ASSESSING THE VARIATIONS IN ALIEN PLANT COMMUNITIES WITHIN POWERLINE CORRIDORS: A CASE STUDY OF FUNDUDZI AND KHAKHU POWERLINE CORRIDORS

By

MUKONDI OLGA LIGEGE

Student number: 17023829

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SUPERVISORS: DR T DALU, DR EM STAM

ABSTRACT

Human activities such as the use of powerline servitude corridors for the secure transmission and distribution of electricity alter natural landscapes and change vegetation patterns, and may also encourage the spread of alien plants. The spread of alien plants from one area to another through intentional and unintentional human activities is a serious threat to the world's biodiversity, including that of South Africa. Vegetation management in powerline corridors in South Africa may be encouraging the spread of invasive alien species. The study therefore aimed to examine whether powerline corridors are encouraging the spread of alien plant invaders. The vegetation communities within and adjacent to powerlines were sampled on the Khakhu line 22KV and Fundudzi 132KV powerlines in Limpopo province, South Africa. The study observed that servitudes or corridors favoured by invasive alien species cross areas close to the urban fabric on productive soils with abundant light. Nine invasive alien species were identified in Fundudzi dominated by common guava *Psidium guajava* (mean relative abundance 48.7 %), black–jack *Bidens pilosa* (mean relative abundance 23.4 %), and common lantana *Lantana camara* (mean relative abundance 15.4 %). Khakhu only had 6 species of invasive alien species that were dominated by fierce thorn apple *Datura ferox* (mean relative abundance 17.7 %) and Khaki bush *Tagetes minuta* (mean relative abundance 67.3 %). Sites closest to human settlements showed higher species richness of invasive species, whilst sites located further away were dominated by *L. camara*, with much less species richness. The invasive alien species observed along the powerline servitudes generally decreased as one moved away from areas with human activities. Principal Coordinates Analysis (PCoA) first two axis of the selected exploratory variables accounted for 68.0 % of the total invasive alien species abundance variance, with PCO1 and PCO2 accounting for 43.2 % and 24.8 %, respectively. Weak overlaps in the polygons for the two powerline servitudes suggest that alien invasive populations are not similar and were different among sites with five groups being identifiable. The study findings corroborated that mature forestscapes present only low levels of alien invasion. The research findings may, however, be related to the partial redundancy of present day land cover data, and should be investigated further with a more robust data set taking into account the soil types, controls and several environmental variables that might affect the community structuring.

Key words*:* Invasive alien species, environmental regulation, powerline servitudes, corridors, invasions

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DECLARATION

I, MUKONDI OLGA LIGEGE, declare that: "ASSESING THE EFFECTS OF POWERLINE SERVITUDES AS CORRIDORS FOR ALIEN PLANT INVASION: A CASE STUDY OF FUNDUDZI AND KHAKHU POWERLINE CORRIDORS" is my own work and that all sources that I have consulted or quoted have been clearly indicated and acknowledged by means of references.

——————— **—13 August 2020————————**

MUKONDI OLGA LIGEGE **Date**

CHAPTER 1: GENERAL INTRODUCTION

Background

The rapid increase in global population, accompanied by the aspirations of higher living standards, have greatly increased human induced environmental impacts through a higher demand for energy, particularly electricity (Iberdrola.com, 2020). Whilst the production and consumption of electricity has several negative impacts on the natural environment, including contributing to climate change, the development of human society depends upon it. Since the advent of the new democratic South Africa, the government has prioritised access to affordable energy, economic efficiency and environmental sustainability (Davidson et al., 2006).

In South Africa, ESKOM is the official state owned power utility company. ESKOM generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa (dpe.gov.za, 2020). Eskom generates, transmits and distributes electricity to industrial, mining, commercial, agricultural and residential customers and redistributors. Additional power stations and major power lines are being built to meet rising electricity demand in South Africa (ibid.). Whilst ESKOM aims to meet these rising energy demands, it also has a 'zero harm' value dedicated to its employees, contractor, the public and the natural environment as one of its mandates (dpe.gov.za, 2020). To this end, ESKOM is committed to preserving environmental integrity, including the rich biodiversity of South Africa in all its operations (Eskom, 2010).

As part of the services that the national energy utility ESKOM provides, is the transmission and distribution of electricity to users through power line servitudes. These man–made linear transport corridors not only shape, but also have the potential to fragment habitats for valuable biodiversity in South Africa (Richardson et al., 2017). In some instances, where habitats have been transformed by processes such as agriculture, these corridors have been noted to be the only available habitats for certain species. This was the case for the fynbos cone bush (*Leucadendron chamalaea*) in 2004 (Esler & Milton, 2006). It is in these circumstances that the Biodiversity Act (10 of 2004) plays a key role in the conservation of these habitats and species.

Corridors such as power line servitudes have been observed to retain genetic diversity (rare species, varieties, populations) and provide ecosystem services that are valuable for the restoration of neighbouring degraded habitats. Within the context of climate change, these linear corridors could provide an insurance policy for biodiversity (Wagner et al., 2014). These same corridors also possess valuable aesthetic, educational and tourism value, as they are at times, the only areas of natural vegetation visible and freely accessible to the general public (Esler & Milton, 2006). Whilst linear servitudes in South Africa are small relative to the remaining landscape, ESKOM transmission line servitudes at 30–80 metres wide, extent for 28, 000 km over private land in South Africa (Figure 1.1). In light of this, their management becomes a critical priority for South Africa, especially for biodiversity.

Figure 1.1. An example of powerline servitude, 132 KV Fundudzi line, Limpopo province, South Africa

Managing powerline servitudes presents many ranging and intersecting technical and logistical, economic and natural environmental challenges for South African managers (Richardson et al., 2017). Amongst the technical and logistical challenges of management, is that posed by private ownership of land upon which servitudes exist. This means that although ESKOM retains the right to erect, operate and maintain powerlines, and the right of access to carry out these activities, the landowner retains the overall responsibility for the land (Eskom, 2010). As ESKOM powerlines lie over several different individual private landowners, this presents logistical management issues.

Another challenge comes with the national job creation initiatives of the South African government aimed at reducing poverty and unemployment by using labour intensive methods to generate jobs and economic growth (Esler & Milton, 2006). The largely unskilled workforce is employed by the Expanded Public Works Programme (EPWP), the Department of Transport and Public Works and ESKOM and other agencies (dpe.gov.za. 2020). Whilst there are potential and realised socioeconomic benefits with these programs, they have also been accompanied by unintended consequences for biodiversity. These result in some cases, from the over–zealous interpretation of the terms of reference for vegetation clearing or poor training (Esler & Milton, 2006). This is particularly problematic ecologically, as any person working within the environment and especially those managing alien invasive plant species need to be able to recognise alien invasive plant species amongst the indigenous species. This frequently results in damaging of natural vegetation and promoting of weeds in linear corridors.

The accessibility and linear nature of human made corridors make them particularly vulnerable to disturbance and invasion (Lampien et al., 2015). That being said, the management of these corridors does not prioritise these biodiversity problems per se, as their core function is not for them to function as biodiversity corridors. Specific to power servitudes, they are managed primarily to maintain safe clearance for power cables and vehicle access for maintenance crews (Esler & Milton, 2006). The need to prevent fires under power lines are a crucial management priority in vegetation management. ESKOM must comply with the Occupational Health and Safety Act (85 of 1993), i.e. that the equipment will be safe and without risks to health when properly used. This act, together with the requirement for minimization of faults, necessitates a clearance distance between the ground and the powerlines of 8 – 15 m (depending on the voltage), dictating vegetation management such as the clearing of tall shrubs and trees below lines (Eskom, 2010).

In an attempt to adhere to the powerline servitude management guidelines, linear servitudes are cleared of natural vegetation cover. Clearing of vegetation below powerlines can cause damage to vegetation, soil or result in introduction and establishment of invasive alien plant species (Esler & Milton, 2007). Certain invasive species are able to take advantage of the absence of competition from native species and begin to thrive. These invasive plant species have the ability to 'jump' into adjacent landscape natural corridors, such as rivers at their intersections (Reynolds et al., 2015). Alien plant species tend to occupy disturbed habitats often characterised by a surplus of unused resources, both of which are typical features of regularly managed powerline corridors (Eyitayo & McCarthy, 2020). Not only does over–clearing of natural vegetation in linear servitude corridors increase the likelihood of invasives to interfere with adjacent natural landscapes, but can also be counter–productive to the management of the servitudes themselves. One clear example of this was observed with the clearing of road verges of vegetation for purposes of improving visibility on the road within 30 m either side of Nieuwoudville, Calvinia and Williston in the Nama Karoo of South Africa. Here, the removal of the natural vegetation led to the clearing being taken over by grasses and weeds such as rolbos or tumbleweed (*Salsola kali*) which grow taller than Karoo bossies, causing more visibility issues than the original vegetation (Esler & Milton, 2006). Should this be the case even with powerline servitudes, then there is an increased danger of fire hazards posed by taller invasive plant species compared to the natural species.

It is thus imperative to come up with solutions to these problems. In designing a viable solution, it is necessary to consider which habitat types are most vulnerable to damage or weed invasion and which types of clearing are most damaging to the natural environment. Research is therefore needed to fill the gaps currently present in coming up with best–practice management guidelines that would minimize habitat impact along corridors without endangering or compromising safety and service quality.

Problem statement

South Africa has a long history of problems with invasive alien species, and of research and management of biological invasions (van Wilgen et al., 2020). Kumschick et al. (2012) highlighted that the number of invasive alien species are increasing and so are the impacts these species cause to the environment and economies. Invasive alien species exacerbate poverty and threaten development through their impact on agriculture, forestry, fisheries and natural systems, which are an important basis of peoples' livelihoods in developing countries. This damage is aggravated by climate change, pollution, habitat loss and human–induced disturbance (Esler & Milton, 2006).

Whilst conservation plans are already in place in many regions of South Africa to address these issues, they depend on local level information on irreplaceability of vegetation types and species level data, in order to appropriately prioritise action. There has been a call towards the prioritisation of large scale inventories of species (van Wilgen et al., 2020). This is crucial especially for the management of alien invasive plant species. Ecological guidelines need to be developed on a per–biome basis. It is necessary to know what plants contribute to the maintenance of ecological processes and which species allow for the suppression of weedy or invasive species. There is also a need to examine whether powerline servitudes are encouraging alien plant invaders into the natural environment (Clarke & White, 2008).

One clearly identified gap in South Africa is that of understanding and dealing with the ecology of linear servitude corridors. Our understanding of many of the broader aspects of servitudes as corridors for alien invasive plant ecology needs to be enhanced (Richardson and van Wilgen, 2004). For example, for specific South African ecoregions, it is not yet fully known which types of vegetation occurs in powerline servitude corridors, and also which invasive alien species are likely to occur there and why. However, ecological research into linear powerline servitudes in South Africa is very limited. This poses problems for their proper ecological management. Research into the effects of servitude management practices such as mowing on vegetation structure and function is required as is an investigation into the effects of pruning vegetation to different heights (Wagner et al., 2014). Ultimately, research attention needs to be given into how a compromise can be reached that takes both the servitude mandate and the ecological requirements of the relevant vegetation type into consideration. It is this identified problem, that this research seeks to contribute towards resolving.

Main aim

The main aim of the study was to investigate whether powerline servitudes are encouraging the spread of alien plant invader species into the natural environment.

Specific objectives

1. To evaluate invasive alien plant species composition and abundances under servitudes.
2. To determine invasive alien plants abundances in areas not influenced by the servitudes.

Hypothesis

In line with findings on open grassland mountain areas (Pykälä et al., 2005; Bennie et al., 2006; Lampinen et al., 2015) and invasion ecology (Davis et al., 2000; van Wilgen et al., 2020), it is expected that the greatest numbers of invasive species will be found in corridors with abundant light and corridors that are close to human settlement areas.

Significance of the study

Protection of biodiversity and sustainable development are especially important as national goals in many countries, including South Africa which has the National Development Goals 2030. In South Africa, alien vegetation in servitudes is to be managed in terms of the Regulation GNR.1048 of 25 May 1984 (as amended) issued in terms of the Conservation of Agricultural Resources Act, Act 43 of 1983. Best practice management guidelines should be tailored for a particular priority vegetation type. Specific to the management of linear servitude corridors, the primary goal is to maintain ecological intergrity and functional diversity (corresponding to an equivalnet reference vegetation community), without disproportionately compromising the mandate of the servitude managers. This study represents one of many studies that are needed to ensure the development of such guidelines for the development of best practice in linear servitude vegetation management.

CHAPTER 2: LITERATURE REVIEW

Background

Biological invasion is regarded as the second threat to biodiversity after habitat destruction (Holmes et al., 2008). Invasive species are alien species that are transported out of their original area of occupancy can end up dominating non–native environments. These invasive alien plant species pose both the socio–economic and environmental effects once they are out of the area that they were initially intended to occupy. In South Africa, various alien plants species have been introduced both accidentally as seeds or other propagules and deliberately for commercial purposes (Holmes et al., 2009; DEA, 2009).

The Department of Environmental Affairs (DEA) (2009) stated that without adequate measures of alien plants control, alien plant growth has spread out and will continue to spread out of their intended areas with serious negative impacts. This spread is also aided by bird's water runoff and wind (Reynolds et al., 2015). Since most alien species do not have their natural enemies within their new environment they become invaders and spread aggressively. Typically, environments that are heavily managed, such as linear servitude corridors, can facilitate invasions by the removal of native species competition, leaving an abundance of resources for alien invasive species to flourish on (Clarke & White, 2008). Most invasive alien plants in South Africa come from Australia and South America and they contribute 70 % of the identified list of alien plants in South Africa (Poona, 2008). Examples of these are the black wattle *Acacia mearnsii*, blackwood *Acacia melanoxylon*, blue gum *Eucalyptus* spp. and pine *Pinus pinaster*. These have significant negative impact on the lower canopy vegetation and water (Chamier et al., 2012).

The ubiquitous sight of power lines through both rural and urban areas creates an obvious corridor for the eye to see. Like most corridors, however, power lines have the potential to support the dispersal of both native and non–native species, due in part to the frequent disturbance caused by their maintenance. Although most research has shown that the potential negative effects of corridors do not outweigh the potential positive impacts, there is still the possibility of power lines creating a habitat that ultimately benefits aliens.

Characteristics of plant species invasions

Different scholars (e.g. Kloar and Lodge, 2001; Holmes et al., 2008; Ratnayake, 2014; Van Kleunen 2015) have listed different factors which give rise to alien plants species becoming invasive. These factors include the lack of a population controls since they are not in their native area, high seed production, strong morphological and ecological characteristics (deep roots and broad climate tolerance), the ability for seed to survive a long time in the ground and the unrestrained vegetative spread and ability to colonize.

Van Wilgen et al. (2020) listed factors that aid the spread of invasive plants:

1. High seeds production.
2. Light seed which is easily carried away by wind dispersal.
3. Seed dispersal by vehicles, road edge cutters, farmers and flower pickers.
4. Ability to produce flowers and/or seeds at an early age because of high growth ability.
5. Ability to regrow from the stem and/or produce asexually.

6. The ability to adapt to a wide range of environmental and climatic conditions.

7. Lack of knowledge by farmers and ignorant people who do not consider the effects of their action.

Powerlines corridor/servitudes as niches for alien invasive species

According to a study by Morrison (2017), power line corridors favour different alien species. They often intersect areas close to both forests and the urban fabric, and are characterized by productive soils and abundant light. Ilangakoon et al. (2015) discuss that recent disturbance, a surplus of unused resources and propagule pressure increase the likelihood of invasion in communities, with both indifferent and invasive alien species following these predictions in the studied corridors. By producing disturbance, corridor management increases the availability of light and other resources in the corridor, while increasing time since previous clear–cut decreases them due to natural succession (Eyitayo & McCarthy, 2020). Recent research has suggested that corridors may influence the spread of some invasive, although the effects may be transient.

Anthropogenic corridors, such as power lines, roads, and trails are common features in urban, suburban, and rural landscapes. Despite their undeniable importance for human activities, the creation and maintenance of these linear structures and their associated rights–of–way may have detrimental effects on the environment by acting as dispersal vectors for invasive plant species (Jodoin et al. 2008; Kalwij et al., 2008). The establishment and spread of invasive plant species in such corridors are facilitated by several factors such as the increase in light intensity and temperature owing to the eradication of tall indigenous species (Parendes and Jones 2000; Delgado et al., 2007), the chemical and physical disturbance of the upper soil layers (Hobbs and Atkins 1988; Johnston and Johnston 2004; Jodoin et al., 2008), the reduction of competition (Parendes and Jones

2000), and the decrease of wind barriers to pollen and seed dispersal (Parendes and Jones 2000; Dubé et al., 2011).

According a study by Morrison (2017), power line corridors favoured by alien species cross areas close to both forests and the urban fabric, and are characterized by productive soils and abundant light. It is important to take into account the possibility of negative, unintended consequences of corridor creation in their design. In the same ways that corridors may facilitate movement of rare, endangered, or declining species, they may also increase dispersal of unwanted species, such as invasive species, or antagonists (predators or diseases) of conservation targets. For the most part, researchers have not encountered negative effects of corridors in conservation. Yet, work is still needed to understand when and where corridors can have negative effects. Perhaps the most important negative effect of corridors is introduced because of their long and narrow shape. This shape creates boundaries between conservation and degraded areas. Species tend to behave differently at these boundaries, or edges, of habitat fragments, and there is concern that in creating habitat patches such as corridors, the high ratio of edge to area might be detrimental to species using the corridor (Pohlman et al., 2007). This concern is somewhat supported by research; because of edge effects, some species do experience corridors as habitat sinks or ecological traps. When edge effects are negative, they should be planned for and mitigated against when designing corridors.

Anthropogenic corridors may also facilitate the spread of invasive plant species to adjacent ecosystems through the creation of new sharp boundaries (Arevalo et al. 2008). The width of the adjacent ecosystems affected by the corridor (or the depth of edge influence) varies depending on the species involved (Euskirchen et al., 2001), the linear feature type (Parendes and Jones 2000), and the intersected community (Delgado et al., 2007). For instance, the depth of edge influence of highways and railways in western Canada is more than 150 m in grasslands but only 10 m in forests (Hansen and Clevenger 2005). Ecosystems with open canopies are indeed more prone to colonization by invasive species than forest ecosystems, since few invasive species, especially exotic ones, are adapted to low light availability (Parendes and Jones 2000; Dubé et al., 2011).

Invasion as a biological process

Blackburn et al. (2011) identified four stages of biological invasions which are transportation, introduction, establishment, and spread. These four stages can be further broken up into more stages. Vosse et al. (2008) highlighted that when the natural ecosystem is disturbed by some anthropogenic activity or due to natural processes, it creates a window for alien species invasion and spread into an area, which may lead to reproduction while expanding and overcoming dispersal barrier like climate. Abundant availability of resources (such as water, nutrients, sunlight) aids the spread of alien species. Alien species then compete with native flora and fauna. With time, this results in successful adaptation of alien species, which can then become invasive when not controlled. Figure 2.1 shows the biological invasion process.

Figure 2.1. The proposed unified framework for biological invasions. Source: Blackburn et al. (2011)

Table 2.1. A categorisation scheme for populations in the unified framework. Human–mediated dispersal has created several novel categories of dispersal pathway (i.e. B1 and B2) (Wilson et al., 2009), and human intervention has also significantly increased the frequency and duration that populations can persist in other categories (C0, C1 and C2) (source: Blackburn et al., 2011).

Category	Definition
A	Not transported beyond limits of native range
B1	Individuals transported beyond limits of native range, and in captivity or quarantine (i.e. individuals provided with conditions suitable for them, but explicit measures of containment are in place)
B2	Individuals transported beyond limits of native range, and in cultivation (i.e. individuals provided with conditions suitable for them but explicit measures to prevent dispersal are limited at best)
B3	Individuals transported beyond limits of native range, and directly released into novel environment
C0	Individuals released into the wild (i.e. outside of captivity or cultivation) in location where introduced, but incapable of surviving for a significant period
C1	Individuals surviving in the wild (i.e. outside of captivity or cultivation) in location where introduced, no reproduction
C2	Individuals surviving in the wild in location where introduced, reproduction occurring, but population not self-sustaining
C3	Individuals surviving in the wild in location where introduced, reproduction occurring, and population self-sustaining
D1	Self-sustaining population in the wild, with individuals surviving a significant distance from the original point of introduction
D2	Self-sustaining population in the wild, with individuals surviving and reproducing a significant distance from the original point of introduction
E	Fully invasive species, with individuals dispersing, surviving and reproducing at multiple sites across a greater or lesser spectrum of habitats and extent of occurrence

The proposed framework recognises that the invasion process can be divided into a series of stages, that in each stage there are barriers that need to be overcome for a species or population to pass on to the next stage, that species are referred to by different terms depending on where in the invasion process they have reached, and that different management interventions apply at different stages. Different parts of this framework emphasise views of invasions that focus on individual, population, process, or species. The unfilled block arrows describe the movement of species along the invasion framework with respect to the barriers, and the alphanumeric codes associated with the arrows relate to the categorisation of species with respect to the invasion pathway given in Table 2.1 (source: Blackburn et al., 2011).

Alien invasive plant species impacts

Invasive plants species have become a major threat to the integrity of plants community and natural habitats around the world (Dogra et al., 2010). Invasive alien plants are problematic because of their ability to exhibit early maturation, high seed production, high germination rate and effective dispersal mechanism. Most of this invasive alien species can propagate asexually by the stem or root fragments (Gordon, 1998; Monaco et al., 2002). Anthropogenic activities have been the leading factor/contributor to the distribution of invasive alien species because of their greater tolerance to a range of environmental condition compared to native plants. Invasive alien plant species have the potential to proliferate and propagate rapidly, extensively expanding the range of their distribution. Their success as invaders relies on the absence/lack of natural enemies and the prevalence for heterogeneous landscape conditions that are suitable for their development (van Wilgen et al., 2008; Ratnayake, 2014). However, despite the negative effects some studies have shown that invasive alien plants do not only have detrimental effects but offer positive contributions as well (Semenya et al., 2012).

Many natural ecosystems have been degraded due to invasion by invasive alien plants (Vilà et al., 2011). The problem is growing in severity and geographic extent as global trade and travel accelerate (Taylor et al., 2012), and as human–mediated disturbances increase, making ecosystems more susceptible to invasion (Holmes et al., 2008). Invasion by invasive alien plants has been reported to erode natural capital, compromise ecosystem stability, and ecosystem services provision as well as threaten economic productivity, coming into conflict with human aspirations (Richardson and van Wilgen, 2004). Several studies have shown that the most damaging invasive alien plants transform ecosystems by adding resources, promoting fire, erosion and litter accumulation (Richardson and van Wilgen, 2004). The conflict over resources between invasive alien plants on ecosystems and human aspirations cannot be measured only in monetary terms (e.g. alien plant effects on crop yield), but also in non–monetary terms (e.g. aesthetic losses, loss of important associated organisms or ramifications of the drudgery of hand weeding, which is often assigned to women and children) (Ukeje, 2007; Pejchar and Mooney, 2009).

The increase in global trade in the past years presents an opportunity for the transfer of invasive alien plants, with both beneficial and deleterious impacts (Banks et al., 2015). Therefore, the geographic extent of invasive plants will increase leading to enormous costs on ecosystems, economy and society (Pejchar and Mooney, 2009; Witt et al., 2018). Interestingly, some invasive alien plants are receiving increased recognition and acceptance due to their ability to contribute positively to rural livelihoods (Kannan et al., 2016). For example, the invasive Australian acacias have a lot of livelihood uses to rural communities around the world (Kull et al., 2011). Also, several invasive alien species are used by several communities as a raw material for craftwork, thus providing the much–needed income to local people (Kannan et al., 2016).

Invasive alien plants have detrimental costs which may be expressed economically and ecologically (Pejchar and Mooney, 2009; Semenya et al., 2012). These costs range from changes in livelihoods, ecosystem functions and economic costs incurred eradicating and managing the invasive plants (Shackleton et al., 2018). These can include (i) altered habitats for species and change in availability of food resources (Vardien et al., 2012; Jevon and Shackleton, 2015), (ii) the suppression of regeneration for native vegetation through release of allelochemicals (Vardien et al., 2012), and (iii) the harbouring of insects such as the tsetse fly (*Glossina* spp) which causes sleeping sickness in local communities (Ngorima, 2016).

Alien aquatic weeds prevent the access of sunlight, thereby affecting the entire food chain (Bromilow, 2010).It is observed that high impact on water resources increases when seasons change (especially into dry periods) because invasive alien plants still have access to groundwater in invaded riparian spaces (McNeely, 2004). Ruwanza (2015) highlighted that the invading of river catchment by alien plants do not only affect the water system alone but also all the sectors that are dependent on water for their daily activity. A study of exotic knotweeds (*Fallopian* spp.) on the European riparian river zones by the National Invasive Species Council (NISC, 2006) showed that the invasion at large scale tends to have effects on the reptiles, amphibians, mammals, and birds whose food consists mostly of arthropods and this seriously reduces the biodiversity.

The effects of reduction of streamflow and water pollution that have been observed nationally and globally has led to the assessment of both the extent and nature of alien invasive plants effects, on the natural resources (water, animals, and vegetation) in South Africa. This assessment led to the integration of management and control measures for invasive plants species that are both economically and environmentally friendly and while improving management methods to be species–specific than one method for all. This development has been focused on the ecological needs of riverine ecosystems (WFW, 2004); attention should be redirected to the vulnerable ecosystem of road–river interchange and wetlands (Gorgens and Van Wilgen, 2004; Richardson and Wilgen, 2004).

Spatial distribution of invasive alien species in South Africa

“Over 10 million ha of South African land have been invaded by alien invasive plant species, 9000 species are alien (with 8 000 herbaceous and 750 tree species introduced), but approximately 379 plants species are considered invasive” (NEMBA Alien and Invasive Species Regulations, 2016). According to Working for Water (WfW, 2014), about 20% of the identified alien plants are considered to be the major invader and only 15% are categorized as developing invaders. In South Africa, 13% of the native plants are Red–listed plants (threatened) and 11% is listed under conservation concern (Raimondo, 2011 and SANBI, 2017). The majority of woody invasive plants were intentionally introduced for plantation, erosion control, and landscaping, medicinal use or agricultural use (Chamier et al., 2012).

In South Africa, the spatial distribution of alien and invasive alien species has been estimated over years (Henderson and Wilson, 2017). In 1996/1997 a reconnaissance survey showed that about 10 million hectares have been invaded by woody invasive alien species and about 180 woody plants species were mapped (Richardson and Van Wilgen, 2004). The survey mapped Woody Invasive Plants (WIP) that had the potential impact on the water resources of South Africa. The South African Plant Invaders Atlas (SAPIA) has a set of recorded data for the whole country in terms of the invasive distribution that have been identified and were mapped (Henderson, 2001).

Richardson and Van Wilgen (2004) reported that in South Africa 7% of water is wasted by invasive alien plants especially the black wattle (*Acacia mearnsii*) and the water hyacinth (*Eichhornia crassipes*). Van Wilgen and De Lange (2011) projected that 30% of surface water runoff will be lost by the next 10 to 20 years while 74% will be lost by 20 to 40 years if nothing is done to clear these invasive alien plants. The projection was raised following a report of cost of invasive species done by Preenthlall et al. (2007) that the cost in South Africa is about R600 million per year to control invasive plant species. The Department of Environmental Affairs (DEA, 2009) reports that the cost to prevent invasive plants is much lower compared to the cost of clearing them.

The Working for Water (WfW) programme has been at the forefront of dealing with invasive species in South Africa and it has kept information on the geographical extent and the expenditure per species since the year 2002. The WfW programme has received much recognition from the government as it creates jobs which lead to poverty reduction in rural areas while equipping participants with knowledge on how to identify and manage alien plants. Levendal et al. (2008) argue that the effectiveness of its operation is limited because it has not implemented an effective system for monitoring and evaluating its projects.

Regulatory and legislative overview

Different legal guidelines affect how invasive alien species are managed. This is because different scholars have documented the economic and ecological trends that are posed by invasive alien plants species globally leading to different laws around the world with the common goal of eradication invasive alien species. In South Africa the government has prioritized the removal of invasive alien plants at all levels of the government and sectors (nationally, provincially, locally) by designing different mechanisms that can be applied for better management (Paterson, 2006). A summary of the relevant portions of the acts that govern the activities and potential impacts to the environment associated with the development are listed below.

Constitution of the Republic of South Africa

The Bill of Rights, in the Constitution of South Africa (No. 108 of 1996), states that everyone has a right to a non–threatening environment and requires that reasonable measures are applied to protect the environment. This protection encompasses preventing pollution and promoting conservation and environmentally sustainable development. These principles are embraced and given further expression in the National Environmental Management Act of South Africa (NEMA).

National Environmental Management Act

The National Environmental Management Act (NEMA; Act No 107, 1998) requires that measures are taken to prevent pollution and ecological degradation; to promote conservation; and to ensure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development. In addition, it makes provision:

1. That the disturbance of ecosystems and loss of biological diversity are avoided, or where they cannot be altogether avoided, are minimized and remedied:
2. That a risk–averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and

3. Sensitive, vulnerable, highly dynamic or stressed ecosystems, such as coastal shores, estuaries, wetlands, and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

Conservation of Agricultural Resources Act

The Conservation of Agricultural Resources Act (CARA; Act 43 of 1983) regulates the utilization of the natural agricultural resources in order to promote the conservation of soil, water and vegetation and gives provision for combating of weeds and invader plant species. CARA is the current legislation used for the classification and control of weeds and invasive plants. Alien invaders are species that are of exotic, non–native or of foreign origin and usually invade undeveloped or disturbed areas. The Conservation of Agricultural Resources Act defines different categories of alien plants and those listed under Category 1 are prohibited and must be controlled while those listed under Category 2 must be grown within a demarcated area under permit. Category 3 plants includes ornamental plants that may no longer be planted but existing plants may remain provided that all reasonable steps are taken to prevent the spreading thereof, except within the flood line of water courses and wetlands. The abundance of alien species at the site should also be very low.

Environmental Conservation Act

The Environmental Conservation Act (ECA; Act 73 of 1989) provides for the effective protection and controlled utilization of the environment. This Act has been largely repealed by NEMA, but certain provisions remain, in particular provisions relating to environmental impact assessments. The ECA requires that developers must undertake Environmental Impact Assessments (EIA) for all projects listed as a Schedule 1 activity in the ESIA regulations (see https://www.eia.nl/en/countries/south+africa/esia–profile).

Protected Areas Act

The Protected Areas Act (act no 57 of 2003) provides for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes; for the establishment of a national register of all national, provincial and local protected areas; for the management of those areas in accordance with national norms and standards; for intergovernmental co–operation and public consultation in matters concerning protected areas; and for matters in connection therewith.

National Forests Act

The National Forests Act (No. 84 of 1998) provides for the protection of forests as well as specific tree species, quoting directly from the Act: "*no person may cut, disturb, damage or destroy any protected tree or possess, collect, remove, transport, export, purchase, sell, donate or in any other manner acquire or dispose of any protected tree or any forest product derived from a protected tree, except under a license or exemption granted by the Minister to an applicant and subject to such period and conditions as may be stipulated*".

Convention of Biological Diversity

The Convention of Biological Diversity, 1995, is an international legally binding treaty with three main goals; (i) conserve biological diversity (or biodiversity); (ii) ensure sustainable use of its components and the fair and (iii) equitable sharing of benefits arising from genetic resources.

Implications for conservation and management of powerline servitude linear corridors

Ecological infrastructure is the stock of functioning ecosystems that provides a flow of essential system services to human communities, such as the provision of fresh water, climate regulation and soil formation. Ecological infrastructure includes features such as healthy mountain catchments, rivers, wetlands, and nodes and corridors of natural grassland habitat which together form a network of interconnected structural elements within the landscape (Lopes et al., 2015). Should ecological infrastructure be degraded or lost, the flow of ecosystem services will diminish and ecosystems will become vulnerable to shocks and disturbances, such as the impacts of climate change (Walsh et al., 2015). It is therefore important to prioritise the control of invasive species that can otherwise contribute to the destruction of ecological infrastructure.

Most of the negative effects of invasive species have been observed to be correlated with the maximum density that a species can attain and its persistence at any site. This raises an argument in management strategy of whether the most heavily invaded area should be cleared first, or area of little invasion should be addressed first. Another dilemma is presented where some invasive species such as certain woody plants have beneficial effects. Certain weeds also have value in local communities, and the public do not perceive them as harmful. These can at times, be overlooked by protected areas' managers, conservationists and scientists. This raises an issue when selecting which alien species to control, for most of this alien species have become part of the community for some are used for traditional medicine, aesthetic values, food and firewood.

Ultimately, there is a consensus that invasive alien vegetation is a major threat to the natural habitat and causes impacts through:

1. competition – indigenous plant species are out–competed,

2. reducing habitat diversity (which directly impacts on the fauna);
3. habitat fragmentation (restricting natural movement of indigenous populations and species);
4. high consumption of water (an average *Acacia cyclops* tree can consume up to 150–200 litres of water per day);
5. the loss of biodiversity – flora, habitats and fauna (what essentially makes the area unique);
6. the loss of the scenic beauty of the area as the natural vegetation is replaced by dense stands of monotonous and unattractive stands; and,
7. the creation of large standing fuel loads which exacerbate the dangers of wildfires.

In light of these, they must be carefully managed within the landscape, which include linear powerline servitude corridors. As corridors act as passages for plants, animals, insects, birds to move from one region to the next, they also play a vital role in allowing species to move from a warmer to a cooler region, and vice versa. The corridor helps land users improve the way they manage the economic, social and ecological aspects of their environment. Projects can be devised to expand protected areas in the region, improve well–being in local communities, develop local economies, raise awareness and get industry involved. According to Mbedzi et al. (2016) including power line corridors in grassland conservation will be most successful in old, dry corridors with steep slopes and a history of use as pastures. Such corridors can be especially important habitats for grassland plants in areas where grazing or other traditional practices have ceased and become difficult to re–establish, such as is the case in urban areas. In turn, deterring the spread of alien species in power line corridors is especially needed in recently clear cut corridors on productive soils and close to the urban fabric. Utilizing such power line corridors in the struggle against invasive alien species is especially important in urban areas, where invasive species may already subject native biotas to heavy competition.

CHAPTER 3: MATERIALS AND METHODS

Study area

The study was carried out in Makhado (formerly Louis Trichardt) Local Municipality, Limpopo province of South Africa (Figure 3.1). The study area is approximately 8300 km², located at the foot of the Soutpansberg mountain range. The study was carried out on the servitudes of the 132KV Fundudzi (Figure 3.2) and Khakhu 22KV powerlines under Siloam Customer Service in April 2019.

The main economic activity for the majority of the population is subsistence farming, with either crop or livestock production being the most common. There is, however, an increase in degradation due to land use activities. The area is a significant birding area – many subtropical forests and savannah bird species are present in the area, including the grey–headed parrot and the Narina Trogon.

The area falls within a summer rainfall region of South Africa. The summer conditions are very hot and the temperature at night ranges from 10°C to 20°C, with an average daily temperature of 14°C to 34°C (Provincial Department of Agriculture, 2007). Thunderstorms may occur during November to March. The prevailing wind direction is north during the months of August to May and west to southerly during the other months (Provincial Department of Agriculture, 2007).

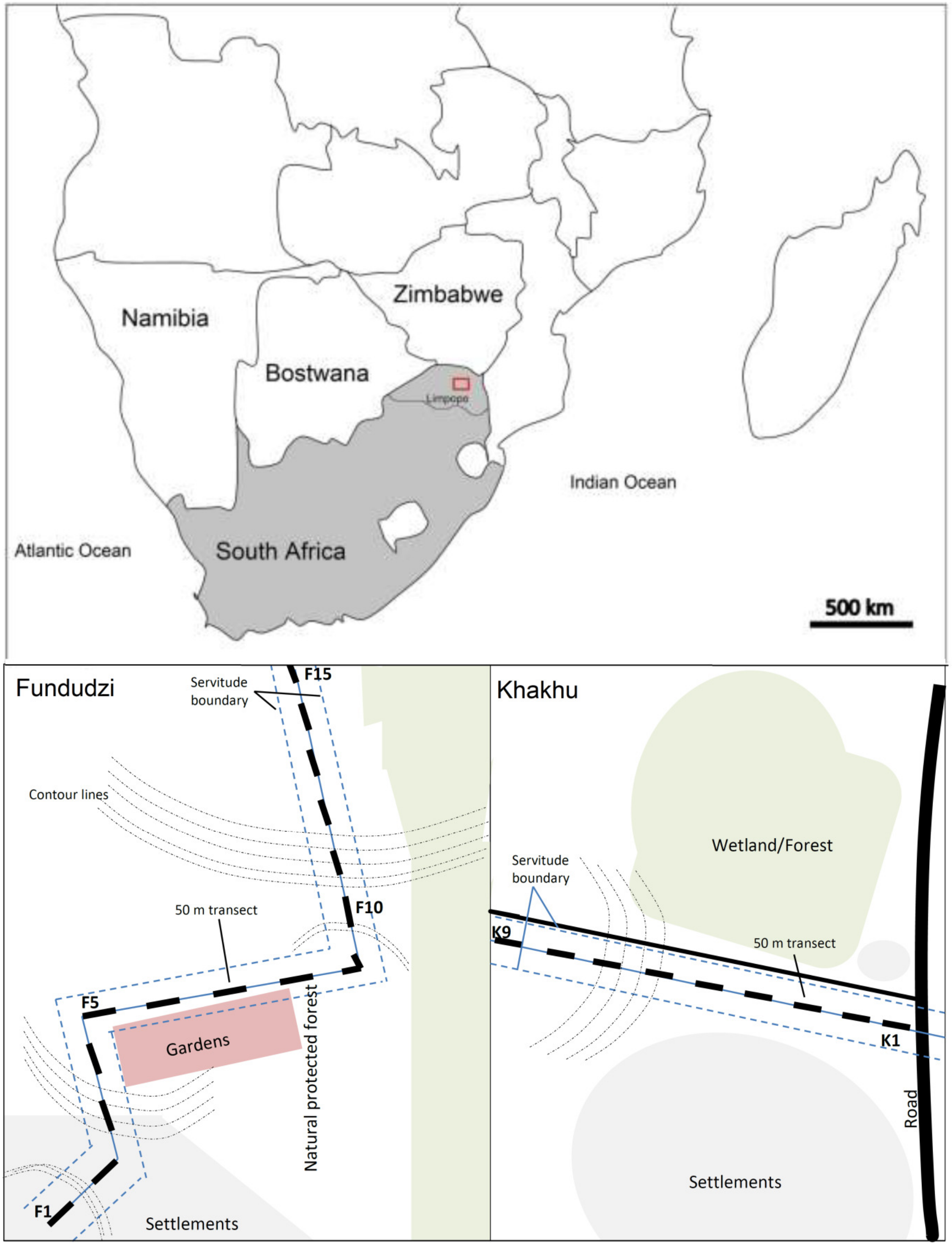

Figure 3.1. Location of the study areas within the Limpopo province of South Africa is indicated by the red square

Figure 3.2. Images of the Fundudzi 132KV power line and servitude

Natural vegetation

According to Hamann et al. (2015) the study area falls within the mixed bushveld, occupying an irregular belt on the gentle slopes to the mountains. Thathe Vondo Forest consists of giant hardwood and yellow wood trees, ferns, thick undergrowth and creepers. Perennial succulents and woody shrubs largely compose this arid vegetation, but annual herbs and grasses may periodically dominate the vegetation in certain parts. Three main vegetation types may be distinguished: (1) evergreen and deciduous bush, (2) subtropical forest and (3) temperate evergreen forests (Sinthumule, 2001; Mucina and Rutherford, 2006). Alien terrestrial (lantana *Lantana camara*, wild tobacco *Nicotiana glauca*, sesbania–red *Sesbania punicea*) and aquatic alien vegetation (water fern *Azolla filiculoides*, water hyacinth *Eichhornia crassipes*) are also found in the study area (Sinthumule, 2001; Mucina and Rutherford, 2006).

Geology

The main rock formations of the mountain comprise of sandstone, quartz sandstone and quartzite, with a couple of igneous intrusions consisting mainly of basalt and dolerite (Hahn, 2011). The main soils of the area are derived from weathered sandstone and quartzite, giving rise to sandy soils. In general these soils are relatively acidic and nutrient poor. The weathered lava gives rise to rich clay soils. Mineral rich areas are found both the north and south of the mountain, whereas the mountain itself is relatively poorly mineralised. The most abundant mineral is quartz, but of poor quality. Other minerals are iron, copper, refractory flint, salt, sillimanite, gold and coal (Hahn, 2011).

Sampling

The recovery of vegetation patterns is not necessarily accomplished by the usual statistical sampling procedures. Sampling theory emphasizes randomization in order to provide a probability structure for statistical analysis or to give credibility to the statistical model used (Gillison and Brewer 1985). Gillison and Brewer (1985) also, however, argue that randomization procedures may be counterproductive to the intent of ecological surveys, especially where the occurrence of natural pattern is known to be non–random.

Data sets need to be representative of the full range of variability in biological patterns in response to variability in the environment. In vegetation surveys, two aspects of pattern recognition should be considered: (1) the recognition of the pattern itself (e.g. a specific forest type) and (2) the frequency and distribution of patches of the pattern (i.e. spatial distribution, number and size of forest stands)

(Godron and Forman 1983, Gillison and Brewer 1985). In landscapes, vegetation patch frequency and distribution vary as a scale–sensitive function of environmental complexity and the level of resolution of the vegetation classifications used to characterise the pattern (Gillison and Brewer, 1985). This variability in landscape level vegetation configuration should be analysed in terms of the driving variables (the abiotic factors) controlling the vegetation. Given that the vegetation patterns within this study area were not known at the scale under which the study was undertaken, and thus, a line transect survey method was applicable under the powerline servitudes.

Servitudes of 1.5 km and 1 km were sampled for the Fundudzi and Khakhu powerlines, respectively. A transect method was used for counting and recording occurrences of the invasive alien species within the study. A 50 m transect, 2 m wide under the powerline was sampled and the next 50 m skipped from sampling (Figure 3.3). The transect method was considered a good technique based of point sampling to determine cover and point readings were taken systematically at all locations along the 50 m transect. All vascular invasive species were identified to species level within each and every species counted. The species on these transects were identified using identification guides by Palgrave and Palgrave (2002) and Bromilow (2010).

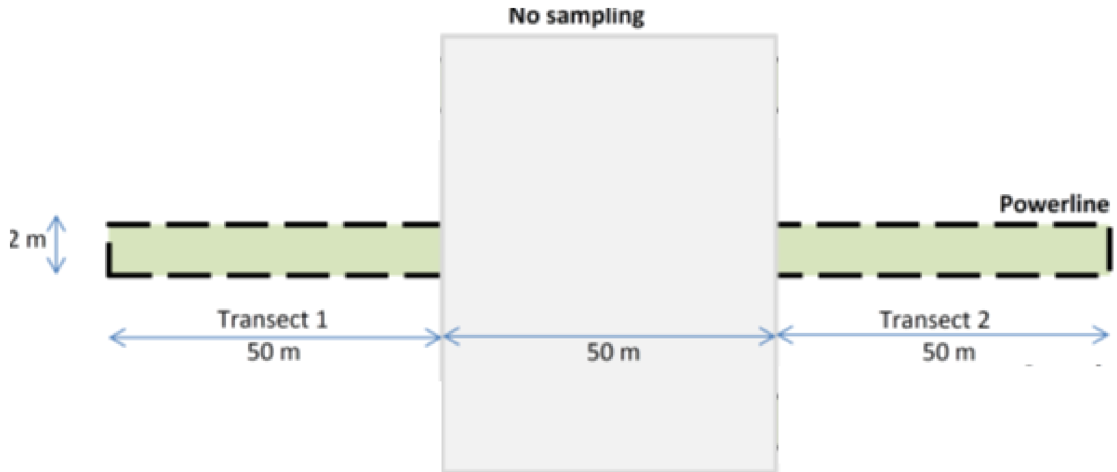

Figure 3.3. Outline of the transect sampling underneath the powerline servitudes

Alien and invasive plant species are categorised into four categories according to Bromilow (2010) and the amended Regulations (Regulation 15) of the Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983), namely:

8. **Category 1** are declared weeds that are prohibited from being planted and need to be controlled and managed. These plants have no purpose and pose a threat to the environment.

9. **Category 2** are declared invader plants with a commercial or utility value. These are invasive plants with commercial uses such as woodlots, animal fodder and soil stabilizer. These plants may be planted in a demarcated area under controlled conditions.

10. **Category 3** are ornamental plants that are currently growing and have escaped from other areas such as gardens but that have proven invasive. No planting of the plants in this category is allowed, nor trade in propagated material. Existing plants may remain but must be prevented from spreading.

11. **Weed plants** do not classify for any of the above categories, but can form dense stands. These plants are usually classified as annual species which germinate after disturbances such as clearing of natural vegetation.

However, for the current study, the following categories were used based on the revised Conservation of Agricultural Resource act (CARA) and the National Environmental Management Biodiversity Act (NEMBA Act 10 of 2004), and are thus included within the present assessment:

12. **Category 1a** plants are high–priority emerging species requiring compulsory control. All breeding, growing, moving and selling are banned.

13. **Category 1b** plants are widespread invasive species controlled by a management programme.

14. **Category 2** plants are invasive species controlled by area. Can be grown under permit conditions in demarcated areas. All breeding, growing, moving, and selling are banned without a permit.

15. **Category 3** plants are ornamental and other species that are permitted on a property but may no longer be planted or sold.

16. **Category X** plants which are proposed weeds or invaders are marked with an X followed by the category (*example*: X3).

Data analysis

All data were assessed for normality and homogeneity of variance and were found to conform to parametric assumptions using the Shapiro–Wilk's W and Levene's tests, respectively. Invasive alien species present within transect (*presence* or *absence*) and species dominance measured by occurrence within transect were calculated. To determine whether the invasive alien species communities differed between sites, a Distance–based PERMutational ANalysis Of VAriance (PERMANOVA; Anderson, 2001) in PRIMER version 6 add–on package PERMANOVA+ was used (Anderson et al. 2008). Each term in the analysis was tested using 9999 permutations (Anderson and ter Braak, 2003; Anderson et al., 2008). The Shannon–Weiner diversity index, taxa richness and evenness of the alien species were calculated for the two servitudes sites, with Shannon–Weiner diversity index and evenness being calculated for transects with 2 or more species. Non–parametric multiple one–way Kruskal–Wallis tests was used to test for differences in Shannon–Weiner diversity index, taxa richness and evenness between study sites using SPSS 16.0 for Windows software (SPSS Inc. 2007).

The magnitude of community differences of invasive alien species found within powerline servitudes was assessed using one–way Analyses of similarities (ANOSIM) performed on each Euclidean similarity matrix to determine resemblance in the invasive species community differences. The test statistic R and significance values were reported in Primer version 6 (Clarke and Warwick, 2001). Principal Coordinates Analysis (PCoA) (Legendre and Anderson, 1999; McArdle and Anderson, 2001) was used to visualise invasive alien species multivariate structure variation among the two sites (i.e. Fundudzi, Khakhu) and 25 transects (i.e. F1–F15, K1–K10) using square–root transformed data for invasive alien species abundances.

CHAPTER 4: RESULTS

Twelve invasive alien species were identified across the two study servitude sites (see Figure 4.1 for examples of the plants recorded; Tables 4.1 and 4.2). Nine invasive alien species were identified in Fundudzi dominated by common guava *Psidium guajava* (mean relative abundance 48.7 %), black–jack *Bidens pilosa* (mean relative abundance 23.4 %), and common lantana *Lantana camara* (mean relative abundance 15.4 %). Khakhu only had 6 species invasive alien species that were dominated by fierce thorn apple *Datura ferox* (mean relative abundance 17.7 %) and Khaki bush *Tagetes minuta* (mean relative abundance 67.3 %) (Table 4.1). Based on PERMANOVA analysis, significant differences (Pseudo–F = 1.89, p (Monte–Carlo) = 0.015) were observed for the invasive alien species community structure across the two powerline servitudes.

Table 4.1. Invasive alien species identified under the powerline servitudes/corridors highlighting the National Environmental Management: Biodiversity Act categories and the mean relative abundances (%)

Common name	Scientific name	NEMBA category	Fundudzi (%)	Khakhu (%)
Black–Jack	*Bidens pilosa*	1b	23.4	
Three lobe false mallow	*Malvastrum coromandelianum*	1b	0.5	
Black–bindweed	*Fallopia convolvulus*	1b	1.0	

Field dodder	*Cuscuta campestris*	1b	0.5	0.9
Silverleaf nightshade	*Solanum elaeagnifolium*	1b	3.5	9.0
Lantana	*Lantana camara*	1b	15.4	
Common guava	*Psidium guajava*	2	48.7	4.8
Gum tree	*Eucalyptus camaldulensis*	1b	4.0	
Fierce thorn apple	*Datura ferox*	1b		17.7
Khaki bush	*Tagetes minuta*	1b		67.3
Bugweed	*Solanum mauritianum*	1b	3.0	
Graveyard plant	*Catharanthus roseus*	3		0.3

[redacted]

Figure 4.1. Some of the different alien invasive plants [(a) fierce thorn apple *Datura ferox*, (b) silverleaf nightshade *Solanum elaeagnifolium*, (c) common lantana *Lantana camara*, and (d) black–jack *Bidens pilosa*] observed under the powerline servitudes/corridors with the study area

The invasive alien species observed along the powerline servitudes generally decreased as one moved away from areas with human activities. In Fundudzi (sites F9– F15) and Khakhu (sites K1, K2, K7 and K8), no invasive alien species were recorded, for Fundudzi sites F2 and F8, and Khakhu sites K4, K5 and K10, only one invasive alien species each was recorded (Table 4.2). Fundudzi sites F4–F8 and Khakhu sites K6 and K9 recorded two alien species each, whereas site F3, K3, and F1 recorded 3, 4 and 5 invasive alien species each, respectively (Table 4.2). High invasive alien species plant abundances were recorded for Fundudzi sites F1 (47 plants), F3 (34 plants), F4 (27 plants), F5 (66 plants) and F7 (17 plants) and Khakhu sites K9 (16 plants) and K3 (306 plants).

Table 4.2. Abundances of invasive alien species recorded within the two powerline servitudes in Limpopo province, South Africa

Species	**Fundudzi**								**Khakhu**					
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**K3**	**K4**	**K5**	**K6**	**K9**	**K10**
Bidens pilosa	43		1					3						
Malvastrum coromandelianum	1													
Fallopia convolvulus	1					1								
Cuscuta campestris	1											1	2	
Solanum elaeagnifolium	1	2	7											
Lantana camara			21						7		5	3	14	100

Psidium guajava		10	21					
Eucalyptus camaldulensis	26	17	45	4	9		16	
Datura ferox					8			
Tagetes minuta							59	
Solanum mauritianum							224	
Catharanthus roseus								1

In Fundudzi, the invasive alien species richness was highest at transect sites F1 (5 species) and F3 (3 species) (Figure 4.2a), whereas Khakhu sites K3 (4 species), K6 (2 species) and K9 (2 species) had the highest species richness (Figure 4.2b). Shannon–Wiener diversity index (H) was generally similar for Fundudzi sites F3–F7 (range 0.63–0.69), with the exception of site F1 which had a low diversity index (H = 0.41) (Figure 4.3a). For Khakhu, site K3 had the highest H of 0.79, followed by sites K6 (H = 0.56) and K9 (H = 0.38) (Figure 4.3b). However, the evenness was generally high for Fundudzi (mean = 0.78) compared to Khakhu sites (mean = 0.71) (Figure 4.3).

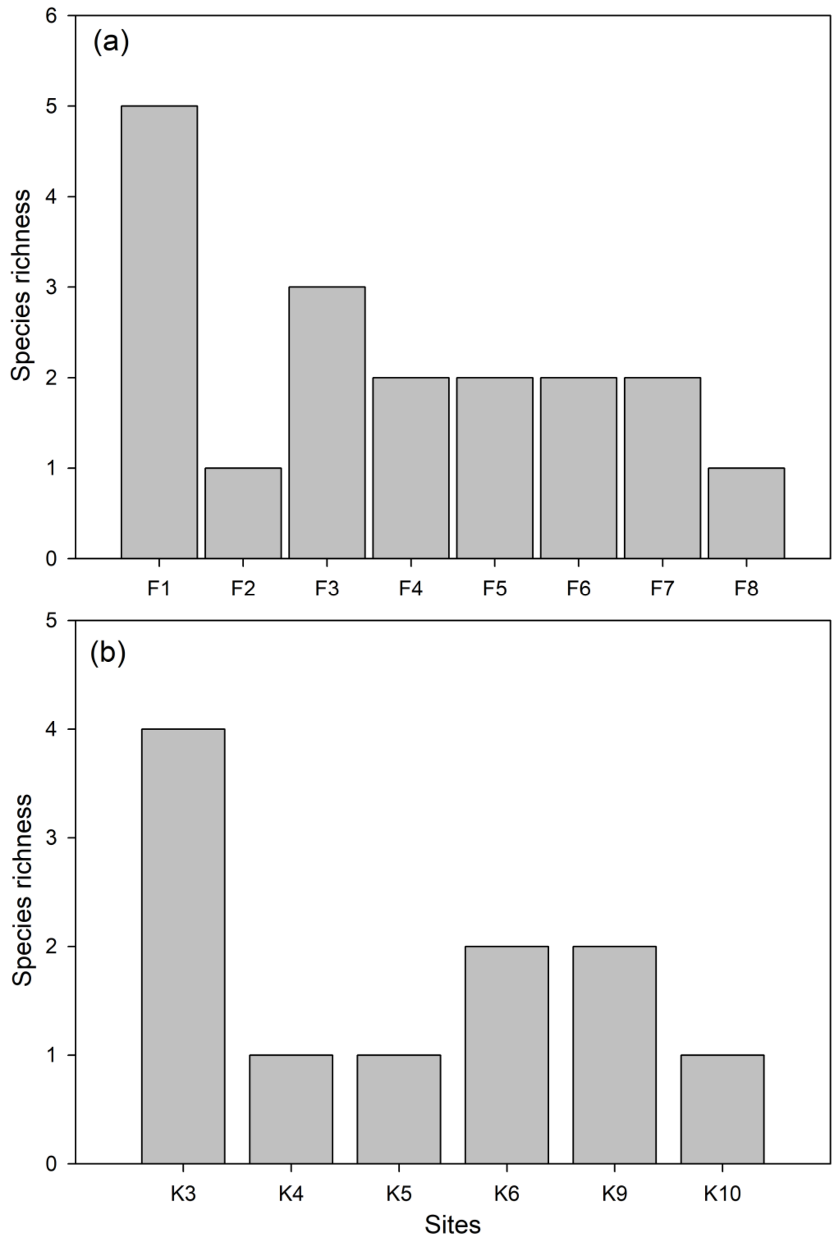

Figure 4.2. Species richness recorded within two transects powerline servitudes/corridors for (a) Fundudzi and (b) Khakhu

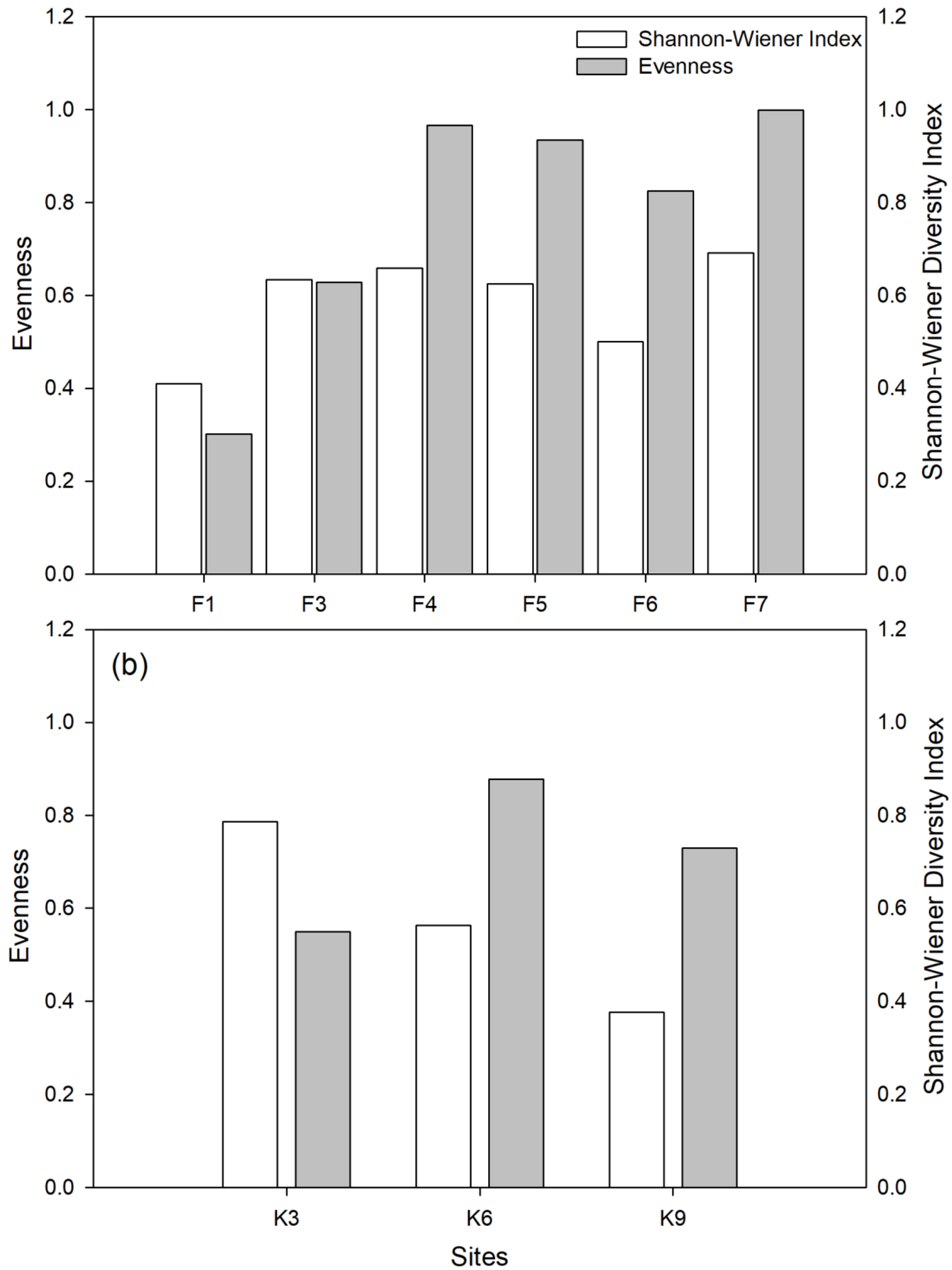

Figure 4.3. Variation in invasive alien species Shannon–Weiner diversity indices and evenness for the two servitude sites: (a) Fundudzi and (b) Khakhu

Principal Coordinates Analysis (PCoA) results are presented in Figure 4.4, with the first two axis of the selected exploratory variables accounting for 68.0 % of the total invasive alien species abundance variance, with PCO1 and PCO2 accounting for 43.2 % and 24.8 %, respectively. Weak overlaps in the polygons for the two powerline servitudes suggest that alien invasive populations are not similar and were different among sites with five groups being identifiable; *group 1* (site K3), *group 2* (site F1), *group 3* (sites F2, F8–F15; K1, K2, K4, K7, K8, K10), *group 4* (site K5, K6, K9) and *group 5* (sites F3–F7) (Figure 4.5). ANOSIM of invasive alien species community structure across the two study sites revealed no significant spatial differences (Global R = 0.01, p = 0.364) in community structure.

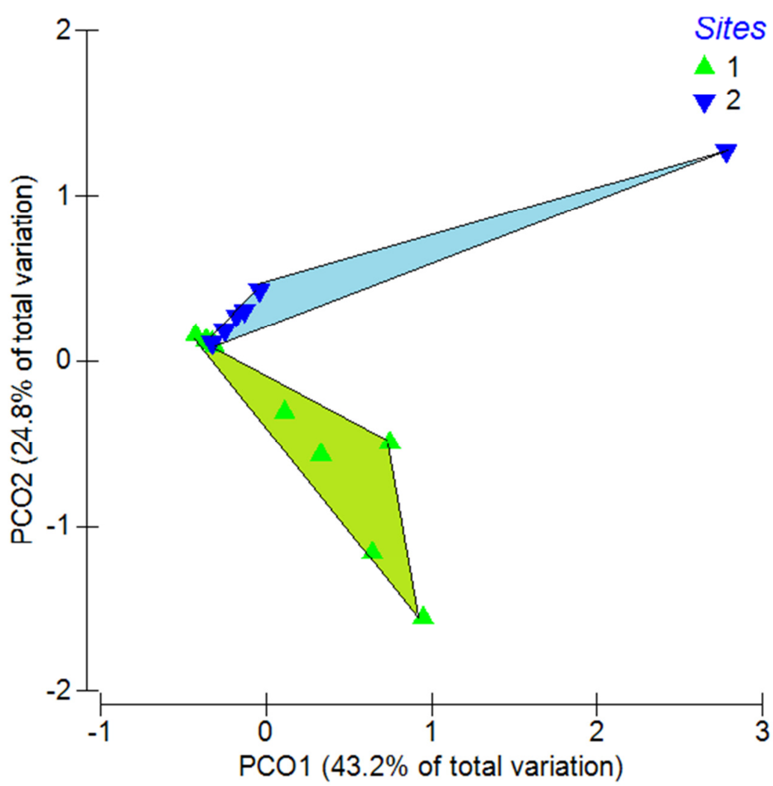

Figure 4.4. Principal Coordinates Analysis (PCoA) for invasive alien species recorded for the Fundudzi (site 1) and Khakhu (site 2) powerline servitudes. The PCoA was based on extended dissimilarities

and abundances which were square–root transformed. The servitude sites (i.e. indicated by shapes and colours) for the different transects are outlined by polygons.

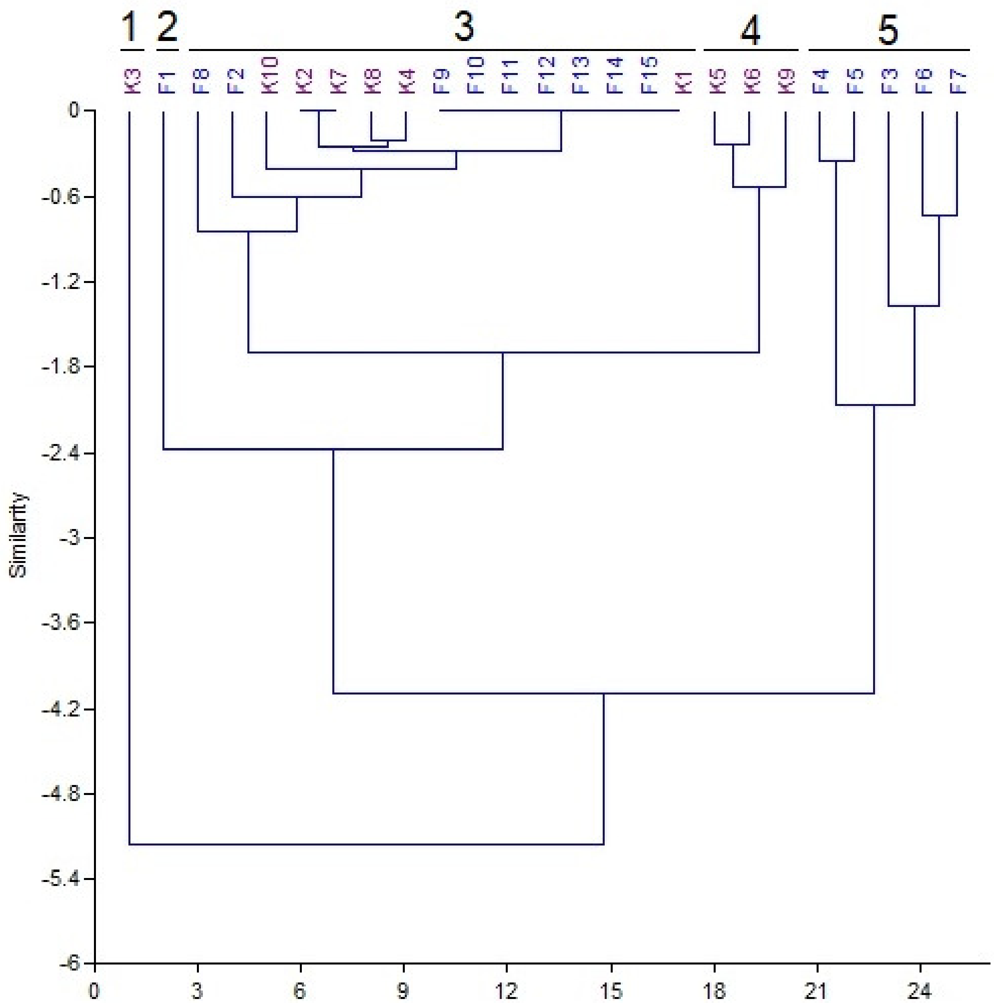

Figure 4.5. Cluster analysis highlighting grouping of invasive alien species within the two powerline servitudes/corridors. The letters and numbers under each branch indicate the transect number for each site i.e. F – Fundudzi, K – Khakhu

CHAPTER 5: DISCUSSION

General discussion

Similar to previous studies on open grassland mountain areas (Pykälä et al., 2005; Bennie et al., 2006; Lampinen et al., 2015) and invasion ecology (Davis et al., 2000; van Wilgen et al., 2020), the current study found that the greatest numbers of invasive species were found in corridors with abundant light and corridors that are close to human settlement areas (Table 4.2; Figures 4.2 and 4.3). In the current study, power line servitudes were favoured by alien species in areas close to both forests and the human settlement fabric, and areas which were characterised by productive soils and abundant light. From scientific literature, it has been observed that corridors crossing agricultural areas or those with a history as cultivated fields appear suitable for mostly invasive alien species, similar to the current study observations. This claim is supported by previous research, which observed that mature forests present only low levels of alien invasion (van Wilgen et al., 2020), while agricultural landscapes appear highly susceptible to invasion due to associated disturbance and structural homogeneity (Chytrý et al., 2009; Lampinen et al., 2015). The study findings may be related to the partial redundancy of present day land cover data, and should be investigated further with a more robust data set taking into account the soil types and several environmental variables that might affect the community structuring. The abundance and composition of invasive alien species also showed a significant level of spatial structuring which might be caused by either the environmental conditions favouring these species being spatially structured or by the limited dispersal of the species along the corridors (Dormann et al., 2007).

According to van Wilgen et al. (2020), certain invasive species are correlated to certain native species richness. Similar to their observations, findings in this study found invasive species such as common guava *P. guajava* and lantana *L.camara*, which are moist subtropical and pervasive/riparian invaders, respectively dominating the area. Their findings also suggested that whereas the moist subtropical native species are mostly encouraged by mean annual precipitation, invader species thrive in areas of increasing human footprint and mean soil water stress. Wild varieties of *L. camara* have been found to have higher shade and drought tolerances than their ornamental varieties, and therefore pose a higher threat to biodiversity (Guasekara & Ranwala, 2018). Coupled with increased human interference which affects soil moisture properties, *L. camara* was found in this study to dominate certain sites, with generally decreased species richness in the sites where it was found.

Sites that were close to human settlements had more gravel than those that were further away. These sites also had higher invasive species richness. This finding was consistent with El–Bana (2015), who found that mean invasive species richness was significantly higher in gravel pad plots compared to wetland plots in their study in Egypt. They also found that these gravel plots were dominated by ruderals, weeds and invasive species. Against the findings of Lampinen et al. (2015) who conducted a vegetation study in powerline corridors in Finland, our study would support that productive soils, abundant light and a dense urban fabric are promoting alien invasive species in powerline corridors in the study areas. For both early successional grassland plant species and disturbance–dependent alien plant species, it is important for light abundance, soil moisture, soil calcium concentration and soil productivity to be measured and controlled, as they were the most important factors determining growth (ibid.).

The type of plant species can suggest the types of management practices being utilised to maintain and manage powerline corridors. In the same way, they can also influence the type of plant species that exist in the corridor. Results in this study showed higher alien species richness in areas closest to human settlements, where clear–cutting was the most likely management strategy used. A combination of clear–cutting and slash piling promoted vertical development of tree sprouts which improved managements actions in a short period in powerlines in a study conducted in the USA (Coban et al., 2019). Their findings suggest similar methods were used in the study sites that had an abundance of common guava and gum tree *Eucalyptus. camaldulensis* that were near human settlements. Similar to these US study's findings, it was also observed that sites dominated by shrubs, such as lantana that were found in this study, suppressed the development and invasion of undesirable trees (Coban et al., 2019).

Forrester et al. (2005) investigated the impacts of increasing the intervals of herbicide or mechanical vegetation management on managed, early successional sites such as powerline corridors. They observed that total herbaceous cover and species richness increased with more regular treatments at shorter intervals. The percentage of non-native (invasive) species temporarily increased following treatment but declined to near pre-treatment levels again as woody cover increased. This would explain why early successional grassland species and disturbance–dependent alien invasive species are particularly problematic for regularly managed electric powerline corridors. Study observations support this claim, evidenced by the dominance of black jack *B. pilosa*, fierce thorn apple *D. ferox*, khaki bush *T. minuta* and lantana. This finding consequently has management implications for invasive alien species control, in that it can point towards the specific environmental conditions that favour these species. Their findings further corroborate observations made in this study of fewer invasive species variety where woody plants were present. A comparative study of two human modified landscapes, namely old fields and powerline corridors, observed that frequently maintained fields which were mowed annually had more abundant invasive plant species compared to powerline corridors that were maintained only at five year intervals using herbicide spraying and selective removal of trees (Eyitayo & McCarthy, 2020). The findings of this study when related to Eyitayo & McCarthy (2020) suggest that frequent maintenance and non–selective removal of plants is occurring in this study area. This perhaps is a consequence of zeal and poor training resulting in inability to differentiate invasive species from native ones, respectively. Furthermore, maintenance of corridors is primarily to ensure accessibility to the powerlines, and this would encourage unselective clearcutting of all vegetation.

Conclusion

The findings of this study point towards the importance of including power line servitude corridors in landscape conservation. Study observations suggest that powerline servitude conservation benefits would be most realised in servitude corridors closest to human settlements as these areas had more invasive alien plant species. Such corridors can be especially suitable habitats for invasive alien plants in areas where agriculture and urban developments are occurring or have occurred. Study findings also encourage management to be informed with knowledge on environmental factors that promote the growth and establishment of specific invasive species. Observations in this study have shown that for two groups of alien species, namely early successional grassland plant species and disturbance–dependent alien plant species, it is important for light abundance, soil moisture, soil calcium concentration and soil productivity to be measured and controlled, as they could be some of the most important factors determining growth. In turn, deterring the spread of alien species in power line servitude corridors is especially needed in recently clear cut corridors with productive soils and those located in close proximity or adjacent to human settlements. In doing so, attention must be given to the type of vegetation management method used, the physical environmental conditions (i.e. steep slopes, productive soils for example), and the frequency of maintenance, in addition to understanding the plant species that are being managed. Study findings also suggest that power line corridors can contribute to biodiversity conservation by providing habitats for native grassland species, as they appeared to have suitable conditions to promote their growth. They, however also can provide further footholds for invasive alien species, which already pose problems in urban areas. Ecologically informed management considering both safe electricity transportation and nature conservation could promote the former and prevent the latter.

Recommendations

This study was able to compare to species abundance and species richness of identified alien invasive plant species across selected sites located on two powerline corridors in South Africa. The study did not compare invasive alien species abundance and richness to adjacent landscapes. It also did not identify and analyse the relative abundance of invasive alien species to indigenous plant species within each site. Thus, to build on this study, studies that would also measure indigenous plant species abundance and richness across different sites located in powerline corridors are recommended (e.g. Wagner et al., 2014). Studies that also compare species richness and abundance with adjacent landscapes are also recommended, as these would show relationships that are important to conservation. Studies that show temporal changes in vegetation structure are also recommended. Lastly, the study findings recommend that future studies take into account environmental factors, particularly investigating various soil properties, and link these to invasive species, such as conducted by Lampien et al. (2015).

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