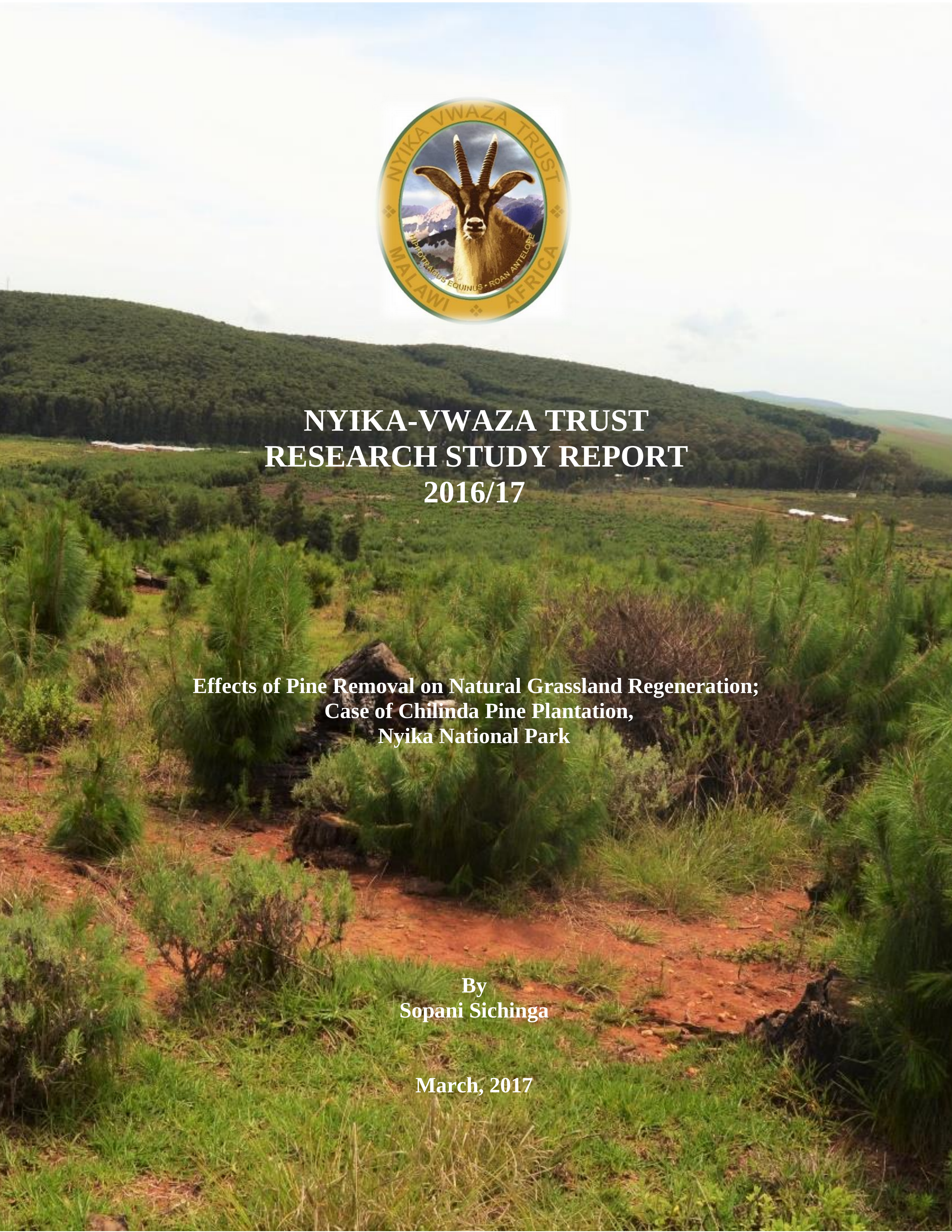

NYIKA-VWAZA TRUST RESEARCH STUDY REPORT 2016/17

Effects of Pine Removal on Natural Grassland Regeneration; Case of Chilinda Pine Plantation, Nyika National Park

By
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March, 2017

ACKNOWLEDGEMENTS

This work was sponsored by the Nyika-Vwaza Trust (UK). Without their generous financial support, and concern towards conservation of the Park this report would have not been possible. Special thanks are due to my supervisor Mr. George Z. Nxumayo for his valuable insight and constructive comments towards production of this report. Logistical support was provided by the DNPW through my supervisor. I am grateful to taxonomic specialists of the Mzuzu National Herbarium and Botanic Gardens for their assistance in plant verification. It would not be justice without mentioning my colleague Andrew Kanzunguze for his untiring support during field work and towards completion of this report. Further, thanks are due to Michael Siska (Chilinda Camp research officer) for his assistance in the field and valuable information he provided in as far as this study was concerned. Lastly, may I salute John Mabethi (Chilinda Camp manager) and the entire people at Chilinda Camp for making my stay there comfortable and conducive.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
ANOVA	: Analysis of Variance
CDC	: Colonial Development Corporation
DNPW	: Department of National Parks and Wildlife
GPS	: Global Positioning System
LSD	: Least Significant Difference
m	: Meters
NVT	: Nyika - Vwaza Trust
QGIS	: Quantum Geographic Information System
UK	: United Kingdom
UTM	: Universal Transverse Mercator
WGS	: World Geodetic System

SUMMARY

The pine plantation at Chilinda Camp was established in 1952 on the Nyika plateau as a pilot project for a potential pulpwood industry in Malawi under Colonial Development Corporation (CDC). Since 1957, after the project was handed over to the department of Forestry in Malawi, the idea of a pulpwood project was abandoned and the plantation was left to supply the Chilinda Camp with fuelwood. By the late 1990s, pine species had been observed to be spreading beyond the original confines on the plateau, and were listed as some of the key invasive species on the plateau. At this point, the Department of National Parks and Wildlife – Malawi (DNPW), decided to address the problem by setting an objective of reducing the main pine plantation from 500 hectares to 90 hectares, as well as constantly removing self-sown pines. The first mass logging exercises began in 2007, but no evaluation to monitor the type of vegetation developing in the cleared sites had been conducted. This study aimed at determining the impact of pine removal on natural grassland regeneration by assessing plant diversity in areas previously occupied by pine species at Chilinda. The study area was delineated based on vegetation status into three sites namely; recovering cleared site (site A), and bare cleared site (site B), as well as the grassland area which was used as a reference site. Plots of 20m x 30m were used to generate data on species composition, abundance and diversity. Simpsons Diversity Index (D) and Shannon's Evenness (E) were used to assess plant diversity in the study area, whereas T-test and One-way Analysis of Variance were conducted to compare mean abundance of species between and within sites in the study area. Results revealed little resemblance in terms of species composition in the recovering cleared site (D=14.9) and the bare cleared site (D=9.5) as compared to the natural Nyika grassland (D=41.2). Grasses were significantly low in abundance in both cleared sites than the grassland site ($P<0.05$), whilst plant invasives were more pronounced in both the recovering cleared site and bare cleared site. It was concluded that vegetation in the cleared sites has not sufficiently regenerated to resemble the plateau's natural grassland after almost 8 years since the last logging exercise. Much as complete grassland recovery after pine removal seems to be a slow process, management interventions aimed at speeding up recovery are recommended lest the area be completely re-taken by the dominant invasive reseeded pines. Particularly, priority would best be directed to the reseeded pines and the scrambling alien invasive bush (*Rubus ellipticus*) which seems to aggressively colonizing the cleared space.

CHAPTER ONE
INTRODUCTION

Background of the Study

Pine species are currently some of the well-known woody plant invaders of grasslands (Scholes and Archer 1997; Van Auken 2000; Ratajczak et al, 2012), following their prior introduction for commercial plantation forestry purposes in the southern hemisphere (Richardson et al, 1994). Specifically, pine species have been widely introduced in Southern and Eastern Africa, South America, and to a limited extent in Asia (Richardson, 1998a, b). At present, Van Wilgen (2015) reports at least 19 pine species that are becoming significant invasives in different areas of the southern hemisphere including South Africa and Malawi. The removal of such alien woody plants from grasslands and other non-forested ecosystems where they have naturalized has been reported to alter secondary plant succession trajectories**,** sometimes even to the detriment of overall ecosystem structure, functioning and provision of vital ecosystem services (Vitousek et al, 1987, Vitousek et al, 1997; Sullivan et al, 2007).

Several pine species were introduced in Malawi in the 1950's, in a number of areas (Nkaonja, 1982), and specifically on the Nyika plateau in 1952 for a potential pulpwood plantation in the country under the Colonial Development Corporation (CDC) (Dorward, 1990). Different pine species (unspecified) were planted in quarter acre plots across the plateau, but the main pine species planted at the time was *Pinus patula* in an area of about 500 hectares at Chilinda (Dorward, 1990). The aim of the trials was to determine the feasibility of large scale plantation forestry on the whole plateau, but the arrangement was abandoned due to a number of factors including inaccessibility of the Nyika (NVT News, 2006).

From the time the plantation was established, all silvicultural practices were supervised by the CDC until 1957, when management of the plantation was handed over to the Department of Forestry (Dorward, 1990). With the political pressures that were then taking place in the country, a shift in management priorities, coupled with unconvincing prospects for successful management and establishment of a pulpwood plantation, the project was abandoned and the remaining pine plantation was left to service the Camp at Chilinda (Dorwood, 1990). It is scantily reported that some of the other trial plots were removed in the 1980s, but currently, the main *P. patula* plantation (which is now about 65 years old with over-grown and untended trees) still exists at Chilinda. Nyika plateau being a protected as well as a catchment area, its conservation remains a priority. As of this 21st Century, serious concerns of pines spreading afield to other areas on the Nyika grassland plateau have been registered (NVT news, 2006; Kanzunguze, 2017). The pine control efforts attempted have largely bent on the rationale of logging the main plantation to leave a smaller portion for sustenance at the Camp as well as constantly removing self-sown pines and burning the stumps to cut further spread of the species and encourage recolonization of native grassland (NVT news, 2007). Logging operations to reduce the plantation from about 500 hectares to 90 hectares started in the year 2007 when the Department of National Parks and Wildlife (DNPW) granted a logging concession to a contractor (Simkoko, 2017). As for removal of self-sown pines, this has been happening since 2007 though in an intermittent fashion because of the limited resources.

The current study focused on assessing the effects of these control attempts especially that of reducing the plantation the purpose of promoting natural grassland regeneration at Chilinda Camp. The aim was to synthesize practical recommendations for management in as far as grassland restoration at Chilinda, as well as biodiversity conservation on the Nyika plateau is concerned.

Problem Statement

About 10 acres of pine were cleared by the year 2007 from Chilinda plantation (NVT news, 2007). Since then however, no assessment has been conducted to determine the newly developing flora on the cleared sites. Empirically speaking, this makes it unclear as to whether pine removal has indeed fostered the recolonization of the plateau's grassland species or promoted a plant succession trend not in favor of grassland species, such as promotion of invasive plants. The paucity of such information limits managements' assessment of whether there is active grassland restoration or there is a need for more appropriate grassland restoration interventions by management.

Objectives

General Objective

The overall objective was to determine the effects of pine removal on plateau grassland regeneration.

Specific Objective

- To determine the species composition in sites cleared of pines.
- To compare species diversity between the sites cleared of pine and plateau grassland.

Research Questions

- What species are coming into the sites cleared of pines?

- Is the diversity of plant species developing in sites cleared of pine similar to that of plateau grasslands?

Significance of the Study

Findings from this study will contribute to DNPW managements' knowledge and understanding of grassland re-establishment following pine removal on the Nyika plateau in Nyika National Park. The report will also provide a reference point from which future studies can assess the status of grassland regeneration on the plateau, as well as contribute to overall invasive plant management and control in Malawi's protected areas

CHAPTER TWO
METHODOLOGY

Study Site

The study was conducted on the Nyika plateau, at Chilinda Camp in Nyika National Park. The plateau is a montane grassland dominated with sub montane forest, roughly oval in shape and oriented in a northeasterly direction lying between 10º15'–10º50'S and 33º35'–34º05'E (Burrows et al, 2005). The plateau was contaminated by the invasive alien plants during 1950's introduced for various reasons, including a pine plantation covering an extensive area (about 500 hectares). To date, this has threatened the value of the plateau as a conservation area, and so served as a sufficient cause for reducing the plantation. So far, the removed portion of the plantation is quite fragmented in that one part of it is dominated by thick stands of reseeded pines, another has been developed for staff housing, another is in the process of recovering with different species and still more another has been heavily eroded. This study focused on the latter two parts of the removed portion which were labelled site A and B respectively (Figure 1 and 2), and a description of the other part dominated by thick stands of reseeded pines has been given at the Appendix.

Figure 1: Cleared sampled sites: Recovering site (A) – left, and Bare site (B) – right.

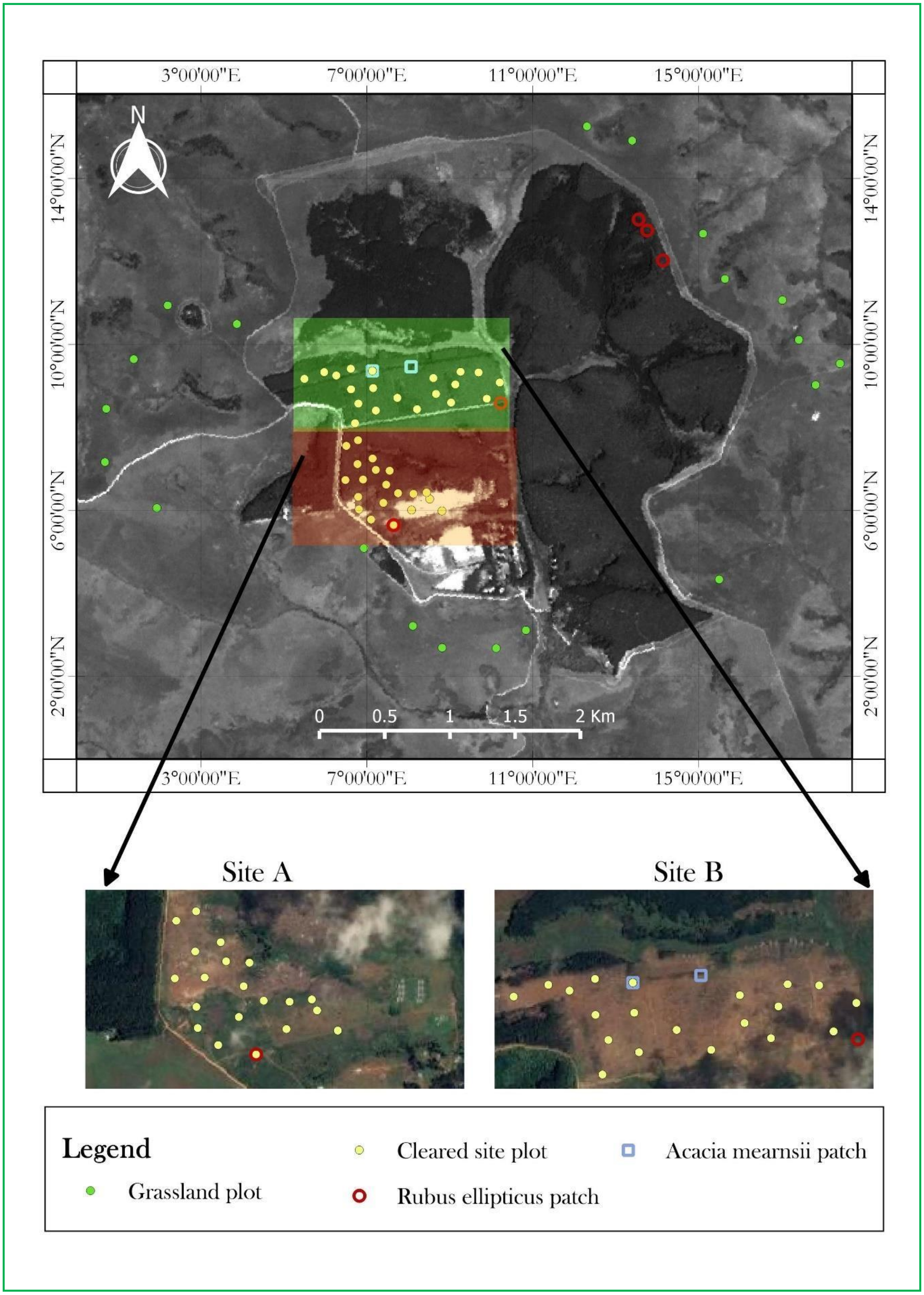


Figure 2: Map showing Chilinda Camp and the plots laid in the study area

Study Design and Sampling

The study assumed a survey design with statistical analyses conducted were necessary. A total of 20 plots of 20m * 30m each were pegged out randomly within each sampled sites (A and B) as well as on the grassland area around the plantation at a distance of approximately ≥ 50m of each other giving an overall total of 60 sampling plots. In each plot, 10 quadrats of $1m^2$ (randomly laid) were used to collect data on herbaceous and grass species whilst complete counts were recorded for pine saplings and other shrubs.

Data Collection

Data collection was carried out in January (2017) to coincide with the blooming of Nyika grasslands. Species identification in the field was done with the help of plant checklists (Plants of the Nyika Plateau and Photographic Guide to Wildflowers of Malawi), and later verified at the Mzuzu National Herbarium and Botanic Gardens. All identified species were categorized into 5 groups namely Herbs, Grasses, Shrubs, Sedges and Invasives. Trees (pine saplings and *Acacia mearnsii*) were included in the shrub category as they were less than 4m in height. Species counts were used to generate data on plant abundance as well as to assess plant diversity in sampled plots. Percentage cover was estimated for plant species that could not be easily counted. In addition to GPS coordinates (in WGS 84 datum) collected for all laid plots (Appendix 3), visual descriptions were recorded for invasive plant species that formed thick patches approximately ≥ $5m^2$ (Table 3 of Appendix 3). All collected data was finally organized using Microsoft Office Excel 2016, and maps were produced using Quantum GIS version 2.8.1.

Data Analysis

For each plant species category (grasses, herbs, shrubs, sedges and invasives) abundance values were calculated using Microsoft Office Excel 2016. Species diversity was determined using Simpson's Reciprocal Index (D) and evenness was assessed using Shannon-Wiener Index of evenness (E), for the purpose of generating information on both diversity and evenness. One-Way Analysis of Variance and Students' T-test were conducted to test significant differences in means in plant abundances between and within sites.

CHAPTER THREE

RESULTS AND DISCUSSION

What species are coming into the sites cleared of pines?

A total of 102 plant species were identified in the all sampled plots, distributed among the sites as illustrated in figure 3 below. Lists of species are presented in tables 1 to 3.

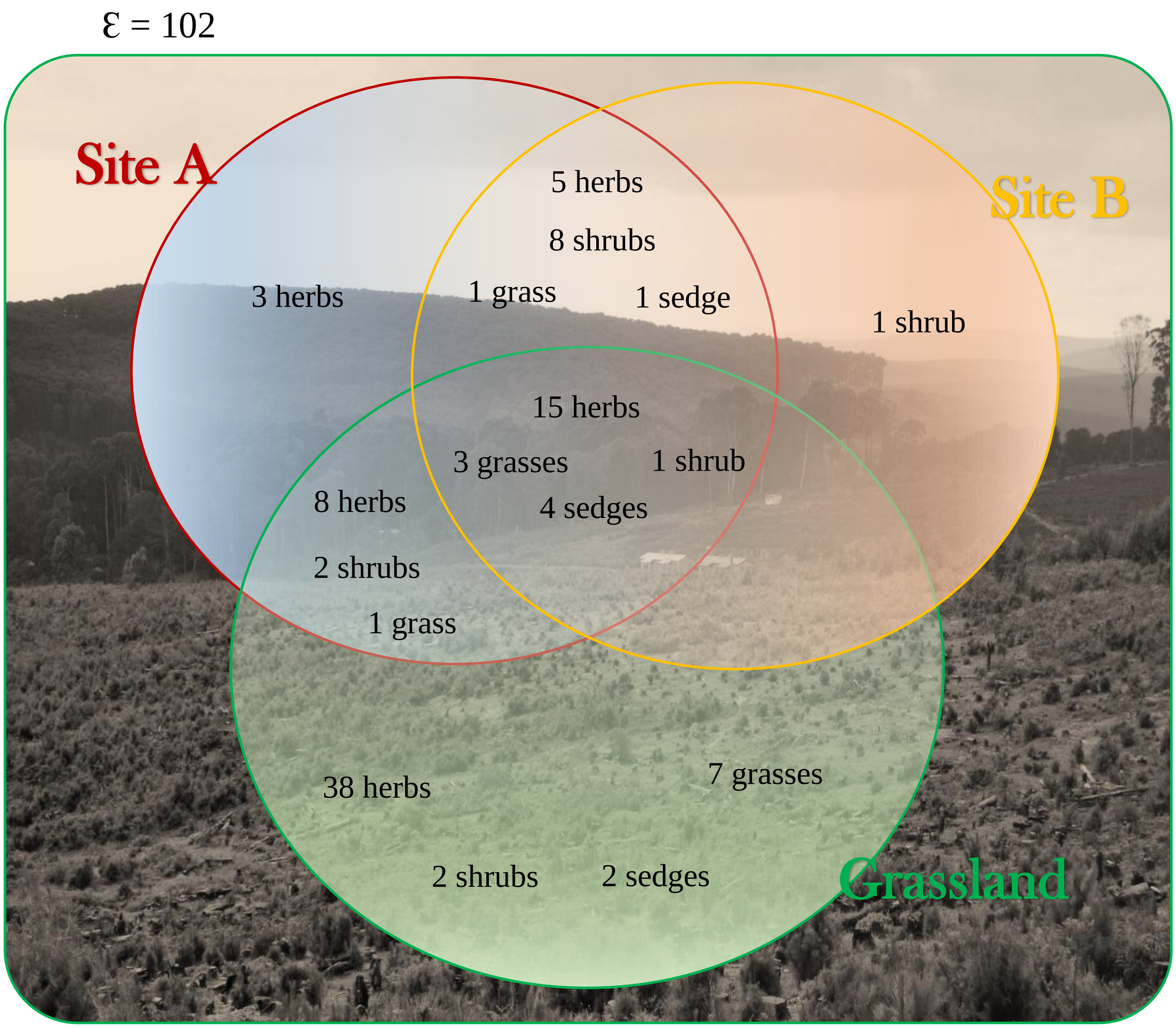


Figure 1: Venn diagram showing plant species distribution per site in the sampled area

Table 1: Plant species uniquely distributed among plots from sites A, B, and the grassland.

Species	**Category**	**Sites where present**
Gerbera ambigua	Herb	A
Satureja punctate		
Solanum aculeastissimum		
*Acacia mearnsii **	Shrub	B
Pennisetum clandestinum	Grass	A and B
Anisopappus kirkii	Herb	A and B
*Pteridium aquilinum**		
Crassocephalum rubens		
Digitialis purpurea		
Helichrysum sp		
Buddleja salviifolia	Shrub	A and B
Hagenia abyssinica		
Myrica salicifolia (mollera)		
*Pinus patula**		
*Pine kesiya**		
Podocarpus milanjianus		
*Rubus ellipticus**		
Stoebe kilimandscharica		
Coleochloa setifera	Sedge	A and B
Exotheca abyssinica	Grass	A and Grassland
Anisopappus chinensis	Herb	A and Grassland
Conyza mildbraeddii		
Gnidia kraussiana		
Helichrysum nitens		
Rumex abyssinicus		
Stomatanthes africanus		
Vernonia natalensis		
Geranium vagans		
Rubus chapmanianus	Shrub	A and Grassland
Microglossa pyrifolia		

NB: Species with an asterisk (*) are invasive. Total number of species (n) =30.

Table 2: Plant species identified in plots from all sites

Species	**Category**
Eragrostis capensis	Grass
Melinis repens	Grass
Sporobolus subtilis	Grass
Aeschynomene oligophylla	Herb
Biophytum nyikense	Herb
Crassocephalum sarcobasis	Herb
Commelina Africana	Herb
Conyza aegyptiaca	Herb
Conyza stricta	Herb
Erigeron karvinskianus	Herb
Helihrysum chloroforum	Herb
Helichrysum herbaceum	Herb
Helichrysum splendidum	Herb
Helichrysum setosum	Herb
Launaea rarifolia	Herb
Senecio hochstetteri	Herb
Tolpis capensis	Herb
Veronica abyssinica	Herb
Hypericum revolutum	Shrub
Bulbostylis collina	Sedge
Courtoisina cyperoides	Sedge
Sedge sp (other)	Sedge
Cyperus pseudoleptocladus	Sedge

NB: Total number of species (n) = 23; Grasses (3), Herbs (15), Shrubs (1), Sedges (4)

Table 3: Plant species identified in grassland plots only.

Species	**Category**	**Species**	**Category**
Alloteropsis semialata	Grass	*Hemezygia bracteosa*	Herb
Diheteropogon amplectens	Grass	*Helichrysum abietinum*	Herb
Loudetia simplex	Grass	*Helichrysum ceres*	Herb
Microchloa caffra	Grass	*Helichrysum plantaginifolium*	Herb
Monocymbium ceresiiforme	Grass	*Hypoxis goetzei*	Herb
Panicum brevifolia	Grass	*Hypoxis polystachya*	Herb
Panicum monticola	Grass	*Impatiens assurgens*	Herb
Alysicarpus rugosus	Herb	*Inula glomerata*	Herb
Artemisia afra	Herb	*Justicia linearispica*	Herb
Blumea axillaris	Herb	*Kniphofia splendida*	Herb
Brachyachne fulva	Herb	*Lobelia ovina*	Herb
Chamaecrista Mimosoides	Herb	*Oxalis chapmaniae*	Herb
Commelina benghalensis	Herb	*Pelargonium luridum*	Herb
Cyanotis longifolia	Herb	*Plectranthus goetzii*	herb
Dolichos kilimandscharicus	Herb	*Plectranthus horridus*	Herb
Dryopteris sp	Herb	*Plectranthus esculentus*	Herb
Gladiouis dalenii	Herb	*Gerbera viridifolia*	Herb
Elaphoglossum salicifolium	Herb	*Plectranthus salubenii*	Herb
Eriosema buchananii	Herb	*Plectranthus nyikensis*	Herb
Eriospermum kirkii	Herb	*Trifolium semipilosum*	Herb
Euphorbia depauperata	Herb	*Anthospermum whyteanum*	Shrub
Eulophia ovalis (orchid	Herb	*Protea heckmanniana*	Shrub
Fuirena stricta	Herb	*Kyllinga alba*	Sedge
Galium bussei	Herb	*Kyllingiella microcephala*	Sedge
Gnidia bucananii	Herb		

NB: Total number of species (n) = 49; Grasses (7), Herbs (38), Shrubs (2), Sedges (2)

The presence of only 19 species unique to the cleared sites leaves room for much speculation regarding potential physiochemical and/or biological alterations in the soil, both as a result of prolonged pine existence as well as pine removal on the sites. It is known that older pines produce significant changes to soil characteristics, including declines in pH, base saturation, exchangeable Ca^{21+}, Mg^{21+}, and K^{1+}, as well as increases in Na^{1+}, Al^{31+} and H^{1+}, that eventually become irreversible (Amiotti et al, 2000; Amiotti et al, 2007) and disrupt the recuperation capacity of grasslands in the area (Cuevas et al, 2010). Additionally, site B appeared to be heavily eroded (most likely as a result of pine removal and burning) and presented fewer species than site A, which seems to be another likely cause for poor plant colonization in the cleared site. Further, the remaining pine plantation surrounding the study area presents a potential barrier between the grassland area (source of seeds and plant propagules) and the cleared sites, which in agreement with Bischoff et al, (2009), could be another challenge for successful speedy re-colonization of native plateau vegetation in the cleared sites.

Generally speaking, cleared sites showed little resemblance in terms of species composition to the natural Nyika grassland. Although 23 species were common between the cleared site and grassland (Table 2), the cleared sites were still less 49 species (Table 3), which is almost half of all identified species. Bredenkamp et al, (2002) state that plant succession after an ecological disturbance results in a secondary grassland which does not resemble the climatic climax grassland. Both in view of this statement and the shrub species dominating the cleared sites, there is a high likelihood of witnessing the creation of a shrub-dominated grassland within the cleared sites. And that is only if the self-sown pines will be removed continually, otherwise there are already high chances for the establishment of a self-sown pine plantation.

Four invasive plants species were also identified in the cleared sites and these were *Acacia mearnsii* (Black wattle), *Rubus elllipticus* (Himalayan Raspberry), *Pteridium aquilinum* (bracken fern), and saplings of *Pinus patula* and *Pinus kesiya* (Figure 4). Some were intentionally introduced for various reasons while some were not, such that their introduction pathway to the Nyika plateau remains a mystery. The identified *P. kesiya* could be one of those four unspecified pine species planted in 12 quarter – acre trial plots as reported by Dorward (1990). Between the cleared sites A and B, *P. kesiya* as well as *R. ellipticus* were significantly abundant in site A than site B (Table 4). Within the same sites however, *P. kesiya* was the least abundant invasive plant as compared to the rest of the other invasives in site A (P<0.01), whilst *P. patula* was the most abundant invasive plant in site B (Table 5).

Table 4: Abundance of invasive plants between sites A and B

SITE	SPECIES			
	R. ellipticus	*P. aquilinum*	*P. patula*	*P. kesiya*
A	10±3.77 **a**	18.85±3.83	16.15±1.85	2.9±0.7 **a**
B	4.85±3.41 **b**	12.55±3.37	18.2±1.5	0.75±0.6 **b**
LSD	3.829	6.991	2.077	2.286
P-value	0.027	0.271	0.2	0.003

NB: Data are means ± standard error. Values with different superscripts are significantly different within each column.

Table 5: Abundance of invasive plants within sites A and B

CATEGORY	SITE	
	A	**B**
R. ellipticus	10±3.77 **a**	4.85±3.41 **c**
P. aquilinum	18.85±3.83 **a**	12.55±3.37 **b**
P. patula	16.15±1.85 **a**	18.2±1.5 **a**
P. kesiya	2.9±0.7 **b**	0.75±0.6 **c**
A. mearnsii	-	1.3±1.15 **c**
LSD	6.739	5.445
P-value	0.001	<0.001

NB: Data are means ± standard error. Values with different superscripts are significantly different within each column.

From the field observation, *R. ellipticus* rarely occurred as a single plant. In most cases they appeared to occur in patches covering not less $1m^2$, demonstrating the point that it also spreads by suckers. Thick patches of greater than $5m^2$, approximately >3.5m in height (Figure 5) were also observed north-east of the camp in a cleared site that has now heavily reseeded with pines. *Acacia mearnsii* was only present in cleared site B where two patches of not less than $20m^2$ reaching up to 2m in height were noted (Figure 5). It would have been expected to find more *Acacia mearnsii* in cleared site A because of its close proximity to previous *Acacia mearnsii* stands established in the 1950s (Dorward 1990), but this is not so since not even a single *Acacia* sapling was observed in cleared site A except for the two patches in cleared site B. In other words, *A. mearnsii* is not spreading and/or recolonizing worrisomely in contrast to other invasives such as *R. ellipticus* in the cleared sites. However, further scientific enquiry from an edaphic perspective into this matter would probably furnish a better explanation.

Recruitment of reseeded pine saplings was also noticeable in both cleared sites. High propagule pressure from the existing surrounding pine plantation, and possibly appropriate environmental conditions could have played a big role for pine recruitment in general. If these pine saplings are left unattended, the entire cleared site might just develop into another complete pine plantation, in addition to the one that has already developed north of the cleared sites.

The identified invasive plants seem to vigorously colonize the cleared sites from the findings of this study as is common for most invasive plants elsewhere (Steckel and Harper, 2008). This can mostly be attributed to edaphic modifications such as changes in pH, alterations in nutrient cycling, soil microbiology as well as fuel/litter dynamics arising from the prolonged presence and removal of pine on the sites, as well as the use of fire (Mitchell et al, 1999; Ehrenfeld et al. 2001; Callaway and Ridenour 2004; Heneghan et al, 2006; Stinson et al, 2006; Cuevas 2010). To cement this assertion, a study on soil changes in the cleared sites would be necessary.

On fire in particular, much has been explained regarding how it often favors the colonization and spread of invasive plants (Brooks et al 2008**)**. For instance, *P. aquilinum* regenerates rapidly after fire and may dominate recently burned areas (Primefacts, 2010), *R. ellipticus* re-sprout vigorously after fire (Lower et al., 2000) and *A. mearnsii* germination is also stimulated by fire (GISD, 2005). Whilst post-fire conditions are ideal for many grass and herbaceous plant species, opportunity for plant invasions is also created when propagules of invasive plants are available (Brooks et al, 2008). In the current case, fire was once used to burn branches and old trunks of pine trees (NVT news, 2006). This could also be another cause for the current status of invasives in the cleared sites.

Figure 4: Identified invasive plants in cleared sites. From top left to bottom right: *A. mearnsii*, *P. aquilinum*, *R. ellipticus*, *P. kesiya and P. patula.*

Figure 5: *Rubus ellipticus* patch (top) and *Acacia mearnsii* patch (bottom)

Is the diversity of plant species developing in sites cleared of pines similar to that of grasslands?

Results from the study revealed that herbs and grasses were significantly more dominant ($P<0.01$) in the grassland area than in the cleared sites, whereas shrubs dominated the cleared sites unlike the grassland area (Table 6). Whilst herbs were the most statistically abundant group of plant species in both cleared sites and the grassland area ($P<0.01$), invasives were equally the most abundant plant species in the cleared sites (Table 7). These are also illustrated in figures 6 to 8.

Table 3: Abundance of plant categories between sites

SITE	**CATEGORY**				
	Grasses	Herbs	Shrubs	Sedges	Invasives
A	11.21 ± 1.81^{b}	38.87 ± 2.43^{b}	6.37 ± 0.89^{a}	7.06 ± 0.96	36.5 ± 3.03
B	9.55 ± 1.9^{b}	39.75 ± 4.46^{b}	7.59 ± 1.2^{a}	6.22 ± 1.21	36.9 ± 3.66
G	21.53 ± 0.99^{a}	61.07 ± 0.67^{a}	2.98 ± 0.27^{b}	5.8 ± 0.65	-
LSD	3.829	6.991	2.077	2.286	8.002
P-value	<0.001	<0.001	0.001	0.644	0.935

NB: Data are means ± standard error. Values with different superscripts are significantly different within each column.

Table 4: Abundance of plant categories within Sites

CATEGORY	**SITE**		
	A (Cleared)	**B** (Cleared)	**G** (Grassland)
Grasses	11.21 ± 1.81^{b}	9.55 ± 1.9^{b}	21.53 ± 0.99^{b}
Herbs	38.87 ± 2.43^{a}	39.75 ± 4.46^{a}	61.07 ± 0.67^{a}
Shrubs	6.37 ± 0.89^{b}	7.59 ± 1.2^{b}	2.98 ± 0.27^{d}
Sedges	7.06 ± 0.96^{b}	6.22 ± 1.21^{b}	5.8 ± 0.65^{c}
Invasives	36.5 ± 3.03^{a}	36.9 ± 3.66^{a}	-
LSD	4.708	6.626	1.639
P-value	<0.001	<0.001	<0.001

NB: Data are means ± standard error. Values with different superscripts are significantly different within each column.

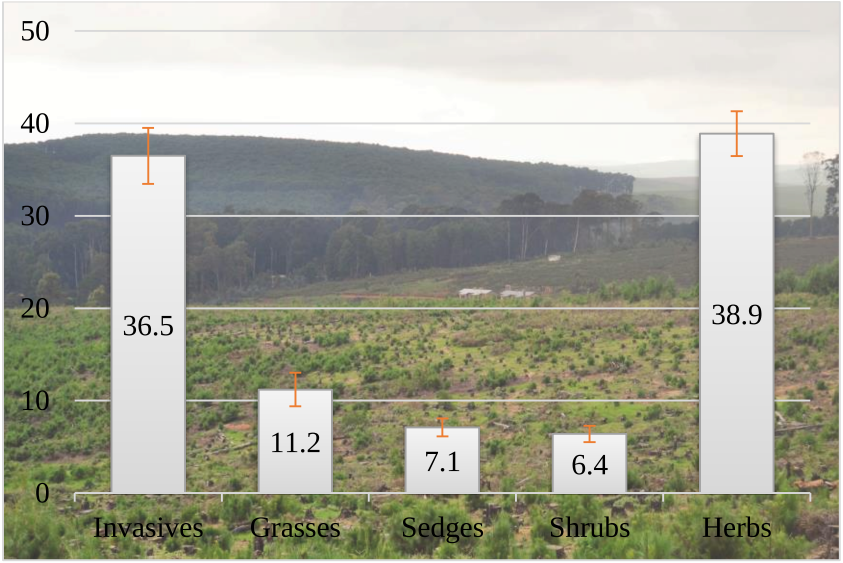


Figure 2: Mean Abundance of Species for Cleared Site A

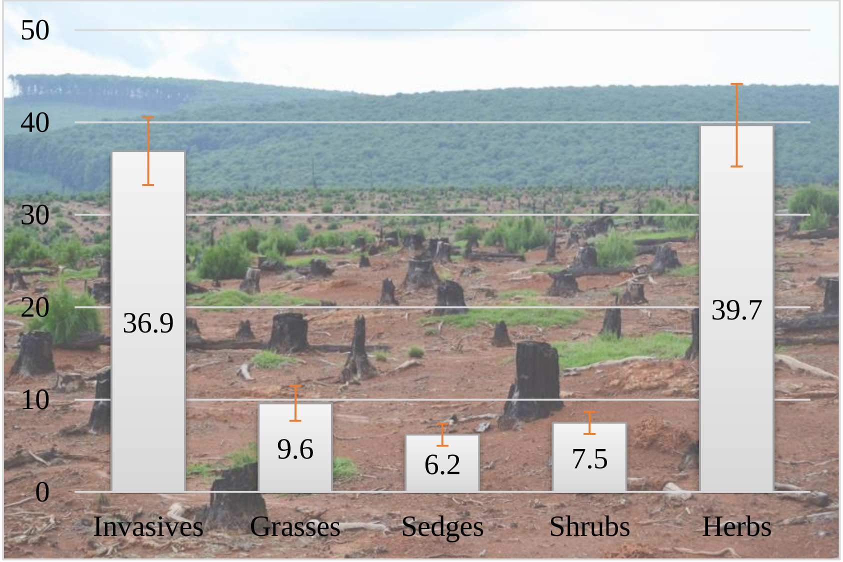


Figure 3: Mean Abundance of Species for Cleared Site B

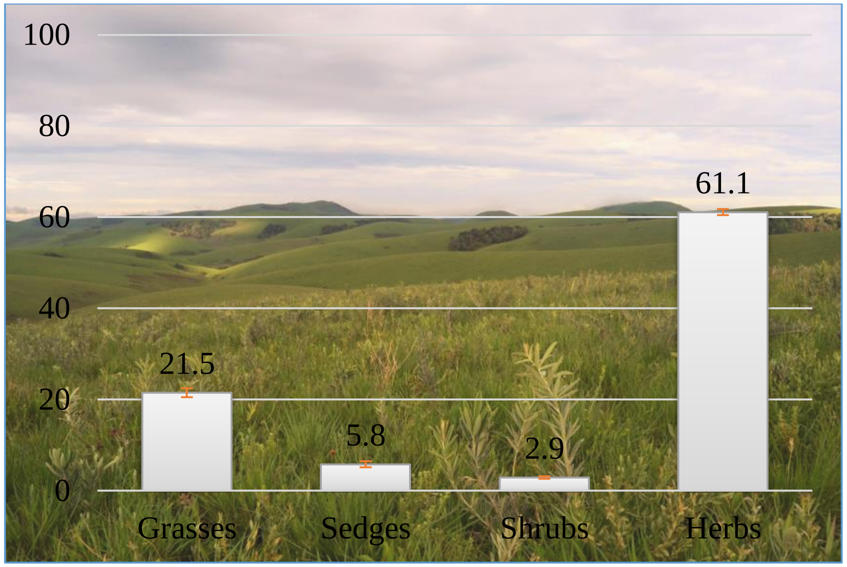


Figure 4: Mean Abundance of Species in grassland area

Plant diversity determined using Simpsons' Reciprocal Index of diversity (D) was very low in cleared sites A (14.9) and B (9.5) as compared to the grassland area (D=41.2), though species were sufficiently evenly distributed in all sites as to provide room for suspecting significant gradients in edaphic properties within sampled sites (Figure 9).

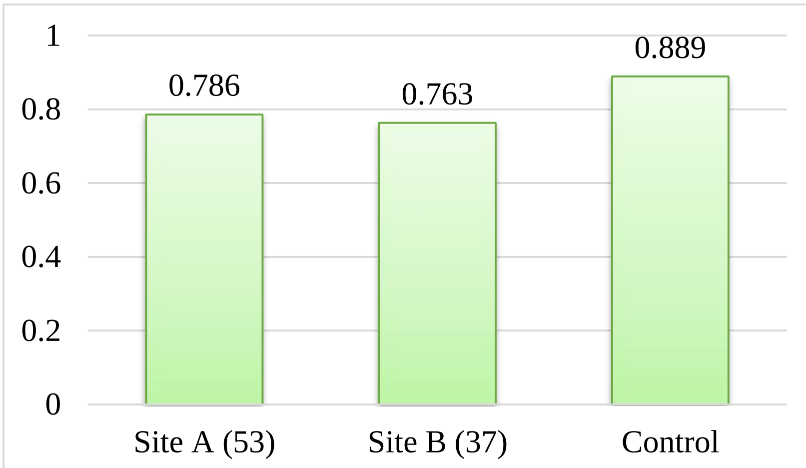


Figure 9: Shannon-Weiner Index of Evenness (E) for sites A, B and the grassland area.

Magurran (2004) highlights that diversity is directly proportional to the stability of ecosystem functioning and service provisioning. By inference, the findings on diversity between the natural grassland and cleared sites from this study provide room for asserting that pine removal has significantly reduced plant diversity and favored the proliferation of other alien-invasive plants in the cleared sites. Fagan et al, (2008) report of an approximate 60 years as requisite for sufficient recovery of sites previously dominated by pines, and O'Connor (2005) states an approximate 20 years for abandoned communal croplands reverting to indigenous grassland (case of southern Drakensberg). Whilst complete removal of invasive trees could be sufficient for recuperating natural grasslands communities, it would best be complemented by control of invasive species and other management interventions such as enrichment planting of native species or even stimulating seed banks of the same (Bakker et al, 1996; Holmes and Cowling, 1997; Bakker and Berendse, 1999; Holmes et al, 2000; Warren et al, 2002). Unless a pragmatic approach is devised by management to speed up the recovery process, recovery of these cleared sites is most likely going to be a slow process.

In line with the aforementioned on plant diversity, certain species were difficult to account for in the abundance estimations, namely *Pennisetum clandestinum* (Kikuyu grass) (Figure 10) and *Trifolium semipilosum* (Figure 11)

Figure 10: *Pennisetum clandestinum*

Figure 11: *Trifolium semipilosum*

Counting the species was a rigorous task such that cover expressed as a percentage (mean percentage of sampled plots per site) was estimated wherever the species was present. Results on this species revealed that *P. clandestinum* covers about 55.25% of site A, and 13.85% of site B.

Though poorly established in site B, there is potential of increased cover with time. In the grassland area, this species was difficult to discriminate from other grasses. Similar to *P. clandestinum,* the species *Trifolium semipilosum was* equally difficult to count, let alone to accurately estimate and discriminate its cover in the identified plots. Regardless of this, the species was commonly found in the grassland area.

CHAPTER FOUR
CONCLUSION AND RECOMMENDATIONS

Conclusion

This study on grassland regeneration found that after almost eight years since removal of pines from the Chilinda pine plantation, two distinct plant communities have developed which show no resemblance with each other or the native plateau grassland species. The management practice of removing pines, occasionally burning the same sites, and then abandoning them to allow for natural succession towards native grassland state to take place, have been proved futile so far. Instead, invasive plant species, especially *Rubus ellipticus* seem to have established themselves in the cleared areas. The apparent non-regeneration of most forbs highlighted in this study, points to the serious potential loss of grassland biodiversity as a consequence of pine introduction and removal, as well as poor grassland restoration practices.

Recommendations

Based on the conclusion of this study, the following are recommended;

- Since results have revealed very little resemblance of species composition between the cleared sites and the plateau grassland species, management should consider cost-effective restoration techniques in the cleared sites in order to aid and speed up natural regeneration. In this line of thought, management could consider direct seeding and/or soil manipulation in cleared sites and amongst other options.
- Prompt and systematic action be taken to remove self-sown pines in the cleared area. Whilst this should be done constantly and in regular manner, this should be complemented with removal of the fast spreading invasive plants, especially should *Rubus ellipticus* receive priority attention in view of its rapid colonization of the cleared sites.
- To prevent further loss of diversity as well as spread of alien-invasive plants on the plateau, it is imperative that another study should assess the other pine trial plots reported to have been planted (and later removed) on the Nyika plateau alongside the main Chilinda *Pinus patula* plantation. These could be a potential source of alien-invasive plant propagules.
- From an architectural point of view, the cleared site would be a good area for prospective construction projects (if any), since the area has already been disturbed and poses a challenge to its restoration.

REFERENCES

Amiotti, N. M., Zalba, P., Sa´nchez, L. F. and Peinemann, N. (2000) The impact of single trees on properties of loess-derived grassland soils in Argentina. Ecology, 81, pp.3283-3290

Amiotti, N. M., Bravo, O., Zalba, P., and Peinemann, N. (2007) Effect of landscape position on the acidification of loess-derived soils under Pinus radiata. Austral Ecology, 32, pp.534540

Bakker, J. P., and Berendse, F. (1999) Constraints in the restoration of eco-logical diversity in grassland and heathland communities. Tree, 14, pp.63-68.

Bakker, J. P., Poschlod, P., Strykstra, R. J., Bekker, R. M. and Thompson, K. (1996) Seeds banks and seed dispersal: important topics in restoration ecology. Acta Botanicsa Neerlandica, 45, pp.461-490.

Bischoff, A. G., Warthemann, and Klotz, S. 2009. Succession of floodplain grasslands following reduction in land use intensity: the importance of environmental conditions, management and dispersal. Journal of Applied Ecology 46:241–249.

Bredenkamp, G.J., Spada, F. and Kazmierczak, E. (2002) On the origin of northern and southern hemisphere grasslands. Plant Ecology, 163, pp.209-229.

Brooks, M. and Lusk, M. (2008) Fire Management and Invasive Plants: A Handbook. United States Fish and Wildlife Service, Arlington Virginia, 27pp.

Bromilow, C. (2001) Problem Plants of South Africa. Briza Publications, Pretoria.

Burrows, J. E. and Willis, C. K. eds. (2005) Plants of the Nyika Plateau: an account of the vegetation of the Nyika National Parks of Malawi and Zambia. Southern African Botanical Diversity Network Report No. 31. SABONET, Pretoria.

Callaway, R. M., and Ridenour, W. M. (2004) Novel weapons: invasive success and the evolution of increased competitive ability. Frontiers in Ecology and the Environment, 2, pp.436-443

Clark, G. F. and Johnston, E. L. (2011) Temporal change in the diversity–invisibility relationship in the presence of a disturbance regime. Ecology Letters, 14, pp.52-57.

Cuevas, Y. A., and. Zalba, S. M. (2010) Recovery of native grasslands after removing invasive pines. Restoration Ecology, 18, pp.711-719.

Coop, J. D., and Givnish, T. J. (2008) Constraints on tree seedling establishment in montane grasslands of the Valles Caldera, New Mexico. Ecology 89:1101–1111.

Dorward, F. S. (1990) The Chelinda Pine Plantations. In: Dorward, R. and Dorward, F. (eds). The Nyika Experience: Reminiscences of Malawi's First National Park. The Wildlife Society of Malawi, pp.14-26.

Ehrenfeld, J. G., Kourtev P., and Huang, W. 2001. Changes in soil func-tions following invasions of exotic understory plants in deciduous forests. Ecology Applications, 11, pp.1287-1300.

Fagan, K.C., Pywell, R.F., Bullock, J.M. and Marrs R.H., 2008. Do restored calcareous grasslands on former arable fields resemble ancient targets? The effects of time, methods and environment on outcomes. Journal of Applied Ecology 45:1293-1303.

Global Invasive Species Database (2005) Acacia mearnsii. Available: ttp://www.issg.org/database/species/ecology.asp? si=51&fr=1&sts=sss [Retrieved 04/01/2017]

Heneghan, L., Fatemi, F., Umek, L. Grady, K., Fagen, K., and Work-man, M., (2006) The invasive shrub European buckthorn (Rhamnus ca-thartica L.) alters soil properties in Midwestern U.S. woodlands. Applied Soil Ecology, 32, pp.142-148.

Holmes, P., and Cowling R. (1997) Diversity, composition and guild structure relationships between soil stored seed banks and mature vegetation in alien plant invaded South African shrub lands. Plant Ecology, 133, pp.107-122

Holmes, P., Richardson, D. M., Van Wilgen, B. and Gelderblom. C. (2000) Recovery of South African fynbos vegetation following alien woody plant clearing and fire: implications for restoration. Austral Ecology, 25, pp.631-639.

Kazunguze, A. (2017) Survey of Alien Plants on the Nyika Plateau, Malawi. (Unpublished report)

Lower, S., Browne, M., Boudjelas, S. and De Poorter, M. (2000) 100 of The World's Worst Invasive Alien Species: A selection from the global invasive species database. The Invasive Species Specialist Group (ISSG), a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), 12pp. New Zealand.

McWhirter, L., and Kemp, H. PRIMEFACTS 730. Bracken fern. NSW Department of Primary Industries.

Magurran, A. E. (2004) Measuring Biological Diversity. Oxford: Blackwell Publishing. The standard reference for conceptual and quantitative aspects of diversity measurement

Mitchell, R. J., Marrs, R. H., Le Duc, M. G., and Auld, M. H. D. (1999) A study of the restoration of heathland on successional sites in Dorset, Southern England; changes in vegetation and soil chemical proper-ties. Journal of Applied Ecology, 36, pp.770–783

Nkaonja, R. W. S. (1982) The Silviculture of Indigenous and Exotic Forest Trees other than Pines and Eucalypts in Malawi. South African Journal Forestry, 121, pp.28-37.

O'Connor, T.G. 2005. Influence of land use on plant community composition and diversity in Highland Sourveld grassland in the Southern Drakensberg, South Africa. Journal of Applied Ecology 42:975-988.

Ratajczak, Z., Nippert, J. B. and Collins, S. L. (2012) Woody encroachment decreases diversity across North American grasslands and savannas. Ecology, 93, pp.697-703.

Richardson, D. M. (1998a) Forestry trees as invasive aliens. Conservation Biology, 12, pp.18–26.

Richardson, D. M. (1998b) Ecology and biogeography of Pinus. Cambridge University Press, Cambridge.

Richardson, D.M., Williams, P.A., and Hobb, R.J., (1994) Pine Invasions in the Southern Hemisphere: Determinants of Spread and Invasibility. Journal of Biogeography, 21 (5), pp 511 – 527.

Rochefort, R. M., Little R. L., Woodward A., and Peterson, D. L. (1994) Changes in the distribution of subalpine conifers in western North America: a review of climate and other factors. Holocene 4:89–100.

Scholes, R. J., and Archer, S. R. (1997). Tree-grass interactions in savannas. Annual Review of Ecology and Systematics, 28, pp.517-544.

Steckel and Harper, (2008) (2nd Ed) A hand Book on Caring Natural Lands. Natural Lands Trust

Simkoko, P. (2017) Logging of the Chilinda Pine Plantation. Interviewed by: Sopani Sichinga, 23rd March, 2017

Stinson, K. A., S. A. Campbell, J. R. Powell, B. E. Wolfe, R. M. Callaway, G. C. Thelen, S. G. Hallett, D. Prati, and J. N. Klironomos. (2006) Invasive plant suppresses the growth of native tree seedlings by disrupting belowground mutualisms. PLoS Biology4:727–731

Sullivan, J. J., Williams, P. A. and Timmins, S. M. (2007) Secondary forest Succession differs through naturalized gorse and native kanuka near Wellington and Nelson. New Zealand Journal of Ecology, 31, pp22–38.

The Nyika-Vwaza Trust, (2007) Pine plantation Clearance and Rehabilitation. Nyika-Vwaza News, issue 4, p7.

The Nyika-Vwaza Trust, (2005) Exotic Species Control Programme. Trust News, 1(1), p2.

Van Wilgen BW (2015) Plantation forestry and invasive pines in the Cape Floristic Region: Towards conflict resolution. S Afr J Sci. 2015;111(7/q8), Art. #a0114, 2 pages. http://dx.doi.org/10.17159/sajs.2015/a0114

VanAuken, O. W. (2000) Shrub invasions of NorthAmerican semiarid grasslands. Annual Review of Ecology and Systematics, 31, pp.197-215.

Vitousek, P. M., D'Antonio, C. M., Loope, L. L., Rejmánek, M., and Westbrooks, R. (1997) Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology, 21, pp.1–16.

Vitousek, P. M., Walker, L. R., Whiteaker, L. D., Mueller-Dombois, D. and Matson, P. A. (1987) Biological Invasion by Myrica faya alters ecosystem development in Hawaii. Science, 238, pp.802-804.

Warren, J., A. Christal, and Wilson.F. (2002) Effects of sowing and management on vegetation succession during grassland habitat restora-tion. Agriculture. Ecosystems and Environment, 93, pp.393-402.

APPENDICES

Appendix 1: Brief description of cleared site dominated by thick stands of the reseeded pines.

North east of sites A and B is a cleared site dominated by un-thinned self-sown pines up to greater than 4m in height (Figure a). The area is virtually larger than both sites A and B combined (Figure f), almost impassable except for the very few roads that were created when logging activities were in progress. The thought of laying plots to collect any data in this site really seemed unnecessary such that I decided to just look around and see what I could learn regarding the area. As I passed through the site, though with much difficulty, worth noting within the area were several piles of sawn pine slabs and pruned branches (Figures b to e show some of these piles). Some of these piles actually contain some planks of wood of good quality that could serve a number of purposes at the Camp. Apart from this, I think they pose a serious fire hazard as a source of fuel in the area already showing prospects of becoming a major self-sown plantation on the plateau. In this regard, I suggest that precautionary measures should be set in advance.

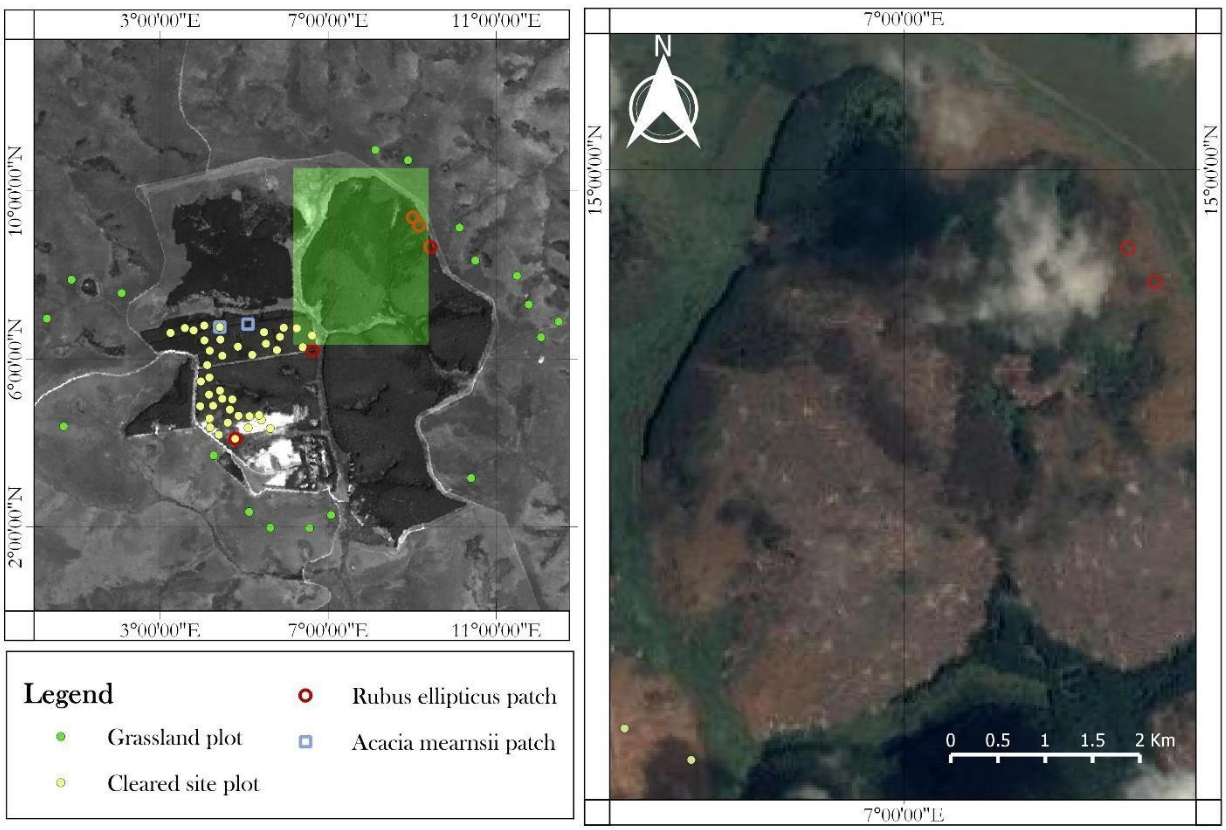


Figure f: Sketch map of the site dominated by thick reseeded pines

Appendix 2: Data Collection Form

DATA COLLECTION FORM

RECORDER'S NAME ___________________________________ DATE ___________

SITE ___________ PLOT # ______ PLOT COORDINATE _____________________

____

QUADRAT # _______

Species name	**Species category**	**Total count**	**Cover (%)**	**Height (m)**

Appendix 3: Coordinates for all Sampled Plots

Table 1: Coordinates for Cleared Site A and B

PLOT NUMBER	GPS COORDINATES (UTM) in WGS 84 DATUM		
	Latitude	**Longitude**	**Altitude**
1	10º34’37.6”S	33º48’13.2”E	2247
2	10º34’34.6”S	33º48’10.1”E	2322
3	10º34’33.0”S	33º48’09.4”E	2324
4	10º34’33.3”S	33º48’06.0”E	2327
5	10º34’37.4”S	33º48’05.6”E	2322
6	10º34’41.1”S	33º48’01.0”E	2324
7	10º34’39.8”S	33º47’55.4”E	2348
8	10º34’35.6”S	33º47’58.4”E	2342
9	10º34’33.2”S	33º48’02.2”E	2337
10	10º34’31.1”S	33º47’59.1”E	2335
11	10º34’27.6”S	33º48’00.0”E	2329
12	10º34’27.4”S	33º47’56.5”E	2340
13	10º34’29.8”S	33º47’53.3”E	2361
14	10º34’34.1”S	33º47’52.1”E	2371
15	10º34’37.2”S	33º47’52.3”E	2349
16	10º34’29.9”S	33º47’48.9”E	2370
17	10º34’25.9”S	33º47’51.9”E	2368
18	10º34’24.5”S	33º47’55.7”E	2346
19	10º34’20.0”S	33º47’52.0”E	2364
20	10º34’21.4”S	33º47’49.1”E	2371
21	10º34’15.7”S	33º47’51.3”E	2376
22	10º34’10.8”S	33º47’52.1”E	2374
23	10º34’07.2”S	33º47’50.2”E	2370
24	10º34’03.8”S	33º47’46.5”E	2363
25	10º34’03.0”S	33º47’43.4”E	2359

26	10^{o}34’04.7”S	33^{o}47’38.5”E	2363
27	10^{o}34’02.1”S	33^{o}47’50.1”E	2359
28	10^{o}34’05.5”S	33^{o}48’27.7”E	2251
29	10^{o}34’09.5”S	33^{o}48’24.5”E	2307
30	10^{o}34’03.0”S	33^{o}48’22.4”E	2318
31	10^{o}34’02.9”S	33^{o}48’17.8”E	2330
32	10^{o}34’06.0”S	33^{o}48’16.5”E	2336
33	10^{o}34’10.5”S	33^{o}48’15.5”E	2332
34	10^{o}34’08.4”S	33^{o}48’11.7”E	2344
35	10^{o}34’04.4”S	33^{o}48’11.0”E	2337
36	10^{o}34’02.7”S	33^{o}47’55.6”E	2339
37	10^{o}34’07.0”S	33^{o}47’55.8”E	2358
38	10^{o}34’12.6”S	33^{o}47’56.5”E	2369
39	10^{o}34’09.4”S	33^{o}48’01.9”E	2357
40	10^{o}34’12.2”S	33^{o}48’06.9”E	2354

NB: Plot number 1-20 are for Cleared Site A; 21-40 for Cleared Site B

Table 2: Coordinates for Grassland (Control) Plots

CONTROL PLOT NUMBER	GPS COORDINATES (UTM) in WGS 84 DATUM		
	Latitude	**Longitude**	**Altitude**
1	10°35'07.3"S	33°48'32.5"E	2264
2	10°35'11.8"S	33°48'27.0"E	2304
3	10°35'11.7"S	33°48'13.4"E	2334
4	10°35'06.3"S	33°48'06.0"E	2337
5	10°34'46.9"S	33°47'53.6"E	2338
6	10°34'54.5"S	33°49'23.3"E	2343
7	10°33'01.5"S	33°48'49.6"E	2362
8	10°33'05.0"S	33°49'01.0"E	2363
9	10°33'28.2"S	33°49'18.9"E	2352
10	10°33'39.5"S	33°49'24.4"E	2343
11	10°33'44.8"S	33°49'39.0"E	2359
12	10°33'54.6"S	33°49'43.1"E	2353
13	10°34'00.5"S	33°49'53.5"E	2355
14	10°34'05.9"S	33°49'47.4"E	2365
15	10°34'37.0"S	33°47'01.3"E	2276
16	10°34'25.6"S	33°46'48.2"E	2334
17	10°34'12.3"S	33°46'48.5"E	2298
18	10°33'59.9"S	33°46'55.4"E	2325
19	10°33'46.4"S	33°47'03.9"E	2340
20	10°33'51.1"S	33°47'21.4"E	2361

Table 3: Coordinates fro/and Description of Invasive Plants *(Black wattle and Rubus ellipticus)* Patches Observed

COORDINATE NUMBER	**GPS COORDINATES (UTM) in WGS 84 DATUM**			**DESCRIPTION**
	Latitude	**Longitude**	**Altitude**	
1	10º33'24.7"S	33º49'02.7"E	2359	Three *Rubus ellipticus* thick patches were observed each measuring approx. 30m^2
2	10º33'25.8"S	33º49'03.7"E	2361	Four *Rubus ellipticus* thick patches, each measuring approx. ≥ 3m height.
3	10º33'27.4"S	33º49'04.8"E	2360	Three *Rubus ellipticus* thick patches, each measuring approx. 3m height
4	10º33'28.5"S	33º49'05.1"E	2359	Two *Rubus ellipticus* thick patches, each measuring approx. 3m height.
5	10º33'34.9"S	33º49'08.8"E	2356	Three *Rubus ellipticus* thick patches, each measuring approx. 3m height
6	10º34'01.6" S	33º48'05.3" E	2329	One patch of black wattle of approx. 3m height.
7	10º34'02.7" S	33º47'55.6" E	2339	One patch of black wattle of approx. 1m height

Appendix 4: Pictures of Some Identified Plant Species

Aeschynomene oligophylla

Anisopappus chinensis

Buddleja salviifolia

Commelina africana

Conyza aegyptiaca

Crassocephalum sarcobasis

Digitialis purpurea

Dolichos kilimandscharicus

Elaphoglossum salicifolium

Eriosema buchanani

Euphorbia depauperata

Eulophia ovalis

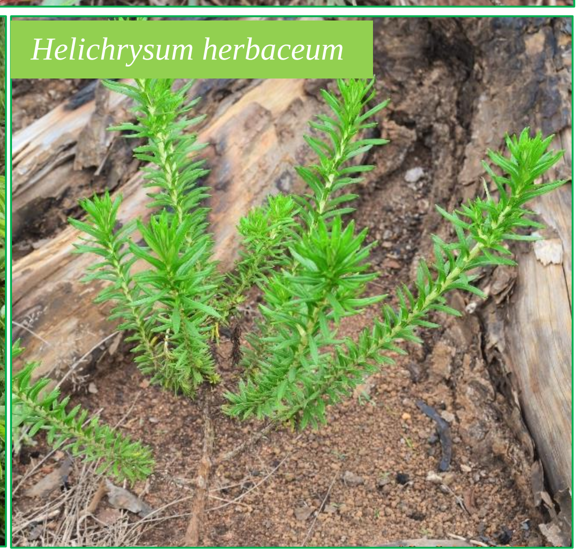

Galium busseii


Geranium vagans


Gerbera viridifolia


Gnidia bucananii


Hagenia abyssinica


Helichrysum herbaceum


Helichrysum splendidum

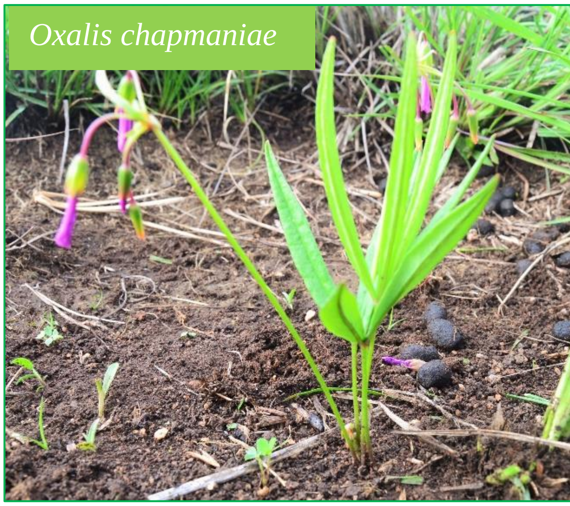

Hypericum revolutum


Impatiens assurgens


Kniepholia


Kyllinga alba


Lobelia ovina

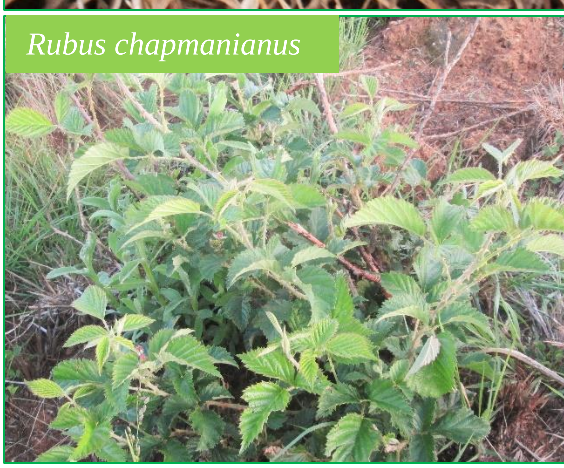


Oxalis chapmaniae

Protea heckmannian

Plectranthus salubenii

Plectranthus horridus



Rubus chapmanianus

Solanum aculeastissimum

Stoebe kilimandscharica

Dryopteris sp