban forests of South Africa found that species richness of mammals was lower in small, isolated patches than larger connected ones and suggested that conservation of habitat networks and corridors is important in the persistence of mammals in the area. As this is a general trend, a lot of focus has been put towards the conservation of larger patches of natural land (see Watson *et al*., 2018). However, Wintle *et al.* (2019) also highlighted the importance of conserving smaller patches of natural land, especially in areas that have experienced urban sprawl, as these smaller natural patches still offer critical ecological benefits. Nonetheless, in order to protect the biodiversity in urban areas, a well-established ecological network needs to be in place with natural areas that are protected and interconnected with corridors that allow the movement of all species in the area (Nor *et al.*, 2017).

2.5 The Impacts of Agriculture Expansion and Intensification on Biodiversity

Many different animal and plant species that are harmed as a result of urbanisation are also very likely to be threatened by other human activities, including agriculture, recreational exploitation and forestry, highlighting the extensive transformations that coincide with urban sprawl (Krausmann *et al*., 2013; Mckinney, 2002). Coupled with urban sprawl is the expansion and intensification of agricultural activities which are key drivers of biodiversity loss (Cardinale *et al*., 2012). A proposed reason for this is that, due to natural land being transformed for many different purposes in the process of urbanisation and urban sprawl, farmers need to intensify their practices in order to deal with the urban pressures, especially the growing urban population (Dupras *et al*., 2016). With the ever-growing worldwide demand for the production of agricultural food products and the environmental degradation associated with agriculture (Krausmann *et al*., 2013), further stress on species in agricultural areas is inevitable (Cardinale *et al*., 2012).

Agricultural intensification (e.g., increased fertilizer and pesticide use and increased labour and machinery) can have many effects on ecosystem processes, disrupting many supporting and regulating services such as water quality regulation, nutrient cycling, pest control and pollination (Lankoski, 2016; Power, 2010; Tschartke *et al*., 2005). This means that, by increasing food production through intensifying agricultural practices at the expense of some ecosystem services, the sustainability of the agricultural practice as well as the integrity of the surrounding ecosystem can be negatively affected (Kehoe *et al*., 2017; Palm *et al*., 2014). Adding to this challenge is the projected impacts of climate change on the agricultural sector and its production which is likely to be hindered in multiple areas in Africa (Scholes *et al.*, 2023). Traditional, small-scale methods of farming, which are known to allow for biodiversity to persist in the area, are being replaced by large-scale, intensive systems that are generally monoculture farmlands (Rudel *et al*., 2009).

The use of land for monoculture crop production, intensification practices and increased pesticide and fertilizer use, and pollutant release associated with large-scale farming are known to be most damaging to biodiversity and ecosystems (Dudley and Alexander, 2017; Clough *et al*., 2011). For example, fertilisers leaking into nearby freshwater systems result in algal blooms from nutrient pollution, depleting the oxygen in the water and as a result harming the biodiversity of the system (FAO, 2015). Additionally, herbicides, fungicides, insecticides or other pesticides have been found to have harmful effects on soil ecosystems as they disrupt the biotic communities in soils. The toxicity of the chemicals can change the soil composition which affects the soil microorganisms, causing disruptions to plant growth, nutrient cycling and the food web dynamics of the soil (Bai *et al.*, 2020). Herbicides, fungicides, insecticides or other pesticides have also been identified to cause serious harm to birds, amphibians and invertebrates (Chagnon *et al.*, 2015). Direct exposure to chemical contaminants such as insecticides and pesticides have been found to affect various organisms. For example, it has been found that pesticides can directly affect birds through food contamination. This can result in the changing of feeding behaviour of birds and can compromise the bird’s immune system, making them more vulnerable to predation, which can also result in the secondary poisoning of birds of prey such as falcons, cranes and eagles. Additionally, exposure to pesticides during reproduction can affect the success of hatchings and survival of young (Mitra *et al.*, 2011). Pesticide exposure has been found to decrease the mating success of red-spotted newts and many frog species (*Notophthalmus viridescens*) as the sexual communication between individuals is disrupted by the chemical exposure (Samual *et al*., 2023). Chemical exposure as a result of insecticides and herbicides can also affect the movement of organisms by disrupting their sensory systems that are used to locate resources and habitats (van den Berg *et al*., 2023). Another negative effect of agriculture is the use of field ploughing and mechanical operations as it causes soil disturbance, which negatively affects many plants growing in the vicinity of the disturbance. The act of ploughing removes plants and reduces the number of resources for other organisms, for example shelter for insects (Emmerson *et al.*, 2016).

Livestock grazing has been identified to have varying effects on biodiversity such as increasing the invasive species in the area (Kimball and Schiffman, 2003). A study by Filazzola *et al.* (2020) assessed studies from twenty different countries all over the world and found that reducing livestock grazing resulted in an increase in plant abundance and diversity. The study also found that with livestock farming present, a decrease in the abundance of other herbivores was seen, possibly as the livestock create increased competition for food for the herbivores. This had a knock-on effect, and the study found a decrease in the number of predators which is suggested to be as a result of decreased prey. In South Africa, Hanke *et al.* (2014) found that species and functional composition were altered by heavier grazing and total plant cover was reduced. Additionally, heavier grazing was found to have an increase in the heterogeneity of the community composition and functional structure. Small mammals are especially affected by livestock grazing as trampling from the livestock causes damage to the mammals' burrows and shelters and reduces vegetation cover, exposing the small mammals to predators (Horncastle *et al.*, 2019). Livestock grazing can also have a significant effect on pollinators as it results in the removal of flowers which in turn decreases the abundance of nectar and pollen (Hatfield and LeBuhn, 2007), and grazing has been known to disturb naturally occurring plant-pollinator visitation networks in Northern Scotland (Vanbergen *et al.*, 2014).

Structures associated with farmlands, such as fences and roads, also influence the biodiversity of the area. These structures can create barriers for the movement of species (Ferguson and Hanks, 2012). Specifically for specialist species, fences can change the community composition of the species by restricting movement. The barrier can affect a species' habitat selection and resource access which can have an impact on the success of the species (McInturff *et al.,* 2020). Fences have also been found to be directly harmful to species, for example, a study by Baines and Andre (2003) found a high mortality rates of the ground nesting birds of the grouse genus (*Tetrao*) in areas with fences that cannot be clearly seen, and a study by Gadd (2011) in South Africa found that most mammals in the vicinity of the study site, excluding small mammals and carnivores, experienced entanglement in fences and as a result, death. Fences also result in animals crowding in areas as their movement is restricted and as a result this can causes overgrazing, habitat degradation, disease outbreaks and eventually starvation. Fences also divide populations and if too few animals are restricted to an area and there is no opportunity for new individuals to immigrate, the population might result in local population declines and ultimately extirpation (Gadd, 2011). Similarly, roads also have adverse effects on biodiversity and result in increased mortality rates, restriction of movement, displacement of individuals and decreased habitat connectivity (Bennett, 2017).

Although there are many negative effects of farming on biodiversity, agriculture can potentially maintain and possibly enhance biodiversity, if the correct policies are put in place (Lankoski, 2016; Dura *et al.*, 2015; Kremen, 2015). For example, a study by Bengtsson *et al*. (2005) found evidence that the species richness of birds, plants and insects is seen to increase with organic farming methods compared to traditional farming methods. Another study by Henneron *et al.* (2015) found that conservation agriculture which consists of organic farming, reduced tillage, use of dead organic soil cover and crop rotations enhanced the soil biota and positively affected the structure of the soil food web.

2.6 The Effect of Agriculture and Other Human Disturbance on Wildlife

Since agriculture and other human disturbance have such a broad range of effects from changes in ecosystem functioning and habitat loss to effects on hydrological processes, alterations to the spatial and temporal patterns of primary productivity and biochemical processes of soil, the evolutionary associations between ecosystems and natural wildlife can be severely disrupted (Wright *et al.,* 2012; Foley *et al.,* 2005). As a result of the significant effects of agriculture and other anthropogenic effects on ecosystems and their integrity, species are vanishing at an alarming rate (De Vos *et al.,* 2015). For example, it was indicated that the intensification of agriculture is the core driver for declines in populations of insectivorous mammals, insects and birds (Sánchez-Bayo and Wyckhuys, 2019).

Additionally, a study by Hurst *et al.* (2014) in Swaziland found an immense decrease in granivorous small mammal populations when moving towards agricultural land from conserved land. Similarly, Gentili *et al.* (2014) found a reduction in small mammal diversity when moving into areas with greater agriculture intensification in Italy. Additional to the fact that human disturbance has been found to decrease species richness of populations, human disturbance, including agriculture, has been found to alter the behaviour of animals compared to animals in natural areas (Greenberg and Holekamp, 2017). Species with highly flexible behavioural ecology can maximise the benefits from human-created habitats and thrive in highly transformed habitats and can be successful in areas beyond their natural habitats (Luna *et al.,* 2018; Abellán *et al.,* 2017; Lowry *et al.,* 2013; Sol *et al.,* 2005). These animals are often referred to as opportunistic species that take advantage of human changes to environments that offer opportunities that these species might not have elsewhere (Fleming and Bateman, 2018). It is suggested that small mammals and birds with personalities that are curious, bold and exploratory are at an advantage as they are able to exploit these transformed habitats and make use of human-provided resources (Miranda *et al.,* 2013). Similarly, Greenberg and Holekamp (2017) found that hyenas in areas with a lower disturbance were shyer and less exploratory than those in areas with greater disturbance. Animals have also been suggested to become more aggressive towards humans when exposed to greater human interaction in disturbed areas which could result in human wildlife conflict resulting in the persecution of these species (Geffroy *et al.,* 2015). For example, a study by Arroyo *et al.* (2017) found that over 19 years of studying the Montagu's harriers (*Circus pygargus*), the birds became increasingly more aggressive and bolder, indicating a decreasing distress by human activity. The study also indicated that over time, the shy individuals gradually disappeared in the population, indicating a phenotypic composition change in the population. On the other hand, as urban areas push further into natural spaces, increased human interaction with animals can also result in various levels of domestication, leading to reduced antipredator behaviour, reduced aggression and fear of humans and tameability (Price, 2002). For example, Scales *et al.* (2011) observed that song sparrows in areas with greater human density take off a lot later when approached by a human than in natural environments.

Although human-altered ecosystems do have multiple negative effects on species success and behaviour, studies have found that these landscapes (such as farmlands, built up areas and degraded forests) can still be utilised and inhabited by some species (Allinson, 2018). The transformed landscapes can provide species with resources needed to survive, for example, maize fields provide species with corn and fruit farms can provide various species with different fruits. However, the human-created feeding areas can have negative effects on species and can create ecological traps for the species that utilise them (Oro *et al.,* 2013). For example, these areas can result in a greater predation risk for species (Morris, 2005), increase their exposure to various pollutants (Kale *et al.,* 2013), boost intraspecific competition (Donazar *et al.,* 2020) and result in the death of species as a result of the infrastructure associated with the areas (for example, heavy machinery for farming) (Tella *et al.,* 2020). Animals can become habituated to these transformed landscapes as they are conditioned to receiving food from the area. Habituation has been linked to a decrease in migration which can cause a high abundance of animals year-round, resulting in degradation of the ecosystem being inhabited (White *et al.,* 2014; Middleton *et al*., 2013). For example, a study by Morelle and Lejeune (2015) found that during crop season, populations of wild boars (*Sus scrofa*) are seen to double in agricultural areas as they search for food and cover, influencing the distribution and movement of the species. Additionally, a study by Ullmann *et al.* (2020) on European brown hares (*Lepus europaeus*) showed that the number of hares in farmlands increased after harvest as the hares can access grains that have fallen to the ground as they generally prefer shorter vegetation. Another example of how agriculture can affect the movement of species is shown by Kay *et al.* (2016). The Australian study showed that the movements of arboreal gecko (*Christinus marmoratus*) were significantly altered by the direction of crop sowings as the geckos followed the planted pattern.

Species that utilise the human created feeding areas can unfortunately also become pests as they can reduce crop production in farming areas and as a result, the species can be removed from the area through various means (Di Marco *et al.,* 2018). For example, Mauri *et al.* (2020) observed that roe deer (*Capreolus capreolus*) have been found to cause severe damage to crops in Italy, resulting in losses for the agricultural sector and as a result, a drive to remove them from the area. For example, Wolfe *et al.* (2018) found that many species of snake exploit the availability of prey associated with human habitation, therefore thriving in areas altered by humans. It has also been observed by Mauri *et al.* (2019) and Sofia *et al.* (2017) that ungulates, such as wild boars (*Sus scrofa*) and rodents, as well as some winged species and a few small mammals have been found to take advantage of human activities which have resulted in the formation of novel habitats for these species to take advantage of.

2.7 Biodiversity Conservation in Agriculture

Since biodiversity is the key to ecosystem services that are critical for agriculture and food production, a clear understanding of the function of biodiversity and how to conserve it in agriculture is essential (Ortiz *et al*., 2021). Increased attention has been given to the environmental aspects of agricultural activities, however its part in biodiversity conservation has been generally overlooked (Ortiz *et al*., 2021; Perrings *et al*., 2006). However, there are a few strategies that have been implemented worldwide in an attempt to reduce the negative effects of agriculture on biodiversity. One strategy, implemented in many countries, includes compensation for farmers to decrease the intensity of their farming practices by reducing pesticide and synthetic fertiliser usage as well as converting their farms to organic farms (Lankoski, 2016; Kleijn *et al*., 2011; Bengtsson *et al*., 2005). In Australia, the United States of America and Europe, financial incentives have been found to be successful in implementing biodiversity conservation plans on privately owned land (De Vries and Hanley, 2016; Binning and Young, 2015; Kamal *et al*., 2015). Kusmanoff *et al.* (2016) found that successful initiatives to conserve biodiversity on farms in Australia concentrate on the benefits for the farmer in putting their efforts towards conservation. This often influences the behaviour of the landowners, especially when the benefits to the landowner in terms of the value of biodiversity conservation are well communicated and explained. However, it has been identified that, although financial incentives to farmers could encourage a change in perspectives and practices, it may not be so straightforward as territorial dynamics due to social structure and culture can determine whether the financial incentives do result in a meaningful change (van Hecken *et al*., 2019).

Some studies have suggested that, while decreasing the intensity of local farming practices does assist in biodiversity conservation in an area (Ortiz *et al*., 2021; Attwood *et al*., 2008; Bengtsson *et al*., 2005), if only one farm in a community reduces its farming intensity, this may not be sufficient to conserve species that have large range sizes (Bellon *et al*., 2017; McKenzie *et al*., 2013; Tscharntke *et al*., 2005). Additionally, if this single farm is surrounded by many other farms that have high intensity farming practices, the farm reducing its intensity might add little benefit for the biodiversity in the area as species would be isolated on that farm or unable to disperse resulting in the degradation of that ecosystem. Hence, to conserve the biodiversity of an area effectively, the entire community needs to reduce their farming intensity (Bellon *et al*., 2017; Tscharntke *et al*., 2005; Ricketts *et al*., 2001). It is also suggested that, in order to better conserve the biodiversity in a large agricultural area, the integration of natural and semi-natural landscapes in areas surrounding farms needs to occur, as well as the maintenance of a high diversity of habitats in agricultural landscapes (Harlio *et al*., 2019; Kennedy *et al*., 2013; Whittingham, 2011). Another strategy is the use of policies that involve environmental regulations for farming practices such as environmental cross-compliance, biodiversity offsets, payment for environmental services, environmental regulations and conservation auctions (Lankoski, 2016). For example, a study by Zu Ermgassen *et al.* (2019) shows that biodiversity offsets, which include a mitigation hierarchy (avoidance, minimization, restoration and offsets) to remediate and offset the biodiversity impacts of human activities, have been implemented in many parts of the world, all with varying success rates. However, the study did identify a mismatch between the worldwide implementation of biodiversity offsets and the proof of their effectiveness. Although the importance of conserving biodiversity in agricultural areas is beginning to become more evident in conservation policies, finding the best methods to effectively conserve biodiversity in agriculture is still a major challenge worldwide (Gonthier *et al.*, 2014).

A study by Wright *et al*. (2018) on biodiversity conservation in South Africa explains that biodiversity conservation sometimes occurs in conflict with the intended land uses. For example, biodiversity conservation could be in conflict with intended farming activities. In Africa, and many other parts of the world, agriculture is a key source of food, an important economic sector and a large source of employment (Wheeler and Von Braun, 2013; Tscharntke *et al*., 2012). Approximately 75% of the earth's poor live in agricultural areas and hence their main source of income is from agriculture (Heinemann *et al*., 2011). Increasing agricultural production and intensity is considered critical for poverty reduction and for moving towards food security. It is projected that by 2050 agricultural production will need to increase by 60% to meet the increasing food demands of the world (Alexandratos and Bruinsma, 2012) and the Stellenbosch Institute for Advanced Studies points out that Southern Africa is currently not producing sufficient food to meet the needs of the current population and will need to increase food production by one to two percent per annum at minimum to meet the needs of the growing population (STIAS, 2015). For these reasons, biodiversity conservation cannot occur at the cost of agriculture and thus combining productive and efficient agriculture with biodiversity conservation is a challenge worldwide (Dudley and Alexander, 2017; Lipper *et al*., 2014). Wright *et al*. (2018) emphasise that, due to the conflict between conservation and farming, it is important to address the farmers' perceptions of biodiversity stewardship and conservation. This is because agricultural lands are socio-ecological systems consisting of many different components such as stakeholders, organisations, institutions, ecosystem services, biodiversity, scales of actions, land uses and decision making. As these socio-ecological systems are so complex, managing these systems is challenging (Lescourret *et al*., 2015). It is suggested that, to bring about conservation and responsible farming in agricultural areas, it is necessary for collaboration amongst the multiple stakeholders, landowners and governors who are associated with the land (Duru *et al*., 2015; Minang *et al*., 2014).

Conservation in socio-ecological systems is reinforced by beliefs, values and different schools of thought which define how people manage their interactions with the natural environment (Manfredo *et al.,* 2017; Robinson, 2011). However, with the rapidly changing world, people's values and ideas are consistently changing too (Steffen *et al*., 2011), emphasising the need for continuous interdisciplinary collaboration and idea development for biodiversity conservation in socio-ecological systems (Duru *et al*., 2015; Robinson, 2011). A balance between enhancing ecosystem resilience and meeting the needs of people is required for the sustainability of the socio-ecological system (Cockburn *et al*., 2018; Chapin *et al*., 2009).

2.8 Biodiversity Stewardship in South Africa

Biodiversity stewardship programmes are a form of biodiversity conservation strategy that is being implemented more frequently in South Africa (Rawat, 2017). Biodiversity stewardship is a method used to secure land in areas where biodiversity is a priority by creating arrangements between landowners of communal or private land and local conservation authorities (SANBI, 2016). To assess the biodiversity and ecosystems of South Africa, the National Biodiversity Assessment (NBA) was formed and the NBA stated that natural habitats are being lost at such a high rate in KwaZulu-Natal, Gauteng and Northwest Province that, if this were to carry on as it is, no natural landscapes not included in officially declared protected areas will be left by 2050 (Driver *et al*., 2012). The overall goals of biodiversity stewardship in South Africa are to ensure the conservation of a representative biodiversity sample, involve landowners in the process of biodiversity conservation, contribute to the economy in rural areas, invest in ecological infrastructure, contribute to the adaptation to and mitigation of climate change and support development that is sustainable (SANBI, 2016).

The Gauteng Biodiversity Stewardship Programme (GBSP) is a partnership between the Gauteng Department of Agriculture and Rural Development (GDARD), the WWF Nedbank Green Trust and the Endangered Wildlife Trust (EWT) and aims to create a functioning model for biodiversity stewardship in Gauteng, ensuring the expansion of protected areas in important conservation areas (Seegers and Taylor, 2018). In addition to the benefits for biodiversity, the programme can also contribute to wider socio-economic goals, including the creation of green jobs, rural development and the inclusion of disadvantaged populations (Rawat, 2017).

Although biodiversity stewardship programmes have been considered fairly successful in South Africa, challenges do exist (Wright *et al*., 2018). The challenges around biodiversity stewardship involve varying interpretations of what it means (Cockburn *et al*., 2019) as well as difficulties in how to put stewardship into practice, as the connections between the theory of the stewardship and how to put it into practice are insufficiently developed (Bennett *et al*., 2018). Another problem in South Africa specifically is that the government has directed its focus and funds towards addressing the rich-poor gap and injustices over the last two decades (Ncube, 2013), meaning less focus and money have been put towards biodiversity conservation (Rawat, 2017) and financial aspects are currently a limiting factor for biodiversity stewardship programmes (Wright *et al*., 2018). There are also issues around other resource constraints, such as human resources (Wright *et al*., 2018). Another challenge is ensuring that the landowners and government conservation members are sufficiently skilled as they require a large range of skills, such as knowledge of environmental legislation, broad ecological knowledge, understanding of management interventions, agricultural practice knowledge and considerations of socio-economic relations (Wright *et al*., 2018).

An important aspect of biodiversity stewardship that needs to be highlighted is that the relationship between landowners and the ecosystems is crucial in ensuring the success of the stewardship programme (Cockburn *et al*., 2019). As a result, an interdisciplinary approach is needed by connecting the social and ecological systems involved in biodiversity stewardship. This involves engaging landowners to direct their time, resources and efforts to ensure sustainable use of natural resources and consideration for ecosystems (Zipperer *et al*., 2011). In South Africa, the property still belongs to the landowner and he or she is responsible for the management of the land, with the support and advice of the conservation authority (SANBI, 2016). Government-subsidised biodiversity stewardship programmes have been established in each of the country's nine provinces and are considered an effective and efficient tool for enhancing biodiversity protection and expanding protected areas in South Africa (Cumming *et al*., 2015). For example, a biodiversity stewardship programme was implemented in eThekwini, KwaZulu-Natal in 2012 and has been considered successful in building partnerships and bringing together traditional and technical knowledge to assist landowners in managing the biodiversity on their properties. The success of the programme has been attributed to the fact that the local government in eThekwini has been a key role player in the implementation and management of biodiversity conservation for decades (Boon *et al*., 2016), however to my knowledge there is no evidence that the programme has resulted in any improvements in biodiversity since it began.

While successful biodiversity stewardship programmes can benefit both people and the environment (Rawat, 2017), the question of how to ensure the sustainability of a biodiversity stewardship programme arises. The success and longevity of a biodiversity stewardship programme will entail the satisfaction of landowners and the government with the benefits they are receiving from the programme and the sufficient and successful services delivered by the landowners towards reaching the aims of the programme (Barendse *et al*., 2016; Selinske, 2015). It is suggested that the best method of ensuring the landowners' long-term participation in the programme is by use of financial incentives that they deem satisfactory. In South Africa, these financial incentives have proven to change landowners' views towards biodiversity stewardship, ensuring that they increase their water yields, protect ecosystems, encourage ecosystem connectivity and moderate flood and fire risks (Rawat, 2017), thereby supporting long-term biodiversity stewardship. However, a study on biodiversity stewardship in the Western Cape by Wright *et al*. (2018) found that the established programmes are limited by a lack of appropriate and consistent benefits for the landowners. The study emphasises that communication and continued supply of benefits to the landowners needs to be prioritised. A study in Australia by Fitzsimons (2015) also revealed issues in terms of the provision of consistent benefits to landowners, supporting Waldron *et al*.'s (2013) findings that this is a problem in many parts of the world. Another possible incentive for biodiversity stewardship to ensure long-term commitment from landowners may be through tax rebates (Rawat, 2017; Paterson, 2005). For example, the

Municipality of Nelson Mandela Bay allowed for landowners who are involved in biodiversity stewardship agreements to be exempted from some taxes and receive rate rebates (The Republic of South Africa, 2009). Additionally, landowners need to be able to see other benefits of the programme to them, besides the financial benefits. For example, the programme has been found to offer landowners a platform for them to show their skills and contributions towards development and conservation (Rawat, 2017). It is also important that landowners are aware of the long-term commitment required for a successful biodiversity stewardship programme in private protected areas, which might entail a multigenerational commitment by landowners (Stolton *et al*., 2017).

The sustainability of a biodiversity stewardship programme also heavily relies on the amount of support from government towards the arrangements and institutional capacity needed for the programme (Barendse *et al*., 2016). On the other hand, Wright *et al*. (2018) in the Western Cape found that reducing the amount of support needed by the government for the programme could be a very effective way of ensuring the long-term sustainability of biodiversity stewardship programmes. This could be done by enhancing the skills of landowners, staff and local community members which could allow for conservation activities to be performed without much assistance. This could also further be implemented through the maintenance of social networks between landowners, allowing for sharing of skills and practices between landowners and community members, strengthening the practice of the biodiversity stewardship landowner community without government input. A sustainable biodiversity stewardship programme also needs to have long-term management plans, strategies and procedures (Barendse *et al*., 2016; Gupta *et al*., 2015) and these strategies need to be consistently monitored and evaluated in order to ensure long-term success of the programme (Chapman, 2014). For example, the biodiversity stewardship programme at Rhinoceros Hill Nature Reserve in the Western Cape has become more effective and sustainable through auditing and monitoring biodiversity conservation strategies, resulting in an effective site-specific management plan (van Noie, 2009). It seems as though the success of biodiversity stewardship programmes has mostly been noted by the programmes acquiring more land and expanding and by ensuring a good relationship between government and landowners to ensure conservation of biodiversity in these areas (Cockburn *et al*., 2019; Cockburn *et al*., 2018; Rawat, 2017; SANBI, 2017; Boon *et al.*, 2016; McCann *et al.*, 2015; van Noie, 2009), however there is a lack of research on the benefits in terms of conservation and whether the programmes have shown an improvement in the biodiversity of the conserved areas.

CHAPTER 3 METHODOLOGY

To better understand the potential benefits of Biodiversity Stewardship Programmes in Gauteng, an existing Biodiversity Stewardship Programme referred to as the Klipkraal Biodiversity Stewardship Programme which was established in 2019 was chosen for this study. In order to assess the potential conservation benefits and sustainability of the programme, this study included both qualitative and quantitative data collection. Landcover mapping was performed to create a visual representation of the landcover types found at the site. Field surveys were performed to assess the vegetation species richness and composition of the two farms that form part of the Klipkraal biodiversity stewardship programme and to assess the mammal diversity, distribution and space use across the two farms. Lastly, interviews were performed to determine the perceptions of participating farmers of the ecological and economic benefits and challenges of the Klipkraal biodiversity stewardship programme as well as to determine the perceptions of the project managers from the GDARD in using this biodiversity stewardship programme for conservation purposes.

3.1 Study Site

The study site (Figure 3.1) is made up of two privately owned farms located in a peri-urban area in the southern part of Gauteng, South Africa (26°47’47” S, 28°13’44” E). The farms are functioning commercial cattle farms each with a different owner with one farm offering eco-tourism activities such as hiking and mountain biking, self-catering accommodation and a wedding venue in the Southern areas of the farm. The area is part of SANBI’s grassland programme which ensures economic and development activities in the area are managed to ensure biodiversity is protected in order to contribute to sustainable development in this biome (Stephens, 2014). The study site covers 2 656 hectares of land divided between the two landowners (Seegers and Taylor, 2018). Of the 2 656 hectares, approximately 1 600 hectares are natural vegetation, and the remaining area is cultivated land used for farming maize and soya. The cattle rotate between the natural area of vegetation that are separated by fences as part of a rotational grazing strategy (Seegers, pers. comm.).

Klipkraal has a semi-arid climate with summers that are moderate to hot with a highest average temperature of 29°C in January and an average nighttime temperature of 18°C. The winters are moderate to cold with a lowest average temperature of 19°C in June and an average night-time temperature of 6°C. The average rainfall per year is 29.3 mm with approximately 118 days of rainfall a year. The highest monthly average rainfall is 79 mm in January with the lowest monthly average rainfall being 0 mm in July. The wind speeds average around 6–11 km/h throughout the year (Best Time to Visit, 2020). The vegetation types found on the site are Andesite Mountain Bushveld connecting to Soweto Highveld Grassland (Mucina *et al*., 2006). The Andesite Mountain Bushveld is characterised by hill slopes and valleys with undulating landscapes and medium to tall, dense, thorny bushveld covering the sandy planes. Catenas support tall *Terminalia sericea* and *Burkea africana* woodland on more deep and sandy soils and broad-leaf *Combretum* woodland on shallow rocky soils. *Vachellia, Ziziphus* and *Euclea* species are found on the flat slopes with eutrophic sands (Mucina *et al*., 2014; chapter 8). The Soweto Highveld Grassland is known for its gentle to moderately undulating landscapes and it is predominantly covered by medium to high, tufted, dense grassland. *Themeda trianda* is the dominating species in this area with a variety of other grasses, including *Eragrostis racemose*, *Elionurus muticus, Tristachya leucothrix* and *Heteropogen contortus* (Mucina *et al*., 2014; chapter 7).

The site has been declared a protected environment (PE) called the Klipkraal Protected Area (Seegers and Taylor, 2018) using the Biodiversity Stewardship Mechanism in October 2019. The area falls within an identified “green corridor” between the Vaal Dam and the Suikerbosrand Nature Reserve. This means that the landowners and the government are in a partnership to protect the biodiversity and resources found in this area. The study area has been identified to have potential protected area expansions to the north and northeast of the site (Seegers pers. comm.).

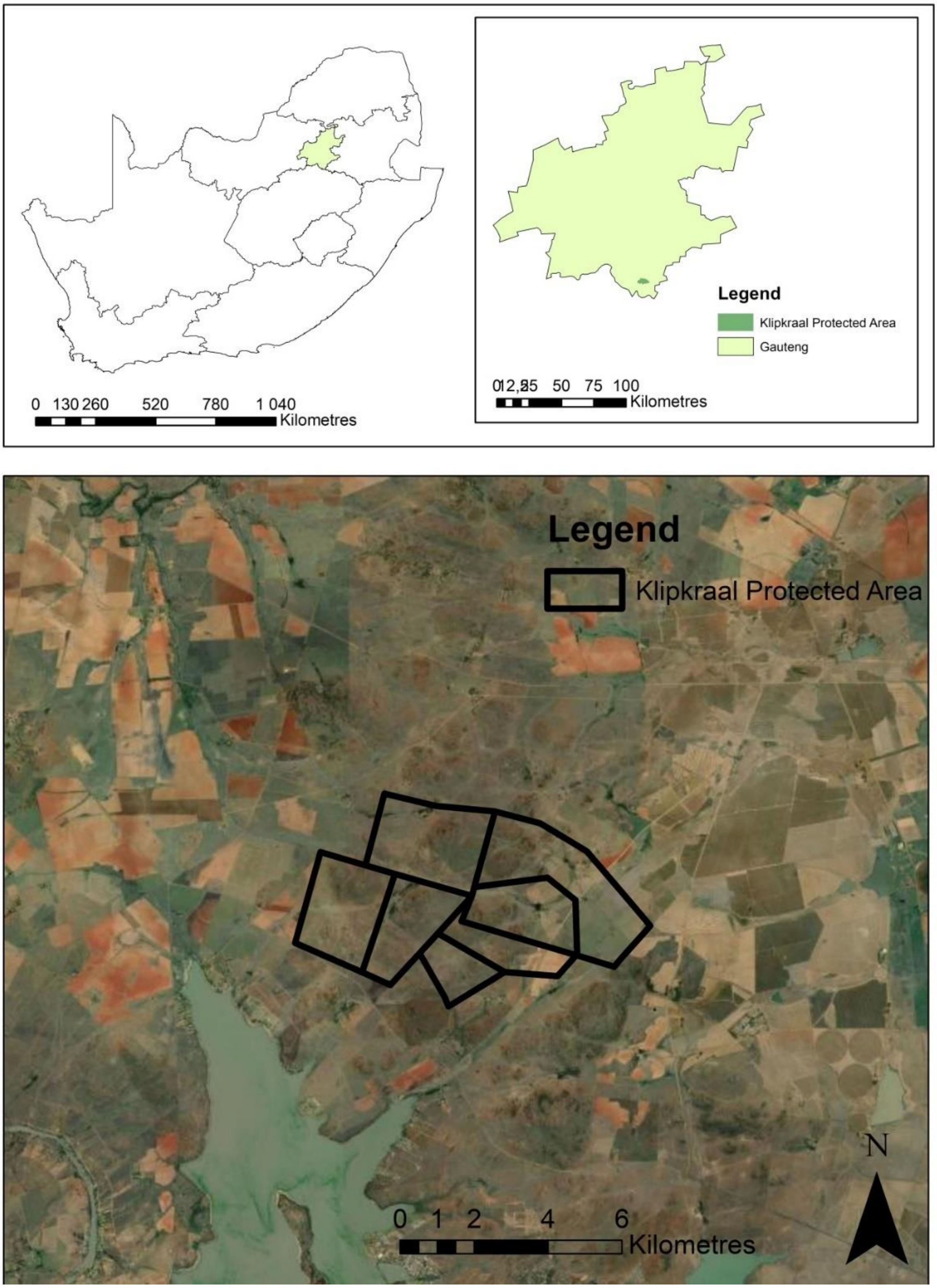

Figure 3.1: Klipkraal Protected Area consisting of two farms that have been divided into seven different regions separated by fences with the Vaal Dam shown to the southwest of the protected area.

3.2 Data Collection

3.2.1 Landcover Mapping

In collaboration with another student from the University of the Witwatersrand (Riley, 2020), field sampling was performed in September 2020 to classify the vegetation types of the Klipkraal area and a landcover map was created using the field analysis and remote sensing data in ArcGIS. The field sampling involved the ground-truthing of the Klipkraal area to observe the different landcover and vegetation types that occurred on site, and to collect a geospatial reference (GPS co-ordinate) which was later used to create the landcover map of the study area. This allowed for the landcover map to be created using real features and vegetation types observed on the ground. Six different landcover types were observed during ground truthing, namely grassland, bushveld/thicket, rocky outcrop, agriculture, water and man-made/artificial surfaces (see table 3.1 for detailed description) and twenty locations for each landcover type were geo-referenced and uploaded to ArcMap which meant 120 training points were used in total which is suitable for the size of the site (Bailey *et al* ., 2015).

Table 3.1: A description of each of the six landcover types identified through ground truthing.

Landcover Type	Description
Grassland	Areas containing mostly natural grass and herbaceous plants, with less than 10% tree and shrub cover, for example, open and managed grasslands.
Bushveld/Thicket	Areas dominated by wooded areas, trees and dense vegetation (including high densities of herbs and shrubs), for example, *Vachellia* and wattle patches and woodlands.
Rocky Outcrop	Landcover with visible bedrock or rock deposits, for example, rocky ridges and hilltops.
Agriculture	Cultivated land mainly used for agricultural purposes and food production, for example, crops, pastures and fallow land.
Water	Water bodies inland, for example, dams, reservoirs, and rivers.
Manmade/artificial	Includes any man-made infrastructure or built-up areas, for example, roads and buildings.

Arcmap 10.5.1 was used to create the vegetation map by uploading the geo-referenced coordinates with their associated different landcover types into the program. The maps were then created by downloading a SENTINEL-2A dataset which is a remotely sensed image for landcover classification that has a fine spatial resolution of 10m which was needed to classify the different areas of Klipkraal into the landcover types. The classification was done by using all 120 geo-spatial coordinates which were classified into the six landcover types and were used as training samples to classify the sentinel image using the Maximum Likelihood Method. This method uses pixels in the sentinel image with unknown classifications and classifies the pixels into one of the six landcover types using the training samples identified in the field surveys with highest likelihood, according to Bayes Theorem (Joyce, 2003). The result is a thematic map of the area where all the landcover types with the same spectral features are grouped together. An accuracy assessment was performed as part of the study by Riley, 2020. The overall accuracy was determined to be approximately 76% which suggested limited errors in the classified landcover map.

3.2.2 Vegetation assessment

Different areas of vegetation were identified using Google Earth (2015) throughout the entire study area (for example, open grassland, bushveld/thicket or rocky ridge). Once on site, using the mapped-out vegetation types, sampling sites were chosen according to accessibility and to ensure that each of the sites were spread out throughout the study site and each located in a different vegetation type from the other sites. The GPS co-ordinates of the five sample sites were recorded (Figure 3.2).

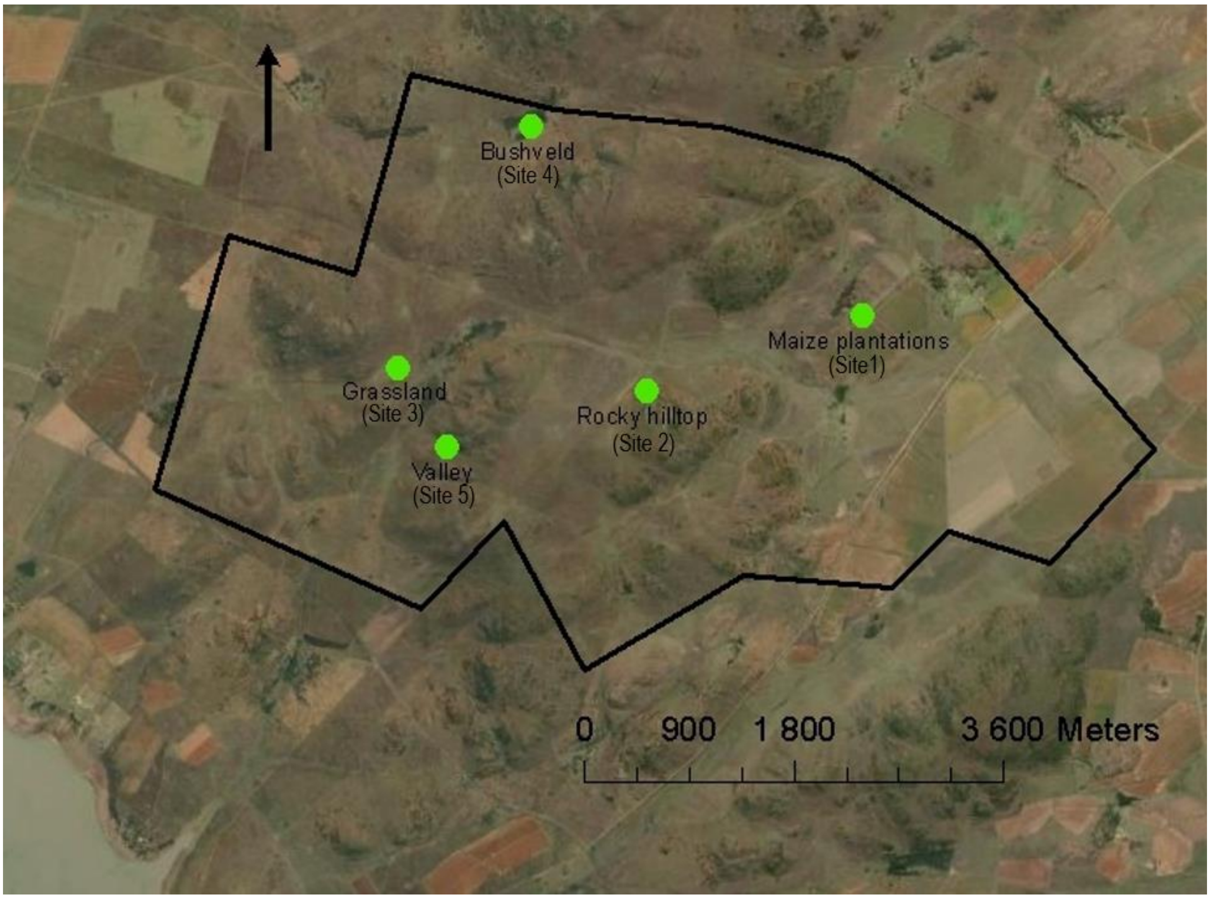

Figure 3.2: The five sampling locations chosen based on habitat type for the vegetation and small mammal assessment.

Table 3.2: A description of each of the five sampling sites used for the vegetation and small mammal assessment.

Study Site	Description
1	Maize Plantation: situated in a grassy area between a dirt road and a maize plantation
2	Rocky hilltop: situated on the side of a rocky hilltop
3	Grassland: situated in an open grassland area
4	Bushveld: situated in a bushy/thicket area along the side of a cattle kraal
5	Valley: situated in a valley characterised with grasses and scattered trees

The GPS co-ordinate was used as a centre point of the sample site. A grid consisting of 12 quadrats (6 squares by 2 squares) was overlayed onto the site map and a random number generator was used to select three sampling quadrats. This was done to ensure that the quadrats were randomly chosen. The theoretical grid in the notepad translated to 192 m² (48 m x 8 m) on the ground as per Bredenkamp and Theron (1978), cited in Grobler (2006). The three randomly selected quadrats were measured out using a tape measure to ensure that each quadrat represented the three theoretical quadrats randomly chosen and covered 16 m² (4 m x 4 m) as per Bredenkamp and Theron (1978) within the 192 m² theoretical study site (Waugh, 2000). This was repeated at each study site and resulted in three randomly selected sample quadrats per identified vegetation type, allowing for comparisons to be made between the five different vegetation types identified.

On site, the vegetation cover type (types included trees and shrubs, grasses, herbs, bare ground and exotic species), species composition and richness were assessed in each of the sample quadrats. Sampling was done during February 2021 in summer when the vegetation was flowering and seeding to assist with species identification. The Domin Scale (Shimwell, 1971) was used to assess percentage vegetation cover in each sample quadrat (see Table 3.3). Percentage cover was estimated for each quadrat according to the amount of area covered with vegetation compared to bare ground. Each quadrat was then assigned a Domin value for overall percentage vegetation cover. The Domin scale was also used to estimate the percentage cover of individual species within each quadrat. Each species within the quadrat was assigned a Domin value by estimating the cover of the species in the quadrat. This was done by dividing the 16 m² quadrat into 16 squares of 1 metre by 1 metre. Each square therefore represented 6.25 percent of the quadrat and this was used as a basis for estimating the species coverage. For example, if a species took up the area of approximately three squares, the area covered was approximately 18 percent and the species would be allocated a Domin score of 5 as per Table 3.3. This was repeated for every quadrat. The individual species were identified using various field guides (Field Guide to the Wild Flowers of the Highveld: *Also Useful in Adjacent Grassland and Bushveld*, van Wyk and Malan, 1997; Field Guide to the Wild Flowers of South Africa, Manning, 2013; Field Guide to the Trees of South Africa; van Wyk, 2013, and First Field Guide to Succulents of Southern Africa, Manning, 2011). Any species that could not be identified were photographed and details of the species including colours, smell, textures etc. were noted for later identification at the University of the Witwatersrand's CE Moss Herbarium.

Table 3.3: Domin Scale (Shimwell, 1971) values used to estimate vegetation cover in each of the 16m² quadrats.

Domin value	Cover-abundance
10	91-100%
9	76-90%
8	51-75%
7	34-50%
6	26-33%
5	11-25%
4	4-10%
3	<4% frequent
2	<4% occasional
1	<4% rare

The abundance and percentage coverage of each vegetation type found within each quadrat were calculated from the species identification performed for each quadrat. An average of percentage vegetation ground cover and structure was then determined across the three quadrats for each of the sites.

Species composition was determined for each site to show the percentage cover of a specific species relative to other species in the study site, using the data obtained from the Domin scale and using the equation (Launchbaugh, 2009):

$$\%\ Composition\ Spp\ A = (\%\ cov.\ of\ Spp\ A / \sum cov.\ for\ all\ species) \times 100$$

Where Spp A refers to the first species within a site and cov refers to the coverage as calculated above from Table 3.2.

Using this calculation for each species within a site, the overall average species composition of the site was calculated. A species area curve was created by plotting the number of species against the sampled area (size) to determine relationship between the number of species and size of the habitat. Species diversity was determined for each sample quadrat using the Shannon-Wiener diversity index (*H*) (Dingaan and Preez, 2017):

$$H = -\sum P_i(\ln P_i),$$

where Pi is the proportion of the species in the sample. Species evenness (*J*) within the sample quadrats was determined using Shannon's equitability (Jha *et al*., 2010):

$$J = H/H_{\max} = H/\ln S,$$

where H is the species diversity and S is the total number of species.

Additionally, any anthropogenic disturbances within a radius of approximately 40 meters of each of the five study sites were recorded. The different types of disturbances at the sites included: physical barriers (e.g., walls, fences and roads), low-to-medium impact human activities (e.g., walking and cycling) and high impact human activities (e.g., clearing of ground for kraals and farming). From the centre point of the site, transect walks were done for 20 metres north, east, west and south in order to identify any disturbances within the vicinity of the study site. Each type of anthropogenic disturbance was noted, and each site was then allocated a disturbance score of between 0 and 4 based on the severity of the disturbance at each site (Table 3.4).

Table 3.4: Disturbance rating scale used to determine the extent of disturbance at each samples site, adapted from the Department of Water Affairs and Forestry's (DWAF) River Health Programme site characterisation field-manual and field-data sheets (Dallas 2005).

Score	**Description**
0	No observable disturbance within vicinity of site
1	Limited or very low indication of disturbance withing vicinity of site; disturbance limited to physical barriers
2	Land-use present; indication of low to medium impact human activities
3	Land-use widespread, small areas unaffected; indication of high impact human activities

Data analysis

The data gathered were analysed in Statistica Version 14.0.0.15 (© Statsoft 2023). The percentage cover of each vegetation growth forms (grasses, herbs and trees and shrubs), bare ground percentage and percentage coverage by exotic species were arcsine transformed and compared between the five sites using a general linear model (GLM) and a Fisher's exact post hoc test (as the data were found to be normally distributed). The site and the vegetation structure type, exotic species or bare ground were chosen as independent variables and the percentage coverage was chosen as the dependant variable. Additionally, as per Diserud and Ødegaard (2007), a multiple - site similarity measure was performed to determine the similarity between the five sites in terms of plant species richness. Exotic plant species richness was also expressed as a percentage of the total species richness for each site to confirm differences between the sites. For all statistical analyses, the significance level was set at $p<0.05$. Descriptive stats were performed on the Shannon Weiner indices and species evenness for each site in order to compare the difference in diversity and evenness at each site.

3.2.3 Small Mammal Trapping

Sixteen standard steel Sherman live traps (26cm x 8cm x 8cm) were set up in two parallel lines approximately 10 metres apart within the five chosen habitat types. Each line consisted of 8 traps, approximately 8 to 10 metres apart. The traps were set up for five trap nights at a time at each of the five different habitat types concurrently to determine small mammal diversity (as per Steele *et al*., 1984; Avenant and Cavallini, 2007).

Three trapping periods occurred, one in summer, one in autumn and one in winter. During the trapping periods, wooden boards as well as vegetation from the surrounding areas was placed on top and around the sides of the traps to protect the animals from the sun, the cold at night and rain. Additionally, cotton wool and a piece of cloth were placed in the traps for nesting. Bait consisting of a mixture of peanut butter, salt, sunflower seeds and sunflower oil was placed within each of the live Sherman traps (as per Lancaster and Pillay, 2010). The traps were checked for any captures early every morning and every late afternoon. If a small mammal was captured, it was carefully placed in a large, clear zip-lock bag so that the length of the animal and its tail could be measured for identification purposes. The animal was also weighed and was photographed for later identification using a field guide (Smithers Mammals of Southern Africa (Smithers, 2012)). The site and trap number were recorded. The animal was then carefully released, and the trap was reset after clearing out any leftover bait and nesting material as well rinsing the trap with some water. The bait and the cotton wool and cloth piece were replaced as well as the boards and vegetation. Animal ethics clearance was obtained from the Animal Research Ethics Committee before any of the mammal trapping went ahead (AREC number: 2020/07/02/B).

3.2.4 Camera Traps

To record the presence of medium to large mammal species on site, 6 unbaited camera traps (Bushnell Trophy Cam HD) were set up in similar areas to the vegetation sampling sites as well as a few additional areas that had the same vegetation type as the five vegetation sites (identified on the landscape maps) throughout the study site for approximately 30 days at a time (as per Goad *et al*., 2014) in an area that is likely to be passed by animals, for example, on wildlife trails and riparian crossings (Figure 3.3).

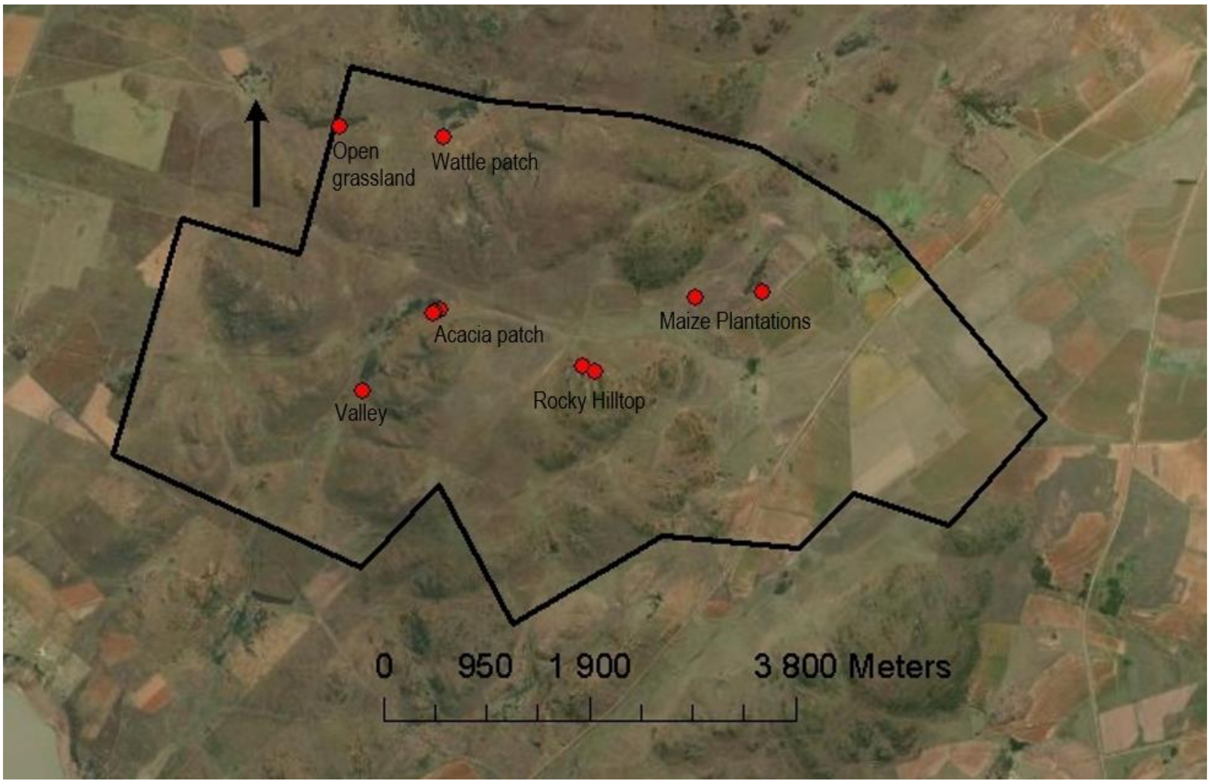

Figure 3.3: The sampling locations chosen based on vegetation type for the camera traps.

The farms have varying levels of human activity (including hiking, maintenance, agricultural activities and cycling) and there was a risk that the camera traps could be tampered with or taken. Therefore, the camera traps were set up in concealed locations where possible to reduce the likelihood of them being stolen. The cameras were checked regularly to ensure they were still recording and to replace the batteries and clear the memory cards when needed. If the photographs showed that the cameras were not in the most suitable position, the cameras were moved to a new area within the habitat type for another 30 days. The cameras were set up during both summer and winter months.

The photographs from the camera traps were downloaded from the memory cards onto a laptop. Each photograph was analysed for the presence of mammals and if found, the mammal species was identified using any distinguishing physical characteristics of the mammal and a field guide (Mammals of Southern Africa, Smithers, 2012). The identified species, location of the camera, habitat type and date were recorded for each photograph. An index of relative activity (RA) was calculated for each vegetation type by dividing the number of photographs taken of each species by the number of days the camera was set up at that site (as per Cutler and Swann, 1999; George and Crooks, 2006). This was used to determine how frequently the various species are using each of the vegetation types (Goad *et al*, 2014). As individuals could not be identified in the images, absolute density could not be calculated, however the relative activity index provides a good indication of relative habitat use by a species for each vegetation type (George and Crooks, 2006). If more than one individual was observed within a single image, the individuals were counted separately. Relative activity was calculated for each habitat type and for each species, as well as across habitat types for all species.

3.2.5 Transect walks

Whilst performing the vegetation assessments as well as checking the mammal traps, approximately 4 transect walks (50m transects) were done at each of the five study sites in Figure 3.2 and from the camera traps in Figure 3.3 in random directions from the site to look for spoor, droppings and scat that provide evidence of medium to large mammals in the area. Additionally, whilst taking walks and driving around the farm during the day, it was possible to identify spoor, droppings and scat in the areas between the sample sites. A photograph of the spoor, droppings or scat was taken, and a ruler was used for scale for later identification using a field guide (Signs of the Wild: a field guide to the spoor and signs of the mammals of southern Africa, Walker, 2015). The GPS coordinates and the habitat type where the signs were found was also noted. Any sightings of mammals were also recorded and photographed where possible for later identification. The GPS coordinates and the vegetation type that the mammal was observed in was also noted.

Data Analyses

The mammal data gathered through camera trapping, live trapping, ground truthing and observation were analysed in Statistica Version 14.0.0.15 (© Statsoft 2023). To assess the differences in small mammal occurrence between the five study sites, a General Linear Model (GLM) with a Fisher's post-hoc tests was performed in which the sites were chosen as independent variables and the species caught was chosen as the dependant variable as the data were found to be normally distributed. A GLM was also run to determine differences in frequency of occurrence between species, with the species caught as the independent variable and the number of captures as the dependent variable. A two-way ANOVA with a Fisher's post-hoc test was used to determine any differences in weight and length of the mammals caught between sampling sites where the site and species were chosen as the independent variables and the weight (grams) and length with and without tail (cm) were chosen as the dependent variables.

In order to assess the difference between sites in terms of the presence of medium to large mammals, a two-way ANOVA with a Fisher's post-hoc test was performed as the data were found to be normally distributed. The number of individuals observed through photographs, sightings and observations of spoor and skat were selected as the dependant variables and the vegetation types and species were selected as the independent variables. A two-way ANOVA with a Fisher's post hoc test was also performed for the relative activity of the medium to large mammals at each of the sites as the data were found to be normally distributed. The relative activity was chosen as the dependant variable and the vegetation type and species were chosen as independent variables. For all statistical analyses, the significance level was set at $p<0.05$. The Shannon Weiner Diversity Index and Evenness calculations were also performed for the medium to large mammals at each of the vegetation types where the mammals occurred. Descriptive statistics were performed on the results to compare the diversity and evenness between the vegetation types.

3.2.6 Interviews with key stakeholders

Interviews were conducted with both of the farm owners and two members of the Gauteng Department of Agriculture and Rural Development (GDARD) that are involved in the Klipkraal biodiversity stewardship programme. Human (non-medical) ethical clearance was obtained from the University of the Witwatersrand before the interviews went ahead (protocol number: H21/07/06). The participants were given an in-depth information sheet explaining the interview process to them as well as the purpose of the interviews. Consent forms were signed by the participants beforehand, giving permission to do the interviews, to audio-record the interviews and to make use of the information provided for future academic purposes.

Thematic coding was performed in order to extract the relevant information from the interviews to be included in the study. The interviews were used to understand the role of the farmers and GDARD in the Biodiversity Stewardship programme, to assess the potential financial and operational benefits or risks of the biodiversity stewardship programme for the farmers as well as the overall benefits for conservation, to understand the challenges involved in implementing the programme for both the farmers and for GDARD and to identify what is needed for the long term success of the Klipkraal Biodiversity Stewardship programme. Additionally, the interviews were also used to determine what GDARD hopes to achieve with this programme and how this programme fits into a larger conservation strategy as well as how GDARD plans on going about expanding the Biodiversity Stewardship Programme to surrounding properties. The complete set of interview questions can be found in Appendix A.

CHAPTER 4: RESULTS

This study included the use of qualitative and quantitative data collection to assess the conservation benefits and sustainability of the Klipkraal biodiversity stewardship programme. Landcover maps were created to show the various landcover types found in the study area. The vegetation species richness and composition and the mammal diversity, distribution and space use across the two farms was assessed in field surveys. Additionally, interviews were held with participating landowners and the project managers from GDARD to understand the benefits and challenges from both perspectives involved with the Klipkraal biodiversity stewardship programme.

4.1 Landcover mapping

The landcover map of the Klipkraal Biodiversity Stewardship area is shown in Figure 4.1. The 2600ha Klipkraal area has been classified into each of the six classification types as described in Table 3.1 in a thematic landscape map. The map provides a baseline idea of the landscape of the conservation area. Table 4.1 shows the sum of the areas classified within each landcover type within the stewardship area.

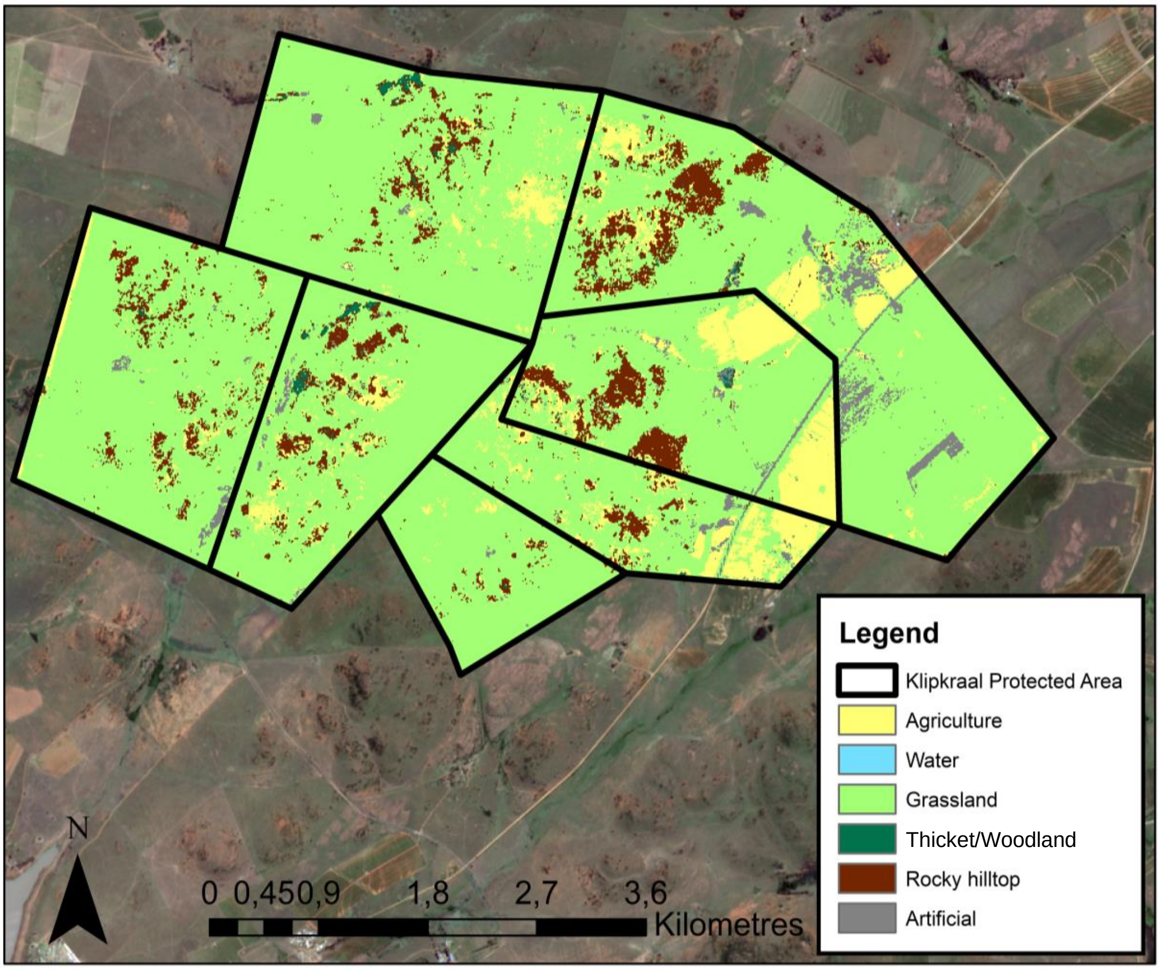

Figure 4.1: The landcover map of the Klipkraal Biodiversity Stewardship site indicating each of the six relevant landcover types (created using ArcMap 10.5.1) (Riley, 2020).

Table 4.1: The total landcover area of each landcover class withing the Klipkraal Biodiversity Stewardship site (created using ArcMap 10.5.1) (Riley, 2020).

Landcover class	Total landcover area (ha)	Percentage of total landcover area (%)
Agriculture	245.13	9.22%
Water	0.25	0.01%
Grassland	21,77.37	81.93%
Thicket/Woodland	9.13	0.34%
Rocky hilltop	166.51	6.27%
Artificial/man-made	59.25	2.23%

4.2 Vegetation Assessment

Each of the five sites where the vegetation assessments were performed varied in vegetation attributes, disturbance and topography. A total of 101 species of plants were recorded across the five sample sites. Of the species samples, 26 species were classified as grasses, 34 species were classified as herbs, 23 species were classified as trees and shrubs and 18 were classified as exotic species, meaning the other 83 species were indigenous. Structurally, the sites did not vary significantly in in the percentage of ground cover of grasses, herbs, trees and shrubs and bare ground (Figure 4.2; $F_{8, 16} = 0.751$, $p = 0.64$) or in the number of species of each vegetation type (herbs, grasses, trees and shrubs and exotic species) ($F_{4, 16} = 1.946$, $p = 0.939$). However, when looking at the entire study site, the grasses percentage coverage was significantly greater than the other ground cover types ($F_{8, 16} = 12.976$, $p < 0.001$). There was also a significant greater number of herb species found at all sites compared to the number of trees and shrubs species ($F_{4, 16} = 160.74$, $p = 0.003$).

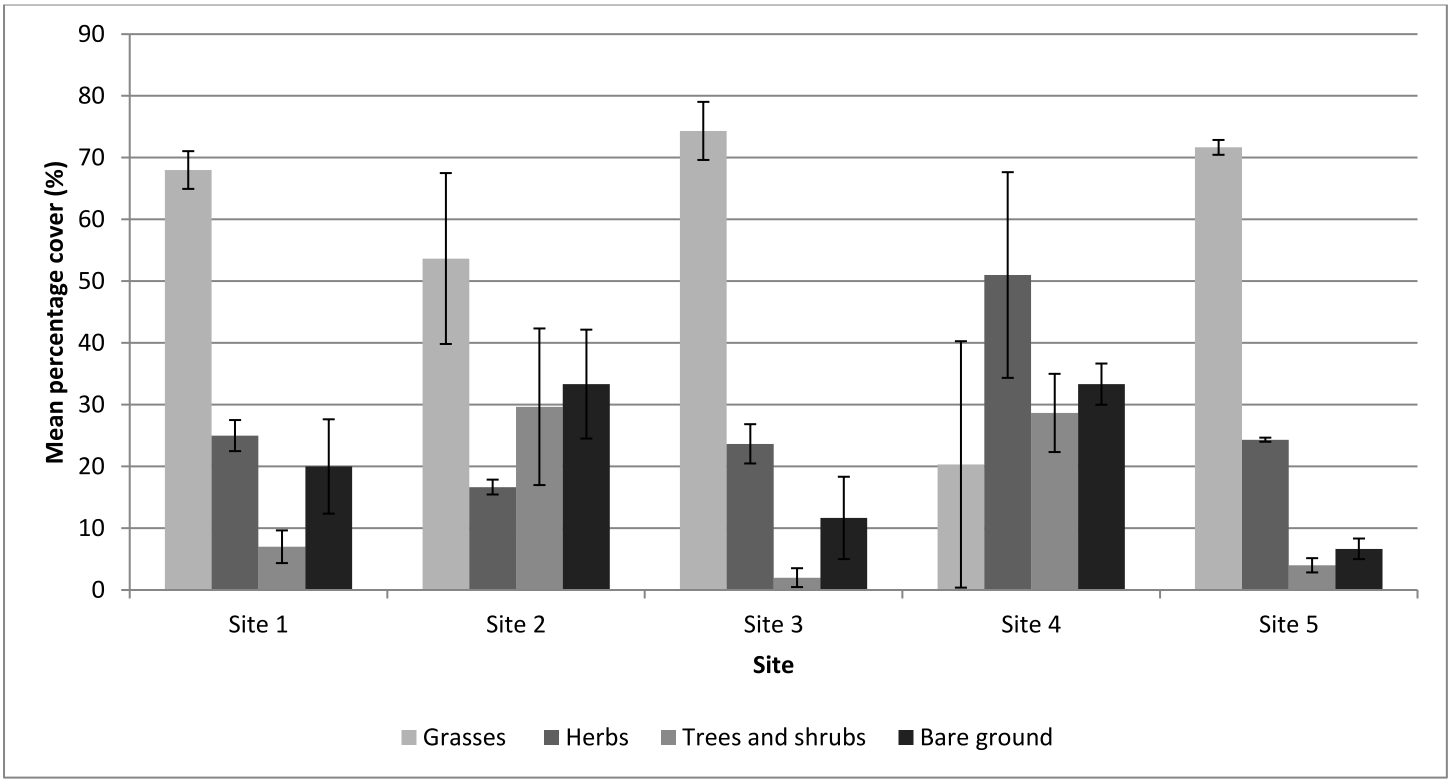

Figure 4.2: Mean (+/-SE) percentage vegetation cover and structure for each site in the study.

A complete list of plant species found at the different sites was recorded for comparison (Appendix B). Each site showed similar totals for species richness with all sites including between 29 and 36 species, and the species diversity index was greatest for sites 2 and 5 and lower but similar for sites 1, 3 and 4 (Table 4.2).

Table 4.2. The species richness and species diversity of each sample site.

Sampling Site	**Exotic species richness**	**Native species richness**	**Total species richness**	**Species Diversity (H)**
Site 1	8	22	30	3.335
Site 2	3	33	36	3.496
Site 3	5	25	30	3.318
Site 4	7	22	29	3.300
Site 5	8	27	35	3.448

Site 4 (bushveld) had a significantly greater percentage of exotic species cover than sites 2, 3 and 5 (Figure 4.3; $p < 0.05$). Sites 1, 4 and 5 had similar percentages of exotic species richness as a percentage of total species richness with 26.67%, 24.14% and 22.86% respectively. Southern cone marigold (*Tagetes minuta*) was the most widespread exotic species, found in three of the five sites. In addition, exotic species that had the greatest coverage across all five sites included Khaki weed (*Alternanthera pungens*), cobblers pegs (*Bidens pilosa*), yellow nutsedge (*Cyperus esculentus*) and Kikuyu grass (*Pennisetum clandestinum*). Site 1 had a high density of cobblers pegs (*Bidens pilosa*), yellow nutsedge (*Cyperus esculentus*) and Kikuyu grass (*Pennisetum clandestinum*). Site 4 had a high density of Khaki weed (*Alternanthera pungens*) (see Appendix B). Additionally, in the northern part of Klipkraal, the black wattle (*Vachellia mearnsii*) was dominant along a small stream that passes through the farm. The bankrupt bush or slangbos (*stoebe vulgaris*), although indigenous to South Africa, was declared an indicator of bush encroachment in every South African province by the Minister of Agriculture in 2019 (SANBI, 2019) and was found at site 1, however whilst driving and walking around the study area, the bankrupt bush was prominent in many open areas.

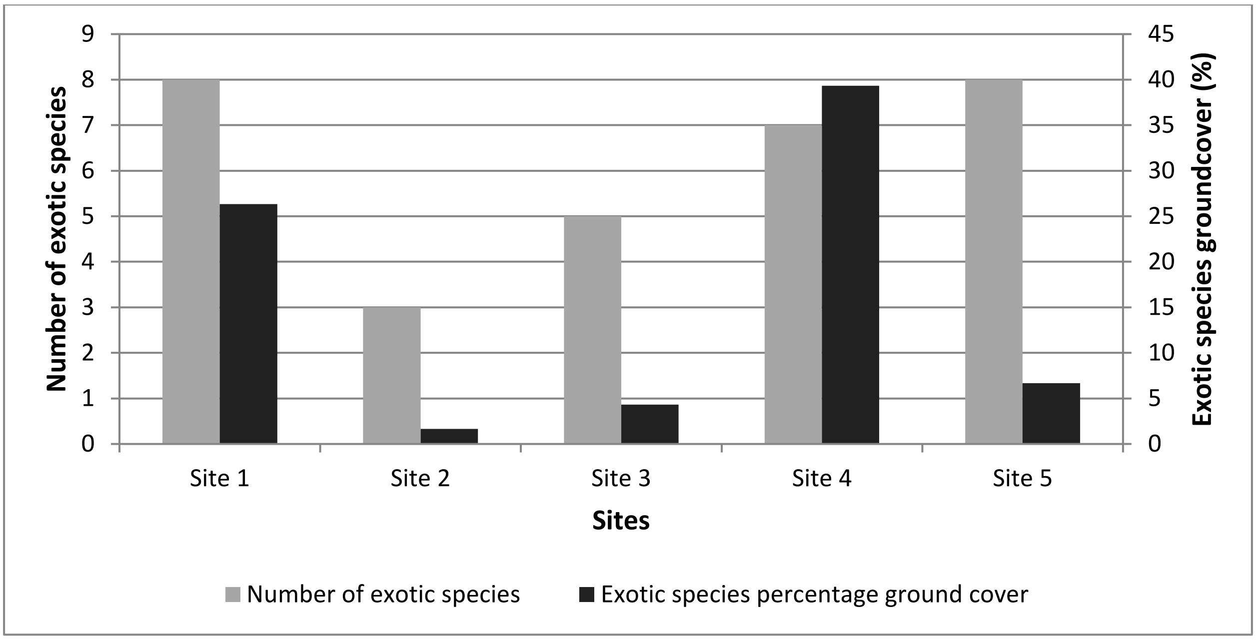

Figure 4.3: Number of exotic species and exotic species ground cover for each site in the study.

Table 4.3 shows the plant species overlap between the five sites, however there was not a single species that occurred at all five sites. The results of the multiple-site similarity index showed that the species composition was similar between the five sites (Cs= 0.609).

Table 4.3. The number of plant species that overlapped between sites.

	Site 1	Site 2	Site 3	Site 4	Site 5
Site 1		7	10	4	5
Site 2	7		4	6	8
Site 3	10	4		10	14
Site 4	4	6	10		10
Site 5	5	8	14	10	

Based on the applied anthropogenic disturbance rating (Figure 4.4), site 1 and site 4 had the highest levels of anthropogenic disturbance, each with a score of 3. The disturbances found within a 20-metre radius of site 1 included a dirt road, a fence and the clearing of vegetation for a maize plantation. The disturbances found within 20 metres of site 4 included a fence, a dirt road, the clearing of vegetation for a cattle kraal and infrastructure (including bricked area, metal poles etc.) associated with the cattle kraal. Site 3 was allocated a score of 2 indicating sporadic or dispersed disturbance as there was a fence and hiking trail within 20 metres of the site. Sites 2 and 5 had the lowest levels of anthropogenic disturbance, each with a score of 1. Site 2 had a hiking trail within 20 metres of the site and site 5 had a dirt road within 20 metres of the site. All five sites had evidence of livestock grazing either through observation of livestock grazing or the presence of dung.

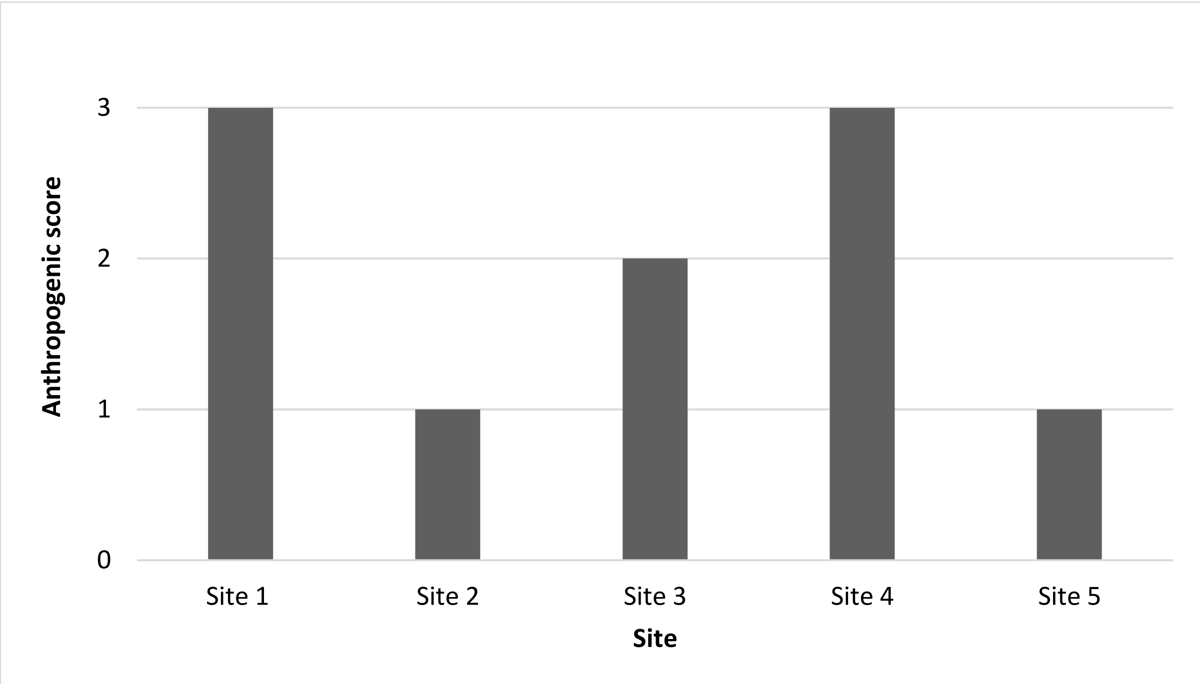

Figure 4.4: The anthropogenic disturbance score allocated to each sampling site.

4.3 Small Mammal Trapping

The small mammal live trapping assessment resulted in the capture of five different species over three sampling sessions, each consisting of 5 trap nights. There were no significant differences between the species trapped during the three different sampling periods, thus data for the three sessions were pooled for further analysis. The most commonly caught and widely distributed species was the Multimammate mouse (*Mastomys coucha*) which was captured at all 5 sites. The African striped mouse (*Rhabdomys pumilio*) and the Highveld gerbil (*Gerbilliscus brantsi*) were both captured at four of the five sites. The Namaqua rock rat (*Aethomys namaquensis*) and the Rock elephant shrew (*Elephantulus myurus*) were both only captured at sites 2 and 4 during the sampling periods (Table 4.4).

The frequency of small mammals caught differed significantly between species ($F_{4, 332}$ = 14.9, $p <0.0001$). At all five sites, the Multimammate mouse (*Mastomys coucha*) was caught significantly more often than the African striped mouse (*Rhabdomys pumilio*), Namaqua rock rat (*Aethomys namaquensis*) and the Rock elephant shrew (*Elephantulus myurus*) ($p < 0.05$). The African striped mouse (*Rhabdomys pumilio*) and the Highveld gerbil (*Gerbilliscus brantsi*) were both caught significantly more often than the Namaqua rock rat (*Aethomys namaquensis*) and the rock elephant shrew (*Elephantulus myurus*) ($p < 0.01$).

There was a significant difference between the weight and length of the mammals caught at the five sampling sites ($F_{4, 320}$ = 36.17, $p < 0.001$) (Table 4.5). For the African striped mouse, the individuals caught at site 5 were significantly greater in mass than at all three other sites where the species was trapped (sites 1, 3 and 4) ($p < 0.05$). There was no significant difference between the length of the individuals caught at the different sites. For the highveld gerbil, the individuals trapped at site 2 were significantly greater in mass than the ones trapped at site 3 and 5 ($p < 0.05$). The individuals caught at site 3 were significantly shorter in length than the other three sites where the species was trapped (sites 2, 4 and 5) ($p< 0.05$). For the multi-mammate mouse, the individuals caught at site 2 were significantly greater in mass than at all four other sites ($p < 0.001$). The individuals caught at site 5 were significantly greater in mass than at site 1 and site 3 ($p < 0.001$). Additionally, the individuals trapped at site 2 were significantly longer in length than at all four other sites ($p < 0.001$) and the individuals trapped at site 5 were also significantly longer in length than the individuals trapped at sites 1 and 3 ($p < 0.01$). For the Namaqua rock rats and the rock elephant shrews, there were no significant differences between sites in terms of the mass or the length of the individuals trapped. The average weight of the small mammals trapped was significantly lower in the June trapping period (43.25 g) than in the February trapping period (54.33 g) and the April trapping period (50.78 g) ($F_{8, 297}$ = 181.05, $p < 0.001$).

Table 4.4: The presence of each small mammal at the five sites during the summer trapping period.

Trapping Session	Site	African striped mouse	Highveld gerbil	Multi-mammate mouse	Namaqua rock rat	Rock elephant shrew
Summer	1	x		x		
	2		x	x	x	x
	3	x		x		
	4					
	5	x		x	x	
Autumn	1	x		x		
	2		x	x	x	x
	3	x	x	x		
	4			x		
	5		x	x	x	x
Winter	1	x		x		
	2		x	x	x	x
	3	x	x	x		
	4	x	x	x		
	5		x	x	x	

Table 4.5: The average weights and lengths (± SD) of the difference mammal species trapped at each of the five sites.

Species	Measurement	Site 1	Site 2	Site 3	Site 4	Site 5
African striped mouse	Average Weight (g)	45.23 ± 12.20	---	42.41 ± 9.29	38.33 ± 7.63	60.71 ± 13.67
	Average Length (cm)	15.23 ± 2.22	---	16.32 ± 2.73	15.33 ± 1.53	16.71 ± 2.12
Highveld gerbil	Average Weight (g)	---	69.29 ± 4.50	43.33 ± 14.38	55.00 ± 7.07	47.00 ± 17.18
	Average Length (cm)	---	24.00 ± 1.73	16.33 ± 2.73	21.75 ± 0.95	24.00 ± 5.96
Multi-mammate mouse	Average Weight (g)	41.32 ± 17.16	61.30 ± 15.42	42.27 ± 13.73	41.60 ± 10.68	48.09 ± 14.51
	Average Length (cm)	15.86 ± 2.89	22.63 ± 4.09	16.55 ± 3.18	17.16 ± 3.87	18.56 ± 4.65
Namaqua rock rat	Average Weight (g)	---	67.31 ± 14.67	---	---	56.25 ± 8.76
	Average Length (cm)	---	23.62 ± 3.12	---	---	22.88 ± 2.36
Rock elephant shrew	Average Weight (g)	---	80.00 ± 15.09	---	---	62.50 ± 24.75
	Average Length (cm)	---	22.10 ± 3.00	---	---	18.50 ± 2.12

4.4 Large Mammal Assessment – Camera Traps and Transect Walks

A total of 21 medium to large mammal species were recorded by either camera traps, sightings or through observations of spoor and skat (Table 4.6). The camera traps were set out for a total of 235 nights and a total of 145 photographs were taken of individual species. A total of 58 animal sightings were recorded and a total of 60 observations of animal spoor and skat were recorded. The open grassland habitat had the greatest species richness with 15 different species recorded, while the valley with scattered trees and grasses had the lowest species richness with a total of 5 species recorded. Black-backed jackal (*Canis mesomelas*), common duiker (*Sylvicapra grimmia*) and steenbok (*Raphicerus campestris*) were the most wide-spread species and were recorded in every vegetation type.

The total number of individual species observed at each vegetation type through camera traps, sightings and spoor and skat observations was significantly different between the different vegetation sites ($F_{4, 88} = 3.86$; $p = 0.006$). The bushveld habitat type had significantly greater individual species presence than the valley ($p = 0.037$) and the open grassland had significantly greater individual species presence than the valley ($p < 0.001$) and the rocky hillside ($p = 0.005$). Additionally, the bushveld and the grassland habitats both had the highest species diversity with species diversity scores of 2.227 and 2.247 respectively as well as evenness scores of 0.896 and 0.876 respectively. The maize field, rocky hillside and valley have diversity scores of 1.927, 1.781 and 1.079 respectively and evenness scores of 0.776, 0.857 and 0.982 respectively.

Table 4.6: The presence of medium to large mammals found in the different vegetation types.

Common name	Scientific name	Maize field	Open grassland	Bushveld	Rocky hilltop	Valley with scattered trees and grasses
Aardvark	*Orycteropus afer*	x		x		
Black-backed Jackal	*Canis mesomelas*	x	x	x	x	x
Blesbok	*Damaliscus dorcas phillipsi*		x			
Blue wildebeest	*Connochaetes taurinus*		x			
Burchell's zebra	*Equus burchellii*				x	
Caracal	*Felis caracal*			x		
Common duiker	*Sylvicapra grimmia*	x	x	x	x	x
Greater kudu	*Tragelaphus strepsiceros*		x	x		
Grey rhebok	*Pelea capreolus*	x	x			x
Ground squirrel	*Xerus inauris*	x	x			x
Leopard	*Panthera pardus*	x				
Porcupine	*Hystrix africaeaustralis*	x	x	x		
Scrub hare	*Lepus saxatilis*		x	x	x	
Serval	*Leptailurus serval*	x	x			
Slender mongoose	*Galerella sanguinea*		x	x		
Small spotted genet	*Genetta genetta*	x			x	
Springbok	*Antidorcas marsupialis*	x	x	x		
Steenbok	*Raphicerus campestris*	x	x	x	x	x
Striped polecat	*Ictonyx striatus*	x				
Suricate	*Suricata suricatta*		x	x		
Yellow mongoose	*Cynictis penicillata*	x	x			
Total		**13**	**15**	**11**	**6**	**5**

The relative activity was found to be significantly different between sites and species ($F_{1, 55} = 14.64$; $p < 0.001$). The valley had a significantly lower relative activity compared to the maize field ($p = 0.04$) and the porcupine (*Hystrix africaeaustralis*) had a significantly higher relative activity compared to the caracal (*Felis caracal*), the greater kudu (*Tragelaphus strepsiceros*), the grey rhebok (*Pelea capreolus*), the small spotted genet (*Genetta genetta*), the springbok (*Antidorcas marsupialis*), the striped polecat (*Ictonyx striatus*) and the suricate (*Suricata suricatta*) ($p < 0.05$) (Table 4.7).

Table 4.7: The relative activity of each mammal caught by camera trap in each habitat type.

Common name	Scientific name	*Vachellia* patch	Open grassland	Wattle patch	Maize field	Rocky hilltop	Valley	Total
Black-backed Jackal	*Canis mesomelas*	0.030	0.043	0.009	0.026	0.004	0.000	**0.111**
Caracal	*Felis caracal*	0.009	0.000	0.000	0.000	0.000	0.000	**0.009**
Common duiker	*Sylvicapra grimmia*	0.060	0.004	0.009	0.017	0.030	0.000	**0.119**
Greater kudu	*Tragelaphus strepsiceros*	0.013	0.000	0.000	0.000	0.000	0.000	**0.013**
Grey rhebok	*Pelea capreolus*	0.000	0.000	0.000	0.017	0.000	0.004	**0.021**
Porcupine	*Hystrix africaeaustralis*	0.013	0.026	0.004	0.119	0.000	0.000	**0.162**
Scrub hare	*Lepus saxatilis*	0.017	0.098	0.000	0.000	0.000	0.000	**0.115**
Small spotted genet	*Genetta genetta*	0.000	0.000	0.000	0.000	0.009	0.000	**0.009**
Springbok	*Antidorcas marsupialis*	0.009	0.000	0.000	0.000	0.000	0.000	**0.009**
Steenbok	*Raphicerus campestris*	0.009	0.004	0.000	0.017	0.004	0.004	**0.038**
Striped polecat	*Ictonyx striatus*	0.000	0.000	0.000	0.009	0.000	0.000	**0.009**
Suricate	*Suricata suricatta*	0.004	0.000	0.000	0.000	0.000	0.000	**0.004**
Total		**0.162**	**0.174**	**0.021**	**0.204**	**0.047**	**0.009**	**0.617**

4.5 Interview Results

Interviews were held with both the landowners as well as two members of GDARD involved in the Klipkraal Biodiversity Stewardship programme (see Appendix C for the questions asked to both parties). In order to ensure the interviewees remained anonymous, they will be referred to as landowner 1, landowner 2, GDARD member 1 and GDARD member 2.

From the questions asked, it was established that GDARD provides guidance to the landowners, including technical support and expertise with regards to protected area management. The landowners are involved in the protected area management and are guided by GDARD to ensure the biodiversity of their farms is protected. Landowner 1 explained that the goal for them is to ensure the natural areas of the farm remain protected from agricultural activities. They explained that the Biodiversity Stewardship Program has taught them a lot in terms of conservation from a specialist perspective. For example, a specialist studied the landowners' cattle grazing rotation and, by learning how to correctly formulate a grazing rotation plan for the cattle based on the studies performed as part of the biodiversity stewardship programme, the landowner has seen many benefits in the conditions of the grass which has in turn allowed him to keep more cattle, resulting in indirect financial benefits. The landowners are involved with the programme as they both have a passion for the environment and conservation. They both want to understand how best to continue with their tourism and farming practices whilst ensuring the natural areas of their land are protected and that little to no harm is being inflicted on the area's wildlife. Landowner 1 believes that the Klipkraal Biodiversity Stewardship Programme will help them learn how to maintain this balance and they hope that their involvement in the programme will inspire other landowners to get involved in biodiversity and conservation programmes. They also would like to pass down their land to future generations in the best condition possible to ensure its sustainability.

All four interviewees identified the management of the bankrupt bush (*Stoebe vulgaris*) encroachment as the most severe problem currently being encountered on the two properties. The bankrupt bush is widespread throughout the two properties and is unpalatable to the cattle, which therefore reduces the areas suitable for grazing. GDARD assists the landowners in invasive species management by providing them with herbicides and other resources for reducing alien invasive species through the National Department of Environmental Affairs. Landowner 1 also explained that a project was being implemented in which the black wattles (*Vachellia mearnsii*) are to be removed by employing people from the local community and educating them on how to effectively remove the black wattle. However, this project has not been implemented yet. Although GDARD does provide assistance for alien invasive species removal, the landowners have had to invest a lot of money and resources into herbicides and removal of invasive species as the Department cannot always supply the resources. Additionally, there is difficulty in obtaining labour for the herbicide application and invasive species management projects which can cause delays in the projects. Currently, the landowners are not receiving any direct financial benefits for being part of the Biodiversity Stewardship Programme.

Landowner 1 believes that GDARD is very committed to the Klipkraal Biodiversity Stewardship Programme and both landowners expressed that GDARD has been very effective in providing information and the latest developments in conservation, such as the most recent effective herbicides, and have also implemented many useful studies. GDARD member 1 explained that the Klipkraal Biodiversity Stewardship Programme has been used as an example of a Biodiversity Stewardship Programme that has been successful, in order to spark the interest of other landowners in other parts of the country. GDARD has asked the Klipkraal landowners to have a conversation with various neighbouring landowners to provide them with more information regarding the programme, as well as what benefits they have seen from the programme. This has allowed for a greater interest from landowners as they feel more comfortable hearing the information directly from a landowner that is already part of the programme, encouraging them to trust GDARD and the intentions of the Biodiversity Stewardship Programmes. GDARD member 2 explained that, once a Biodiversity Stewardship Programme is implemented, a change in landowner behaviour is generally seen, and the landowners tend to manage their land with a greater focus on conservation compared to when landowners are not part of a programme. Since the Biodiversity Stewardship Program began in 2019, benefits for biodiversity have been seen. For example, there has been success in the clearing of the bankrupt bush in some areas on the north side of the farm and landowner 1 has seen an increase in the water levels of the dams after the removal of some black wattles. Additionally, there is an area of the northern part of the farm that has been left with no roads or fences and is not used for grazing that has allowed a safe quiet space for the wild animals. Landowner 1 believes that this has allowed for more wild animals to move into the area. Both landowners stated that they do not see any direct risks in participating in the Biodiversity Stewardship Programme and landowner 1 identified that the only risk the programme poses is a possible security risk, as more people have access to the farm and have more inside information on their farming practices.

Both GDARD members identified several focus areas to ensure the long-term success of the Klipkraal Biodiversity Stewardship Programme and other programmes in Gauteng. These include ensuring that the GDARD units involved in the Biodiversity Stewardship Programme are adequately equipped and resourced to ensure projects can be carried out efficiently and effectively. In terms of Klipkraal specifically, long term solutions and efforts towards tackling the invasive species issues is critical in ensuring the natural biodiversity is protected and maintained in the area. The expansion of the Biodiversity Stewardship Programme is also essential for its sustainability as the programme is more likely to be successful if it involves a larger area and efforts from a greater number of landowners. Additionally, poor land management practices can have negative effects on surrounding areas and therefore, if the surrounding landowners are not focused on conservation, it is possible that the areas in the Biodiversity Stewardship Programme will be negatively affected, and conservation efforts could be wasted. It is important to note that areas of expansion are worthwhile conserving and in order to do this, studies need to be conducted to understand the environment and the biodiversity that occurs at the possible expansion areas as well as the socio-economic factors that affect that area. Landowners also need to be properly educated and upskilled on the conservation practices needed, as the programme heavily relies on landowner input. Therefore, training and education material needs to be readily available to landowners to ensure the success of the conservation efforts.

Both GDARD members further suggested that some sort of incentive is favourable, to firstly attract landowners to participate in the programme, and then ensure they remain invested in the programme. Incentives could include financial incentives, reduction of rates and tax rebates which could incentivise farmers to rather keep the natural areas of their property, instead of transforming it for financial gain, as they are receiving benefits as being part of the programme. Lastly, it is important that the agreement is legally binding to ensure that the property will remain part of the Biodiversity Stewardship Programme once sold or passed down to family members. This will ensure that long-term conservation projects can persist and that the new landowners will still have certain obligations for conservation and ensuring which areas of the farm are to be kept in a natural state.

Landowner 2 was not part of the initial agreement made and the responsibility of the Biodiversity Stewardship Programme was handed over to them after the unfortunate passing of the initial responsible family member in late 2019. From the interview it was observed that the landowner is not very involved in the conservation strategies as part of the Biodiversity Stewardship Programme that are taking place as they were not fully aware of what was occurring at the site in terms of conservation and GDARD has a much larger role in the conservation projects that takes place on landowner 1's portion of Klipkraal than on the other portion.

From a recent update with GDARD member 1, it was established that landowner 2 sold their portion of the farm mid-2023 to the neighbouring cattle farmer directly to the west of Klipkraal. The property is still part of the Biodiversity Stewardship Programme by default because, in order for the new landowner to withdraw from the program, the landowner has to withdraw the notice that was published in the Government Gazette. However, GDARD is still in the process of getting the new landowner to sign a new declaration agreement to appoint them as the management authority. The previous landowner has explained all the benefits to the new landowner and has convinced them to remain a part of the Biodiversity Stewardship Programme. According to GDARD member 1, the new landowner is eager to join, especially because of the benefits seen in terms of invasive species clearing, as grass quality is important to the new landowner as their focus is cattle farming. Also, it is important to GDARD to ensure that they keep this portion of Klipkraal as it includes a very large portion of the natural land percentage of the entire area.

GDARD member 1 explained that the goal is to expand the programme to properties surrounding Klipkraal. GDARD’s latest Conservation Plan is currently in the process of being updated and they have been working with their conservation planner to identify spatial priorities in the province where they should be focusing their protected area expansion efforts. Currently the area to the North and Northwest of Klipkraal have been identified for expansion. Expanding a Biodiversity Stewardship Programme involves identifying the land for expansion and then engaging with the landowner in order to explain the program and ask whether they would like to join, as the stewardship is based on landowner willingness to join. This has not started at Klipkraal yet, but this is in the future plan, although a set timeline of when this will take place has not been given.

GDARD member 1 explained that there are some difficulties in getting landowners to sign up to Biodiversity Stewardship Programmes. These include having difficulties contacting the correct person to engage with once a property has been identified for expansion. Another issue is that the process of beginning a Biodiversity Stewardship Programme can take some time. This was an issue in Cullinan where GDARD intended to declare process and the property was sold. So, unless they can convince the new landowner to agree to the program, all the effort that has been invested there for over two years will be lost if the new landowner does not continue with the stewardship process.

Fragmentation is also an issue. GDARD has had willing landowners, but their properties are very small and isolated, so therefore it does not make sense to put efforts and focus into those properties for expansion. Another issue experienced is that in some areas, for example, there might be 50 landowners for 150 hectares of land, which means all 50 landowners have to be engaged with, and the process ends up taking a lot of effort and resources to secure the land in the programme. Therefore, GDARD will only go through this process if the land is deemed important for conservation. Additionally, there is a chance that some of the landowners will not agree to joining the programme, resulting in a fragmented area for conservation. For example, this is an issue in the Bronberg mountains, east of Pretoria. which has the only population of the Juliana's golden mole (*Neamblysomus julianae*), but the land portions are so small that GDARD would have to engage many landowners to secure 200 hectares of the land, making securing the area under the programme challenging. Small land portions create a big challenge in Gauteng for conservation.

Another challenge is that landowners are usually concerned that they might lose development rights, which they do to a certain extent under the nature reserve category. Landowners are also concerned that GDARD might tell them what to do with their property and how to do it and that is usually the main reason why landowners are hesitant to participate. Additionally, there is also a general lack of distrust in Government, creating scepticism when entering into an agreement with GDARD. Lastly, landowners want to know what benefits they will receive from the programme. This normally involves wanting access to government programs that assist with invasive vegetation clearing and protection against unsustainable and incompatible land uses, like mining for instance.

Landowner 1 also identified a few issues with implementing biodiversity stewardship programmes in South Africa from a landowner perspective. These include that there is a lack of education about conservation in the agricultural space. Farmers do not understand that conservation and farming can go hand in hand and that, by preserving the environment and biodiversity on their land, their farming practices will benefit in the long term. They explained that landowners do not always think about the long-term consequences of neglecting conservation and are normally just focused on farming to produce profits. Again, the landowner believes that there needs to be an incentive for farmers to join the programme, otherwise GDARD will have challenges getting people to sign up. The landowner also suggested that there is a lack of active drive to get more landowners to join the programme. They believe that more effort should be put into engaging with the landowners to encourage them to join the programme by educating them on what exactly it means to be part of a Biodiversity Stewardship Programme and how involved landowners have benefited from being in a programme. Landowner 1 learned about Biodiversity Stewardship Programmes through a phone call with a landowner in Kwa-Zulu Natal who was involved in a Biodiversity Stewardship Programme. Once understanding all the benefits received and what it means to be a part of the program, both landowners decided to sign up to the Klipkraal Biodiversity Stewardship Programme in 2019. Landowner 1 does believe that they would not have joined the programme if they had not heard such positive feedback from other landowners already involved. The landowner does not think that there are many farmers within in the Klipkraal area that are aware of the Biodiversity Stewardship Programme and explained that the Biodiversity Stewardship Programme needs to fit the business model of the landowner. For example, Klipkraal is deemed a protected area but could have been declared a game reserve if there were less than 80 cattle on the property, but since this is not financially viable, the landowner chooses to rather deem the property a protected area. The landowner knew of a farmer in the area that was interested in joining the Klipkraal Biodiversity Stewardship Programme but was hesitant to join as the farmer was not fully sure of his plans with the property, and after a while ended up ploughing the area that was going to be deemed a protected area. Therefore, landowners do not want to fully commit to the programme until they have a clear plan of how they want to utilise the property.

CHAPTER 5: DISCUSSION AND CONCLUSION

There is a lack of research on the conservation benefits of Biodiversity Stewardship Programmes and whether they have shown to improve the biodiversity of the conserved areas. The question remains whether biodiversity stewardship programmes are sustainable, adding value to both biodiversity and the landowners involved. This study assessed the Klipkraal Biodiversity Stewardship Programme located in Gauteng and sought to answer the question: what is the ecological state of the area and does this programme have potential for conservation in the long-term? To do this, this study investigated the biodiversity stewardship programme to determine the ecological state of the area; the biodiversity stewardship programme's potential for conservation, and the programme's sustainability in the long term in terms of the relationship between landowners and GDARD. Using this information, the aim was to determine if the biodiversity stewardship programme does in fact show potential as a suitable method of conservation in agriculture in the long term and to the potential for expansion to surrounding areas.

5.1 The State of the Vegetation of the Klipkraal Biodiversity Stewardship Programme

The landcover map (Figure 4.1) of the Klipkraal Biodiversity Stewardship site provides a baseline for the state of the landcover of the protected area. Figure 4.1 and Table 4.1 clearly show that the study site is dominated by natural vegetation with 81.9% grassland coverage, 6.27% rocky hilltop coverage and 0.34% thicket/woodland coverage. The human-impacted areas make up a much smaller percentage of the Klipkraal area with 9.22% agricultural coverage and 2.23% artificial/man-made structures. These results show that farmlands can comprise of a diverse range of natural habitats, and it is evident that the farmers have managed to ensure a large portion of the land is kept natural. It has been suggested that successful biodiversity conservation in agriculture normally occurs when a high diversity of habitats in the area are kept intact and are left untouched (Harlio *et al*., 2019; Kennedy *et al*., 2013) and areas to be included in biodiversity stewardship programmes are generally areas that have a large portion of land that is kept natural and has a high diversity of plant and wildlife (Barendse *et al.,* 2016). This is consistent with many other studies on biodiversity stewardship programmes in South Africa where the majority of the landowner's land consists of natural land (Boon *et al.,* 2016; McCann *et al.,* 2015; SANBI, 2016; van Noie, 2009).This is also similar to other conservation projects in other parts of the world, for example, in Finland, a 20,000 km^2 conserved area in the Southwest of Finland showed that the majority of the land is being kept natural and only 25% of the area is currently being used for agriculture (Harlio *et al.,* 2019) and in Spain, where a large portion of the landcover in conservation agreements with landowners on olive farms is kept in its natural state (Penker, 2017).

As part of the vegetation field assessment, the vegetation species, structure, cover, composition and species diversity and evenness as well as the level of anthropogenic disturbance of the five study sites were assessed. Each of the five sites where the above-mentioned vegetation assessments were performed varied in vegetation attributes, disturbance and topography. Structurally, the sites did not significantly differ in the percentage of ground cover of grasses, herbs, trees and shrubs and bare ground (Figure 4.2), however this could be attributed to insufficient sampling repeats for the vegetation assessment. The results also suggest, in line with the landcover map, that the area is dominated by grassland with pockets of other landcover types that contain high biodiversity. Areas with greater variations in habitat support a greater number of species as they provide more habitat niches and varying resources for a number of species (Kivinen *et al.,* 2006; Connor *et al.,* 2000). The species composition was fairly similar according to the results of the multiple-site similarity index and the sites showed multiple species overlap (Table 4.3). However, it should be noted that for the thicket/woodlands study site, a larger vegetation sampling site would be beneficial to ensure a better vegetation representation of the woodland area. The effects of human impacts might alter the vegetation composition of an area (Chace and Walsh, 2006). This may suggest that the human disturbance across the five sites was fairly uniform or not significantly different between sites which may explain the similar vegetation composition shown between the sites. Additionally, this could suggest that the grazing rotation plan put in place by GDARD is already showing positive effects on the vegetation of the farms as it is suggested that grazing can affect species composition in areas where grazing is dominated (Nenzhelele *et al.,* 2018). The diverse vegetation units noted as part of the vegetation assessment and the diversity of habitats suggest that the study site is useful in terms of conservation for vegetation and for animals since the site can provide a number of habitats and resources for various animal species.

A total of 101 species of plants were recorded across the five sample sites; 83 of these species were indigenous and 18 were exotic species and of these 18 exotic species, two are considered invasive species (Table 4.2). A good indication of the damage to areas as a result of human impacts is the presence of exotic and invasive species (Johnson and Munshi-South, 2017). Sites 1 (maize plantations) and 4 (bushveld) had the highest percentage of exotic species ground cover as a percentage of total vegetation cover with 26.3% and 39.3% respectively, with the exotic species vegetation cover being significantly higher at site 4 than site 2 (rocky hilltop), site 3 (open grassland) and site 5 (valley). Both sites also had the highest anthropogenic disturbance scores with a score of 4, indicating high disturbance levels. Exotic species having a negative effect on biodiversity has been known for many years (Godfrey *et al.*, 2017; Marzluff and Ewing, 2008). Juani *et al.* (2015) assessed over 390 studies worldwide which all reported the response of exotic species to various disturbances including grazing, fire, disturbance through animal and human trampling, addition of nutrients, farming, road disturbance and plant removal through mowing or cutting. The study indicated that exotic plant species increase in abundance and diversity following disturbance. It is suggested that this is because different disturbances damage the native species and thus their ability to take up nutrients, increasing the amount of nutrients available, creating opportunities for adaptable exotic species to take over that space (Hulvey and Teller, 2018). From the presence of exotic vegetation as well as the fairly high anthropogenic disturbance, it is possible that some of the disturbances (such as the agricultural practices at site 1 and the activities associated with the cattle kraal at site 4) may have resulted in the higher exotic species cover. In total, the number of exotic species observed out of the total species sampled does not indicate that the study sites are severely affected by human impacts. This could indicate that the efforts by GDARD and the landowners to reduce the exotic species in the area as well as the newly established cattle grazing rotation plans could be reducing the overall impact on the areas and in turn, decreasing the number of exotic species.

During the interviews with one of the landowners and the stewardship manager at GDARD, both interviewees identified invasive species as being the biggest challenge in conserving the Klipkraal area and the most problematic invasive species was emphasised to be the bankrupt bush or slangbos (*Stoebe vulgaris*). Sundberg (2020) found through interviews with multiple different farmers involved in biodiversity stewardship programmes that the invasion of the bankrupt bush is affecting many farmers across Gauteng and that many farmers have actually signed up to the programmes in order to get some assistance and guidance in managing the problematic species. During the interviews it was established that the removal of exotic species is costly and sometimes has to be paid for by the landowners. Whilst driving and walking around the study area, the bankrupt bush was prominent in many open areas. The bankrupt bush is a woody dwarf shrub that has invaded some savannah-dominated areas and many grasslands as it competes with the natural species in the area and replaces them at an alarming rate. Avenant (2015) identified in an extrapolation study that, as a result of bankrupt bush encroachment, many farmers have lost about 30 to 60 percent of their grazing areas and the species has been identified as the biggest threat to the South African grasslands.

Woody shrub encroachment of grasslands has been broadly considered to be an indicator of land degradation for many years (Maestre *et al.,* 2009; Van Auken, 2009; Adeel *et al.,* 2005; Schlesinger *et al.,* 1990). It has also been identified that encroachment of the bankrupt bush has been attributed to a mismanagement of grasslands by farmers (Avenant, 2015). Since many open areas have shown bankrupt bush encroachment at Klipkraal, this could be as a result of the cattle grazing that has occurred for many years and other large herbivores, such as the wildebeest and buck that occur in these areas. van der Waal *et al.* (2011) suggest that large herbivores, such as cattle and other large herbivores, affect the soil fertility and nutrient availability of the area, which in turn affects the vegetation structure of the area and encourages bush encroachment.

Efforts have been put into controlling the bankrupt bush encroachment through herbicide applications and improvements in its regrowth has been seen on the northern side of the study area. Additionally, landowner one explained they have learned how to correctly formulate a grazing rotation plan that allows for the grasses to recover and improvements in grass condition has been seen since initiating this. It has been noted that through effective management procedures and calculated rotational grazing, the negative effects can be offset (Gaitan *et al.,* 2014). Since the bankrupt bush is such a huge threat to grasslands and to the farmers (Avenant, 2015), this may suggest that the implementation of the Klipkraal Biodiversity Stewardship Programme is critical for ensuring the protection of the biodiversity and ecosystems of the two farms as well as the continuation of cattle farming for the landowners. Since some positive effects of GDARD's actions have already been seen at Klipkraal from 2019, it is suggested that the programme has been successful in its objectives and with future follow up studies, greater impacts of the programme on the management of alien invasive species might indicate its long-term sustainability.

A study by Grobler *et al.* (2002) in Gauteng found an average of 37 species per 200 m^2 and a study by Bezuidenhout (2014) observed an average of 35 plant species per 100 m^2 in a vegetation study performed on a farm in Centurion. Additionally, a study by Mochesane *et al.* (2019) observed a total of 235 different plant species in a total sampled area of 1,800 m^2 in three different nature reserves in Gauteng. In this study, the range of vegetation found throughout the five study sites resulted in a relatively high species richness and diversity despite a fairly small study area and limited study sites. Sites 2 and 5 both had the highest species richness with 36 and 35 species respectively. Additionally, sites 2 and 5 also had the greatest species diversity indices with 3.496 and 3.448 respectively. Both site 2 and site 5 were also allocated the lowest anthropogenic disturbance scores, both having a score of 1 indicating limited or very low disturbance within the vicinity of the site and that the disturbance is limited to physical barriers. Site 3 was allocated a score of 2 indicating sporadic or dispersed disturbance as there was a fence and hiking trail within 20 metres of the site. The Intermediate Disturbance Hypothesis (IDH) expects that intermediate levels of disturbance result in a high species diversity as there is an equilibrium between the exclusion of species as a result of competition and the establishment of dominant vegetation (Grime, 1973). This has been observed in many studies in various vegetation types (Cursach *et al.,* 2020; Sasaki *et al.,* 2015; Piou *et al.,* 2008; Ikeda, 2003; Weithoff *et al*., 2001; Beckage and Stout, 2000).

5.2 The Small Mammal Diversity and Distribution Across the Study Sites

As part of the assessment of the current ecological state of the two farms involved in the Klipkraal Biodiversity Stewardship Programme, a mammal assessment was performed in which small mammals were trapped in each of the five study sites where the vegetation assessments took place. Small mammals have been found to be an essential component of ecosystems in South Africa. They make up the principal link between primary producers and secondary consumers, and also play an essential role in habitat modification, consumption of plants, seed dispersal and nutrient recycling (Avenant and Cavallini, 2007). Therefore, by assessing the small mammals at Klipkraal, a better understanding is obtained of the ecological state of the study area.

Five different species of rodents were captured throughout the study. The most commonly caught and widely distributed species was the Multimammate mouse (*Mastomys coucha*) which was captured at all five sites. The Multimammate mouse can be an indicator of disturbance as it is extremely adaptable (Lema and Magige, 2018; Avenant and Cavallini, 2007; Makundi *et al*., 2004) and has been found to be prevalent in small mammal communities occupying areas disturbed by humans (Avenant *et al*., 2008). The Multimammate mouse being the most dominant species in a study area is consistent with many other studies that occurred in maize fields (Imakando *et al.*, 2023; Sluydts *et al*., 2009; Vibe-Peterson *et al*., 2006), rice fields (Mulungu *et al*., 2013), fallow lands (Massawe *et al*., 2011; Mulungu *et al*., 2015), sugar cane fields (Mamba *et al.*, 2019) in areas throughout Africa and along a disturbance gradient on a University campus in Ghana (Gbogbo *et al*., 2017).

In terms of small mammal occurrence, the five sampling sites differed significantly. Habitat preference is likely to have played a significant role in small mammal occurrence across the five sites. As the Multi-mammate mouse is considered a generalist, this could explain its occurrence at every study site. Additionally, the African striped mouse (*Rhabdomys pumilio*) has also been identified as a generalist species (Schmohl, 2008; Skinner and Chimimba, 2005) and was trapped at every site except site 2 which is categorised as a rocky outcrop, a habitat unsuitable for the species. Gerbils and Elephant shrews (Schmol, 2008) as well as the Namaqua rock rat are considered specialist species (Lancaster, 2009). Neither the Highveld gerbil (*Gerbilliscus brantsi*), the Namaqua rock rat (*Aethomys namaquensis*) nor the Rock elephant shrew (*Elephantulus myurus*) were found at site 1 which was located along the side of a maize field. The Highveld gerbil (*Gerbilliscus brantsi*) has been known to cause a lot of damage to crops and is seen as a problematic pest by most farmers. It has been found that tilling on farms kills many Highveld gerbils, therefore reducing the number of Highveld gerbils in the tilled areas (Nell, 2014). This may suggest why no Highveld gerbils were found at site 1 along the side of the maize field as it does appear that tilling occurs in the maize field. However, the Highveld gerbil was trapped at every other study site. The Rock elephant shrew (*Elephantulus myurus*) and the Namaqua rock rat (*Aethomys namaquensis*) were only trapped at site 2 (rocky outcrops) and site 5 (valley covered in grasses and scattered trees with a few rocky areas) which were both given the lowest anthropogenic disturbance scores. These two species are known to coexist on rocky areas throughout the country but more specifically in the highveld region (Lancaster, 2009). This supports other findings that suggest that land transformation and disturbance increase the number of generalist species and decrease the number of specialist species (Liang *et al*., 2020; Börschig *et al*., 2013; Manor and Saltz 2008; Rodríguez and Peris, 2007).

Variations in plant density, cover and diversity has been correlated with greater abundance of small mammals (Getz *et al.,* 2005; Monadjem and Perrin, 1998) and areas for species to hide is most important habitat characteristic for small mammals as it offers the animals protection from the sun and predators and offers food (Friggens and Beier, 2010; Wright, 2006). Sites 2 and 5 both had the greatest vegetation species richness and had a variety of rocky areas and trees which could explain why more rodent species were found at these sites as this may have provided more areas for the species to hide. Another reason as to why there could be variations between the small mammal abundance at the different sites is that the areas could have varying amounts of livestock grazing. Livestock grazing has various negative effects on small mammals as the animal's trample on their burrows and holes (Horncastle *et al.,* 2019). All five sites had evidence of livestock grazing and therefore the varying levels and frequency of livestock grazing could have influenced the small mammal abundance at the five sites.

The small mammals trapped during summer were significantly larger in weight than the small mammals trapped in winter. This was expected as the food availability will be greater during the summer months (Mulvey *et al.,* 2023). Additionally, the small mammals caught at sites 2 (for the Highveld gerbil and Multimammate mouse) and 5 (for the African striped mouse and the Multimammate mouse) were significantly larger in both length and weight than their counterparts in the three other sites. This suggests that these two sites may provide significantly more food resources and cover, resulting in increased size due to better nutrition and less energy expenditure to find food. This is consistent with a number of studies that found a similar correlation (Afonso *et al.,* 2021; van der Mescht, 2011; Mcnab, 2010). Sites 1 and 4 also had the highest anthropogenic scores and were associated with maize plantations and the clearing of vegetation for a cattle kraal which could suggest the reason for the smaller body sizes observed at these sites. This was similarly observed by Lomolino and Perault (2007) which suggests that fragmentation of ecosystems as a result of anthropogenic effects may result in a lower body mass and shorter length in mammals in temperate rainforests. The diverse number of small mammals that occurred in the various habitats throughout the study site suggests that the study site is important for conservation as small mammals have been found to be an essential component of ecosystems in South Africa.

5.3 Medium to Large Mammal Diversity and Distribution

The presence of a total of 21 medium to large mammals was confirmed throughout the entire sampling period. All of the observed species are native to South Africa. Of the species found across the two farms, two species, the grey rhebok (*Pelea capreolus*) and the serval (*Leptailurus serval*) are classified as “Near threated” according to the IUCN Red List for South Africa (2024) and one species, the Leopard (*Panthera pardus*) is classified as “Vulnerable” (Endangered Wildlife Trust, 2024). This emphasises the need for the protection of the area in order to ensure these species persist. According to Low and Rebelo (1996), a total of 125 mammal species exist in Gauteng. The presence of 21 medium to large mammals and 5 small mammals in the study site of 2,656 hectares therefore suggests that the study site has a fairly high mammals species richness. Since decreases in species richness have been found to correlate with an increase in disturbance (Ramesh *et al.*, 2016; Mckinney, 2008; Fahrig, 2003), is the high number of species occurring at Klipkraal may suggest that, despite the farming activities on site, the area can still be considered as suitable for larger mammals.

The species richness of mammals can provide an effective indication of habitat condition and can be a helpful indication of the disturbance to natural areas (Ramesh *et al.,* 2016; Mckinney, 2008). Mammal species richness is generally linked to climate and is generally limited by the availability of water and temperature (O’Hara and Tittensor, 2010). At smaller scales where the climatic conditions are similar, however, species richness and distribution are commonly influenced by other factors such as changes in land use, competition, predator presence, topography and altitude (Ramesh *et al*., 2016; Msuha *et al.,* 2012). Grasslands generally support wildlife that thrive in large conservation areas while the species within wooded/thicket areas and rocky hilltops can function in smaller habitat patches (SANBI and UNEP-WCMC, 2016). Areas with greater variations in habitat support a greater number of species as they provide more habitat niches and varying resources for a number of species (Kivinen *et al.,* 2006; Connor *et al.,* 2000).

The open grassland site had the greatest species richness with a total of 15 animal recordings. The bushveld and the grassland habitats both had the highest species diversity. This suggests that the species distribution throughout the study area was not uniform (McKinney, 2008) indicating there could be fewer barriers to wildlife in the open grassland areas (Crookes *et al.,* 2013). If an area has good habitat connectivity, it would be expected that the relative activity (RA) levels would be fairly constant across each site for each species. The RA levels were not consistent for any of the species caught by the camera traps. This suggests that the habitats could possibly be disconnected by barriers in the study site such as the fences and roads. These structures can create barriers for the movement of species (Ferguson and Hanks, 2012). Specifically for specialist species, fences can change the community composition of the species by restricting movement. The barrier can affect a species' habitat selection and resource access which can have an impact on the success of the species (McInturff *et al.,* 2020). Fences and dirt roads can be observed throughout the two farms at Klipkraal and whilst driving from one side of the area to another, multiple fences have to be opened and closed along the way. The fences are required to keep cattle within a certain area before moving them to another area as part of the cattle grazing rotation plan. Additionally, the fences separate the two farms from one another. The number of fences throughout the study site could be restricting the mammal movement between different areas of the farm. It has been suggested that in order to make a farm "wildlife friendly" fences should be removed where possible and gates should be left open in order to allow species to move throughout the entire area Schurch *et al.* (2021). This could be something GDARD could consider as part of their conservation strategy whilst still ensuring the farmers are able to rotate their cattle effectively.

The maize field showed the highest mean relative activity out of all five habitat types. It also had the second highest species richness with a total of 13 different species recorded at the site throughout the study period. It also had the third highest species diversity and the lowest species evenness score of all the sites. This suggests that many of the same animal species were frequently found here. This is inconsistent with a study by Lomba *et al.* (2022) which found an increase in mammal diversity and species richness when moving along a gradient of declining agricultural intensity. However, other studies have shown that a few animals such as the common warthog (*Phacochoerus africanus*) (Swanepoel *et al.,* 2016), aardvark (*Orycteropus afer*) (Whittington-Jones *et al.,* 2011) and the porcupine (*Hystrix africaeaustralis*) (Bragg *et al.,* 2005) have been found to frequently occur in and around farm areas in South Africa. The most common reason for this is that these animals rely on the farming area for food and therefore burrow in the vicinity of the area in order to have easy access to the food source. This could result in human wildlife conflict resulting in the persecution of these species (Geffroy *et al.,* 2015), however the farmers as part of the Klipkraal Biodiversity Stewardship Programme have indicated that as part of the agreement, they do not harm any wildlife within the vicinity of their farms. The most commonly found animal in the maize field was the Porcupine (*Hystrix africaeaustralis*) which was frequently photographed in the area. Porcupines are considered habitat generalists but are known to be associated with farm areas as they receive an abundance of food from the crops (Mori *et al.,* 2014). Animals can become habituated with human transformed landscapes as they are conditioned to receiving food from the area. Habituation has been linked to a decrease in migration which can cause a high abundance of animals year-round, resulting in degradation of the ecosystem being inhabited (White *et al*., 2014; Middleton *et al*., 2013). For example, a study by Morelle and Lejeune (2015) found that during crop season, populations of wild boars are seen to double in agricultural areas as they search for food and cover, influencing the distribution and movement of the species. It should be noted that the difference in RA between different sites could have also been affected by the placement of the cameras. If a camera was placed in a better location within a habitat frequented by animals, it may likely have captured more mammals more frequently.

The black-backed jackal (*Canis mesomelas*), common duiker (*Sylvicapra grimmia*) and steenbok (*Raphicerus campestris*) were the most wide-spread species and were recorded in every habitat type. These three animals are considered generalists and therefore it is expected that they would be observed throughout the study area (Sosibo *et al.,* 2024). The porcupine (*Hystrix africaeaustralis*) and caracal (*Felis caracal*) are also both considered generalist species, however both these species were only found in one and three different habitats respectively which could also be an indication of disconnectedness between habitats. During the interviews it was explained that landowner 1 has designated a portion of their property in the northern part of Klipkraal to have no roads or fences to ensure the animals can freely move throughout this area. This shows that the landowner is aware of the problems associated with barriers to movement for wildlife. A study by Schurch *et al.* (2021) found that through removing the internal farm fences, increases in mammal abundance and richness were seen over a four-year period. With future actions and involvement with Klipkraal, this could possibly be further applied to other areas of the farm at Klipkraal, allowing for free movement of mammals within the farm’s vicinity. The presence of a diverse range of mammals in various habitats throughout the study site as well as the presence of multiple native species and near threatened and vulnerable species emphasises the need for the protection of the area in order to ensure these species persist.

5.4 The Social Aspects of the Biodiversity Stewardship Programme

As part of the assessment of the social aspects of the Klipkraal Biodiversity Stewardship Programme, interviews were held with both the landowners as well as two members of GDARD involved in the programme. Based on the interviews, it is clear that the programme has had a number of positive outcomes since it began in 2019. Some of these include that the landowners have been upskilled and educated on a number of conservation topics, including how to effectively formulate a grazing strategy that benefits the grass conditions, GDARD has sourced new herbicides for invasive species management and there has been evidence that invasive species management on the properties has been effective in some areas and it appears as though both parties have a positive outlook on the programme and are fully committed to ensuring that the objectives of the programme are met. Since biodiversity stewardship programmes are a signed agreement between landowners of communal or private land and local conservation authorities in order to conserve the land (SANBI, 2016), the relationship between the landowners and GDARD is crucial in ensuring the long- term success of the stewardship programme (Cockburn *et al*., 2019). From the interviews it was established that both parties are committed and have been working together to effectively come up with conservation strategies. GDARD regularly checks in with the landowners and visits the properties to ensure a good relationship is maintained and that they are aligned with the activities at Klipkraal.

A few other factors were identified through the interviews that are needed for the long-term success of the stewardship programme, including that the GDARD units involved in the Biodiversity Stewardship Programme are adequately equipped and resourced to ensure projects can be carried out efficiently and effectively. It has been identified in a study by Wright *et al*. (2018) that there are issues in Biodiversity Stewardship Programmes in South Africa involving financial and resource constraints, such as human resources. This was brought up by one of the GDARD members and landowners interviewed stating that the landowner has had to put in a lot of money towards the purchasing of herbicides and clearing of exotic vegetation as the government is not able to always fund this. Additionally, it is often the case that herbicides are secured but GDARD is unable to get people to apply the herbicides. Specific to Klipkraal, both GDARD members identified that long term solutions and efforts towards tackling the invasive species issues is critical in ensuring the natural biodiversity is protected and maintained in the area. GDARD is also in the process of eliminating the exotic species and is constantly monitoring the regrowth and progress of the exotic species removal and Chapman (2014) explained that for biodiversity stewardship programmes to be successful in the long-term management strategies need to be consistently monitored and evaluated.

It has been identified that if only one farm in a community reduces its farming intensity, this may not be sufficient to conserve species that have large range sizes (McKenzie *et al*., 2013) and that the effects of the farming intensity of the surrounding farms might outweigh the benefits of the conservation of an isolated piece of land (Bellon *et al*., 2017). The study area has been identified to have potential protected area expansions to the northwest and north of the site towards the Suikerbosrand Nature Reserve (Seegers pers. comm). From the landcover map in Figure 4.1, Riley (2020) expanded the thematic map to the areas surrounding Klipkraal, classifying the surrounding areas into the six landcovers. Using the least-cost pathway method, he then identified the best path to expand the Klipkraal Biodiversity Stewardship program by ensuring the path runs through similar habitat types to what occurs at Klipkraal (Figure 5.1). This study could be used by GDARD to identify properties and landowners in order to expand the Klipkraal Biodiversity Stewardship Programme to create an ecological corridor between Klipkraal and the Suikerbosrand Nature Reserve (Riley, 2020). It has been noted that in order to protect the biodiversity in an area, the restoration and protection of heterogeneous and connected ecosystems needs to be put in place (Dupras *et al*., 2016), emphasising the importance of expanding the Klipkraal Biodiversity Stewardship programme to create a connected pathway of conserved habitats.

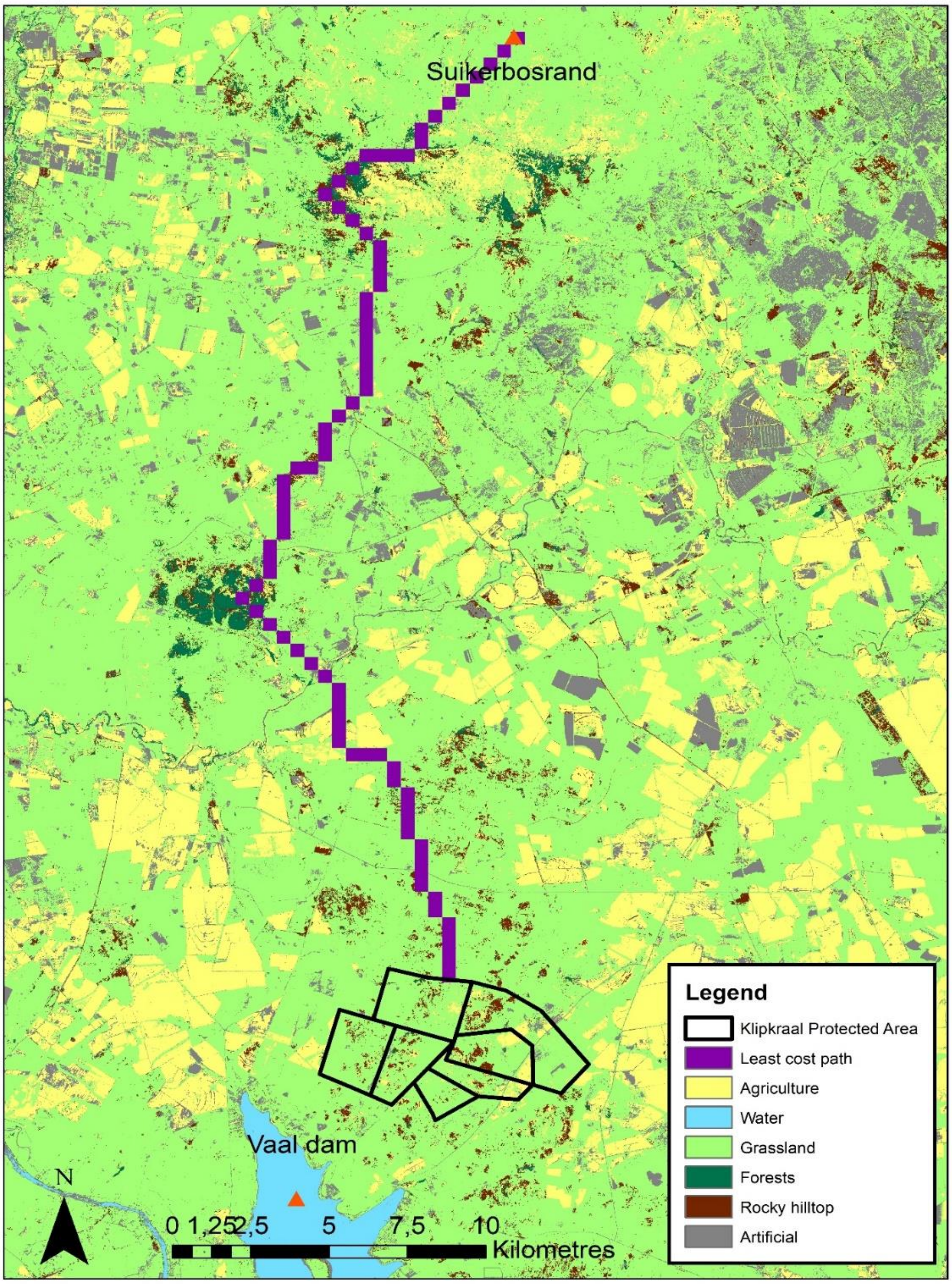

Figure 5.1: The least-cost pathway between the Suikerbosrand Nature Reserve (north) and the Klipkraal Biodiversity Stewardship Programme (south) on a landcover classification map (created using ArcMap 10.5.1) (Riley, 2020).

From the interviews, it was established that GDARD is in the process of updating their Conservation Plan which will include identify spatial priorities in the province where they should be focusing their protected area expansion efforts with the help of a conservation planner to identify spatial priorities where protected area expansion efforts should be prioritised. This process has not begun at Klipkraal as of yet as explained by GDARD at the start of 2024, but this is in the future plan, although a set timeline of when this will take place has not been set.

Since there are a number of factors that make biodiversity stewardship programme expansion difficult and time consuming and that there is a pressing need to expand protected areas to ensure interconnected patches of biodiversity priority areas are conserved to create an ecological network (Nor *et al.*, 2017) due to the high rate of natural habitat loss in Gauteng (Driver *et al*., 2012), it is important that GDARD begin assessing possible expansion areas. It was explained during the interviews that the latest conservation plan is being developed by GDARD and that expansion plans for the stewardship programme will be included in this. One of the landowners also suggested in the interview that they believe there is a lack of drive in to get more landowners to join the biodiversity stewardship programme. If the fragmentation levels because of urbanisation and urban sprawl are high, a region can move past connectivity thresholds, making restoration challenging and costly (Dupras *et al*., 2016). Therefore, the need for GDARD to begin with expansion efforts is very apparent and necessary to ensure the overall conservation success of the area.

In a similar study, Sundberg (2020) found through interviews with multiple different farmers involved in biodiversity stewardship programmes or protected area programmes in Gauteng that many landowners are very willing to spread the word of the programmes and in some cases have been successful. For example, one landowner explained that through conversations with other farmers they have encouraged 15 out of a total 75 farmers within the area to join the programme. An additional advantage of having multiple landowners is that a social network forms between landowners, allowing for the landowners to discuss and share ideas and skills related to conservation (Wright *et al.,* 2018). Additionally, as more landowners join the biodiversity stewardship programme, the benefits of the programme could spread to further landowners, encouraging more opportunity for a number of landowners to get involved. Duke and Ivento *et al.* (2004) found that one of the most effective ways of ensuring landowners learn about conservation strategies and programmes is through word of mouth from other landowners. Both the landowners that signed up to the Klipkraal Biodiversity Stewardship Programme joined the programme as a result of hearing about the multiple positive impacts experienced by other landowners involved in a similar stewardship programme. As one of the GDARD members also explained that the Klipkraal Biodiversity Stewardship Programme has been used as an example of a successful Stewardship Programme to spark the interest of other landowners already, greater efforts could be put into spreading the news of the biodiversity stewardship programme through word of mouth from the involved landowners, especially since landowners have difficulties trusting the Government and are sceptical in entering agreements with them according to GDARD.

It was suggested during the interviews that a way to encourage landowners to sign up for the Biodiversity Stewardship Programmes is through incentives such as financial incentives or tax rebates, which has been deemed successful in encouraging environmentally friendly practises by landowners through conservation programmes (Rawat, 2017). The landowners at Klipkraal are currently not receiving any financial incentives and are mostly part of the programme because of their love for the environment, their desire to learn and the want to pass their farm down to future generations in a good condition. Sundberg (2020) also found that multiple farmers are a part of a biodiversity stewardship programme due to their passion for conserving the environment and wildlife species, the desire to preserve their land for future generations and to obtain research and skills from the programme. Additionally, some farmers have identified that their motivation for being a part of the programme is for the protection of their land from expropriation such as mining activities. A GDARD member also pointed this out as a very common reason for interest in Biodiversity Stewardship Programmes from landowners in South Africa.

In terms of education and upskilling, the landowners stated that they have learned a lot from GDARD in terms of conservation which has allowed them to better manage their property. This is important as understanding how to farm alongside wildlife can be complex and requires a depth of knowledge in both ecological and agricultural areas (Nattrass and Conradie, 2015). Like this study, Sundberg (2020) found that the most valuable knowledge that has been gained by landowners from being a part of the Biodiversity Stewardship Programmes in Gauteng is how to effectively manage alien invasive species and how to effectively manage grazing and burning strategies to ensure the least damage is inflicted on the environment.

During the interviews it was noted that one of the current landowners had taken over as the responsible landowner in the programme from a family member in late 2019 and did not appear to have much knowledge on the conservation efforts that are taking place on their property. Additionally, during an update in 2024 it was noted that the other landowner had sold their portion of the property to the neighbouring landowner who is by default a part of the programme but has also agreed to continue the efforts of the previous landowner in the biodiversity stewardship programme. This may suggest that more effort is need by GDARD to upskill both “new” landowners to ensure their efforts align with GDARD’s goal of the Klipkraal Biodiversity Stewardship Programme and in order to formulate a new relationship and understanding with the landowners taking over the responsibility. It has been shown that this is a challenge and ensuring that there is a multigenerational commitment and a way of handing over the responsibilities of being involved in the biodiversity stewardship programmes by landowners is essential for the long-term success of a programme (Stolton *et al*., 2017). Follow up interviews with the landowners and GDARD members would be useful in determining how successful the handover process has been, what challenges have been encountered in this process and whether the new landowner has similar priorities and perceptions as the previous landowner.

5.4 Conclusion and Limitations

Biodiversity stewardship programmes can be an effective tool for conservation in South Africa, despite the many challenges involved with these programmes. This study analysed the landcover, vegetation, mammals and social dynamics of the Klipkraal Biodiversity Stewardship Programme established in 2019. The landcover map showed the various landcovers and percentages of each of the identified six landcover types for the Klipkraal site. This baseline map can be used by GDARD to monitor any changes in landcover over time. By doing this, GDARD can see if there is any change in the ratio of natural land to agricultural land and man-made structures as time goes on. Additionally, GDARD can use the landcover map to make comparisons to other Biodiversity Stewardship Programmes in order to assess the progress of conservation against landcover and what seems to be working best as well as to assess future areas identified for conservation to identify if the landcover is appropriate for the conservation strategy.

The vegetation and mammal data indicated the current ecological state of the two farms involved in the programme. Diverse vegetation species were sampled as part of the vegetation assessment and the diversity of habitats found on site suggest that site can provide a number of habitats and resources for various animal species. Additionally, a diverse number of small mammals were found in the various habitats throughout the study site which is important as small mammals have been found to be an essential component of ecosystems in

South Africa. Lastly, a diverse range of mammals in various habitats throughout the study site and multiple native species and near threatened and vulnerable species were found at the site. All three of these factors emphasise the need for the protection of the area and suggest the Klipkraal Biodiversity Stewardship Programme is protecting land of a high conservation value.

The ecological data presented can be used by GDARD as a baseline assessment of the vegetation and mammal species that occur on site. GDARD could then perform follow up studies on the vegetation attributes in terms of structure, cover, composition, species diversity and evenness as well as the number of exotic and invasive species present at the site as well as for the small, medium and large mammals that occur on site to observe any changes in these measures over time. This could then verify whether the efforts put towards conservation are making a difference at the Klipkraal site and could also be used to monitor changes that could be caused by any new disturbances or changes at the Klipkraal site. This data could also be used to compare the ecological data to surrounding areas that are part of conservation strategies to assess progress against other conservation strategies which could allow for more effective conservation methods to be observed. Lastly, when assessing new areas to expand the biodiversity stewardship programme into, the ecological data from this study could be used as a baseline to assess the viability of conserving new areas and could possibly provide guidance on conservation strategies for the new area. Future studies could also assess the efforts by GDARD in expanding the Klipkraal Biodiversity Stewardship Programme in order to see the progress in securing a larger area as part of the protected area.

Lastly, interviews were held to understand the challenges and perceptions of the various stakeholders within the Klipkraal Biodiversity Stewardship programme. This allowed for an in depth understanding of the dynamics between Klipkraal as well as the challenges from both a landowner and GDARD perspective. The interviews allowed for the multiple challenges involved in the Klipkraal Biodiversity Stewardship Programme to be revealed. Additionally, the requirements in order for the programme to be sustainable were also explored as part of the interviews. Some of the key findings include a need for willingness of landowners to put their time and resources into conservation efforts considering GDARD is not always able to provide resources and financial assistance, a need for constant monitoring of management strategies in order to track the progress of these programmes and find ways to improve them and the importance of expanding the stewardship areas to ensure surrounding areas are included in the programme and as a result effective conservation of the entire area.

However, key challenges in expanding the programme were also revealed, such as scepticism by landowners in entering land agreements with the government and concerns by landowners in losing their property rights and in Gauteng, many areas of conservation interest are made of multiple small properties that are owned by different landowners which means a lot of effort is required in getting each landowner to sign up to the programme which is time consuming and expensive. Insight was also given into the roles of the various stakeholders and the relationship between the GDARD and the landowners and it was indicated that GDARD's role is to provide guidance, education and resources when available to the landowners in order to manage their protected area as well as initiate programs and assist the landowners in monitoring the effectiveness of programmes in order to better the programmes. This study can be used as a baseline study for GDARD to monitor any changes in landowner-GDARD dynamics.

The study began in 2020 just before the Covid-19 pandemic resulting in delays in the field studies and interviews as a result of the restrictions put in place. Additionally, the study was limited to the two sites in the Klipkraal Biodiversity Stewardship Programme and therefore comparisons between the data collected on site could not be made to the surrounding areas to understand if the Biodiversity Stewardship Programme is in fact beneficial for conservation compared to these surrounding areas. For the thicket/woodlands study site, a larger vegetation sampling site would be beneficial to ensure a better vegetation representation of the woodland area. Additionally, there were a lack of repeats and uncertainty as a result whether the 5 sites sampled are in fact representative of the larger area. Further studies could be used to compare the ecological state of the Klipkraal area to the surrounding properties, including the Suikerbosrand Nature Reserve. The study was also limited as the only people interviewed were two GDARD members and the two landowners involved in the programme. It would be beneficial to expand the population to surrounding landowners to understand their perception of the programme as well as to interview landowners and government officials that are a part of different stewardship programmes to obtain a broader perspective on the matter.

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Appendix A – interview schedule

Interview questions for landowners:

1) What is your role as the landowner in the Klipkraal Biodiversity Stewardship Programme?
2) What are the benefits to you as the landowner in participating in the Klipkraal Biodiversity Stewardship Programme?
3) Are there any risks to you in participating in the Klipkraal Biodiversity Stewardship Programme?
4) Are there any personal reasons for your involvements in the Klipkraal Biodiversity Stewardship Programme?
5) How long are you planning on committing to your involvements in the Klipkraal Biodiversity Stewardship Programme?
6) How would you like to see the Klipkraal biodiversity stewardship programme develop in the future and what additional benefits would you like to receive from participating?
7) What do you think the challenges are in implementing biodiversity stewardship programmes in South Africa?
8) What do you think is needed to ensure the long-term sustainability of the Klipkraal Biodiversity Stewardship Programme?

Interview questions for GDARD:

1) What is your role as a member of GDARD in the Klipkraal Biodiversity Stewardship Programme?
2) What is GDARD hoping to achieve with the Klipkraal Biodiversity Stewardship Programme and does the programme fit into a larger conservation strategy?
3) What challenges have been encountered in implementing the Klipkraal Biodiversity Stewardship Programme?
4) What do you think is necessary in ensuring the long-term success of the Biodiversity Stewardship Programme?
5) What challenges do you think will be encountered in ensuring the longevity of the Klipkraal Biodiversity Stewardship Programme?

6) How do you think the Klipkraal Biodiversity Stewardship Programme has been beneficial for conservation since it started in 2019?
7) What do you think the challenges and benefits are to the landowners in participating in the program?
8) Are there plans to expand the Klipkraal Biodiversity Stewardship Programme to include surrounding properties and landowners? If yes, how will GDARD go about doing this?

Appendix B: Complete list of plant species found at Klipkraal.

Grasses	**Herbs**	**Trees and shrubs**
Andropogon appendiculatus	*Aloe maculata*	*Asparagus suaveolens*
Aristida congesta	*Alternanthera pungens*	*Combretum molle*
Aristida diffusa subs. Burkei	*Amaranthus hybridus*	*Cryptolepis oblongifolia*
Aristida scabrivalvis	*Berkheya radula*	*Dichapetalum cymosum*
Brachiaria serrata	*Berkheya rigida*	*Diospyros lycioides*
Cenchrus ciliaris	*Bidens bipinnata*	*Lantana rugosa*
Chloris pycnothrix	*Bidens pilosa*	*Lippia javanica*
Cynodon dactylon	*Bonatea speciosa*	*Pavonia burchellii*
Digitaria eriantha	*Centella asiatica*	*Phyllanthus parvulus*
Eragrostis curvula	*Chaetacanthus setiger*	*Ruellia cordata*
Eragrostis plana	*Chenopodium album*	*Searsia leptodictya*
Eragrostis racemosa	*Chenopodium carinatum*	*Sida rhombifolia*
Eragrostis superba	*Commelina erecta*	*Solanum elaeagnifolium*
Heteropogon contortus	*Convolvulus sagittatus subsp sagittatus var. hirtellus*	*Solanum linnaeanum*
Hyparrhenia hirta	*Conyza bonariensis*	*Solanum panduriforme*
Melinis repens	*Conyza podocephala*	*Sphenostylis angustifolia*
Panicum maximum	*Cucumus zeyheri*	*Stoebe Vulgaris*
Paspalum dilatatum	*Cyperus esculentus*	*Tephrosia rhodesica*
Paspalum urvillei	*Emex australis*	*Thunbergia atriplicifolia*
Pennisetum clandestinum	*Euphorbia hirta*	*Vachellia karroo*
Schizachyrium sanguineum	*Euphorbia prostrata*	*Vachellia robusta*
Setaria nigrirostris		*Zanthoxylum capense*

Setaria pallide-fusca	*Felicia muricata*	*Ziziphus mucronata*
Sporobolus africanus	*Helichrysum rugulosum*	*Ziziphus zeyheriana*
Sporobolus stapfianus	*Hermannia depressa*	
Themeda triandra	*Hilliardiella oligocephala*	
Tragus berteronianus	*Hypochaeris radicata*	
Triraphis andropogonoides	*Ipomoea transvaalensis*	
Urochloa panicoides	*Ledebouria ovatifolia*	
	Limeum viscosum	
	Monsonia angustifolia	
	Nidorella anomala	
	Oenothera tetraptera	
	Oxalis corniculata	
	Oxalis semiloba	
	Polygala hottentotta	
	Rhynchosia totta	
	Ruellia patula	
	Salvia runcinata	
	Sansevieria aethiopica	
	Schkuhria pinnata	
	Senecio erubescens	
	Senecio lydenburgensis	
	Sida alba	
	Sida cordifolia	
	Tagetes minuta	
	Teucrium trifidum	
	Verbena brasiliensis	
	Walafrida densiflora	

Appendix C: Ethical Clearance Certificates

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Butler

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H21/07/06**
PROJECT TITLE	Biodiversity Stewardship in South Africa – An Assessment of the Klipkraal Biodiversity Stewardship Programme and its Potential for Conservation
INVESTIGATOR(S)	Miss K Butler
SCHOOL/DEPARTMENT	Animal, Plant and Environmental Sciences/
DATE CONSIDERED	23 July 2021
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	16 August 2024
DATE 17 August 2021	**CHAIRPERSON** (Professor J Knight)

cc: Supervisor : Dr U Schwaibold

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I agree to completion of a regular progress report. For Minimal and Low studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

Signature

18 / 08 / 2012
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

ANIMALS RESEARCH ETHICS COMMITTEE (AREC)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

STRICTLY CONFIDENTIAL

CLEARANCE CERTIFICATE NUMBER: 2020/07/02/B

APPLICANT: Ms K Butler
School: School of Animal, Plant and Environmental Sciences; Department: ; Location: On the two farms included in the Klipkraal biodiversity stewardship programme

PROJECT TITLE: Biodiversity Stewardship in South Africa- An assessment of the KlipKraal Biodiversity Stewardship Programme and its potential for conservation
Category: B; Species and Numbers involved: *All animal species caught on site, male/female of different weights and ages*

Approval is hereby given for the use of animals for the research project named above and described in the application reviewed by a quorate meeting of the AREC held on 28 Jul 2020. This approval remains valid until 20 Jan 2023 and is conditional to the following (if blank there are no special conditions):

Condition 1	Condition 2	Condition 3	Condition 4

All material changes to the approved research must be reported to the AREC before they are implemented. Failure to do so will invalidate this clearance certificate.

An annual progress report must be provided to the AREC.

The use of these animals is subject to AREC guidelines on the use and care of laboratory animals, is limited to the procedures described in the application and is subject to additional conditions listed below:

I, the Chair of the AREC (or my designated representative) am satisfied that the proposed research is ethical as judged by local law, international standards and University policy.

Signed: ______ ________ Date: ___21/01/2021_

(Chairperson of the AREC)

I am satisfied that the persons listed in this application are competent to perform the procedures described in the application, in the context of Section 23 (1) (c) of the veterinary and Para-veterinary Professions Act (19 of 1982).

CC: Student supervisor: «Title1» «Initials1» «Supervisor_surname»
Director Central Animals Service: Dr Kim Jardine