How successful is grassland restoration after removal of pine plantations on the Eastern Shores of Lake St Lucia?

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ABSTRACT:

The coastal grasslands that occur along the Eastern Shores of Lake St. Lucia are rich in plant species, including endemics. These grasslands in North KwaZulu-Natal, South Africa, are remnants of a severely threatened vegetation type. Large portions of the Eastern Shores have been utilized for commercial pine plantations over the last 50 years; however these have been removed over the last 17 years. It is therefore important that efforts to restore grasslands that have been previously afforested stands of pines are successful. These grassland systems are fire driven and therefore many plants have adapted to these conditions by having massive storage organs below the ground. Using several response variables I was able to assess the effects of plantations on alpha- and beta-diversity and functional traits of forb and other grassland species and attempted to determine whether these disturbed grassland were returning to their original state. A high level of community heterogeneity was found at both scales for natural vegetation, while more homogenous, species low patterns were seen in post-plantation sites. Most notable was the large number of missing resprouting species in pine sites and that, in contrast to forest rehabilitation studies, no evidence for succession was found. The implication of this is massive as grassland rehabilitation may be a lot harder than was previously thought. It is likely that the fire adapted forb species are bad colonizers and have struggled to return to disturbed sites. These grasslands are therefore susceptible to activities that remove or eliminate the considerable amount of below ground biomass from the soil, and these sorts of disturbances should be avoided. Active rehabilitation methods will be required if any progress is going to be made and until such methods are effective considerable effort should be made in conserving the remaining grasslands that we have left and promoting its pharmaceutical, horticultural and societal value.

Keywords: Grasslands, Pine plantations, fire, storage organs, response variables, community heterogeneity, rehabilitation, disturbance.

INTRODUCTION:

The vegetation along the Eastern Shores of Lake St Lucia, in Isimangaliso Wetland Park, is a mosaic of coastal dune forest and grassland (von Maltitz *et al.*, 1996). The area falls in the Indian Ocean Coastal Belt (Moll & White, 1978), and has such distinctive floristic and structural features that it has been elevated to 'biome' status by some authors (Mucina & Rutherford, 2006). The grasslands of the Eastern Shores are rich in plant species, including endemics, and form part of the Maputaland centre of endemism, a remarkable region of apparently recent speciation (van Wyk, 1996) including many 'geoxylic suffrutices', dwarf woody plants that look like herbs (van Wyk 1992 cited by Taylor, 2004).

The Kwa-Zulu-Natal sections of the Indian Ocean Coastal Belt, and particularly the Maputaland sections, are severely threatened by crop farming, dune mining, afforestation and urbanisation. The small remnants conserved in Isimangaliso Wetland Park are therefore of special conservation interest (Mucina & Rutherford, 2006; Taylor, 2004). However large sections of grasslands in this section of the park were afforested with commercial pine plantations (*Pinus elliottii*) from the 1950s (Taylor *et al.*, 2006). Since the 1990s, and particularly since the park was declared a world heritage site in 1999 (Mograbi & Rogerson, 2007), the plantations have been removed (completed on the Eastern Shores in 2006 (Dalton, 2007)) and efforts have been made to restore the pre-plantation native vegetation (Taylor, 2004; Taylor *et al.*, 2006). Studies to investigate the effects of these plantations or other major disturbances on the ecology of the grasslands have focused on soil, ground water and woody species (Dalton, 2003; James, 1998; Lubke *et al.*, 1996; Taylor *et al.*, 2006). Some work has also assessed responses of vegetation and communities to defoliation disturbance such as fire and mowing but these have not explcitly considered the effects of plantations (Dalton, 2007; Fynn *et al.*, 2004). The actual effects of afforestation on species diversity of grassland species and whether there is any evidence of community succession after removal of plantations have not been sufficiently investigated. How vegetation responds and recovers from this form of disturbance should also help us further understand how other human affiliated disturbance may affect vegetation heterogeneity and rehabilitation efforts, especially in the controversial case of open cast mining on dune communities.

There has been considerable research on restoration of dune forest along the north-eastern coast of South Africa following destruction of the vegetation for dune mining (Avis & Lubke, 1996; Lubke & Avis, 1999; Lubke *et al.*, 1996; Mentis & Ellery, 1994, 1998; van Aarde *et al.*, 1996a; van Aarde *et al.*, 1996b; van Aarde *et al.*, 1998; Wassenaar *et al.*, 2005; West, 1999). However restoration of the grasslands, which are also destroyed in the mining process, has not received that much attention (Lubke *et al.*, 1996). One study that focused on grasslands rehabilitation in highveld grasslands after open cast mining showed that the successful establishment of vegetation is situation-dependant and the overall process of secondary succession is slow (Mentis, 2006). For a number of reasons, grasslands may be more difficult to restore than forests (Lubke *et al.*, 1996). Unlike forests, grasslands are usually not at equilibrium with climate and soils. High rainfall grasslands such as those on the Eastern Shores are often maintained by frequent fires (Dalton, 2007; Fynn *et al.*, 2004; Grace *et al.*, 2001; Mucina & Rutherford, 2006; Overbeck *et al.*, 2005; Uys, 2006; Uys *et al.*, 2004). Long-term fire exclusion eliminates many forb species in South African grasslands (Uys *et al*,. 2004). Afforestation may therefore result in a loss of many grassland forbs. Re-colonisation by forbs of South African grasslands recovering after destruction by ploughing, or afforestation has not been studied. Plant traits that promote persistence of individuals through disturbance, such as large underground storage organs, are often associated with poor colonising ability in woody plants (Bond & Midgley 2001). If this is also true for herbaceous species, then the most persistent forb species in frequently burnt pristine grasslands may be the species least likely to colonise rehabilitated grasslands.

This study compares the composition and diversity of grasslands in old plantation areas with grasslands that have never been afforested. I also determined whether secondary successional processes are likely to restore grasslands to their original condition and what interventions, if any, may help in facilitating the process of rehabilitation. The following questions were used to guide the study:

1. How has biodiversity been affected by the establishment of pine plantations in the region in relation to pristine grasslands?
2. What are the successional trajectories, if any, following plantation removal and will grassland composition converge to that of pristine grasslands with time?
3. What are the ecological attributes associated with different species in different successional states?
4. What additional interventions are needed to restore post-plantation environments to pristine conditions?

To fully explore the effects of afforestation on coastal grasslands we assessed plant species richness using several response variables for both natural and plantation vegetation. These combined methods comprehensively evaluated the species diversity of the Eastern Shores. The traditional method of assessing species numbers in plots to evaluate treatment effects (such as afforestation) seldom considers variation in species number with increasing plot size and fails to identify changes in species composition (such as from trees to grass). Changes in the kinds of species are the focus of interest as is heterogeneity, or species turnover, as a measure of diversity in a landscape. Heterogeneity, like species richness, is scale dependent varying within a plot, between plots and sites and between treatments. Where composition is studied, it is commonly evaluated by testing for similarity of plots between treatment sites. For a number of rehabilitation studies, this has been used to assess whether rehabilitated sites eventually converge around a calculated bench mark or endpoint mean of similarity between natural sites (van Aarde *et al.*, 1996a; van Aarde *et al.*, 1996b; Wassenaar *et al.*, 2005). But an emphasis on similarity among sites fails to identify what is missing from rehabilitated sites, which could include rare species or species with particular functional traits or characteristics. There is therefore a need to establish an idea of what should be found in a natural state and also what to look for when testing for successional trends. In this study species heterogeneity was compared between natural sites and post-plantation sites at two scales, the local plot scale with point diversity and intra-community turnover and between plots, a measure of Beta-diversity for the Eastern Shores. Plant functional traits and species characteristics were compared between natural and post-plantation sites to determine whether there were missing functional groups. This was also useful for testing successional trends and trajectories in trait composition.

The intention of this study is to inform wetland park management on the success of current restoration efforts. The analysis of patterns, if any, in plant traits present or absent in different grassland states will help indicate any additional interventions that may facilitate grassland restoration. The study should contribute to greater understanding of the ecology of Northern Kwa-Zulu Natal coastal grassland communities, especially in the context of future restoration attempts when grassland habitat has been completely transformed (e.g. through mining operations, ploughing, afforestation). It will also contribute to a better understanding of grassland conservation in general by indicating relative sensitivities of species to different kinds of disturbance.

METHODS:

SITE SELECTION

The Eastern Shores of Lake St. Lucia are situated in the southern section of the parks range. Plantations in this area have been removed in various stages since the early 1990's in an effort to restore the park to original vegetation. This has created an opportunity to investigate both the success of the restoration and the vegetation succession in post plantation sites. Dates of when the plantations were cleared and burning data in the region were be used to help determine the sampling design of this project in an attempt to create comparison sites. Georeferenced aerial photographs of the region in Arcview (Applegate, 1992) were then used for selecting all possible sites within two different topographies, low lying and westerly sloping. Site selection also took into account proximity to analysed soil sites from a master's thesis by James (1998) who found most soil characteristics between Post-plantation and Natural sites to be similar. Wetland and bottom-land sites support a different grassland community tolerant of seasonal water logging and were avoided in this study.

A survey of each site was then performed at each to select the optimum sixteen final sites for the project. Site selection was dependent on recent fire activity and to allow for comparisons between topographies. Eleven low lying sites were selected and divided into five post-plantation sites and five natural vegetation sites and one previous fire-break. Five sloped sights were selected and divided into three post-plantation sites and two natural vegetation sites. The Decimal Degrees range of the sites occurred as follows: Longitude, 32.4 – 32.6; Latitude, -28.1 – -28.5. Sampling took place within spring from the 6th to the 23rd of September.

Overall the seven natural vegetation sites were used as reference site to gain a better understanding of the natural floral diversity on a local scale as they did not have any previous plantations. Although fire breaks in the old the plantation area were also to be used as reference sites, there was some concern over the effects of past fire break management practices which may have included ploughing and seeding with a particular grass species (Ricky Taylor Pers. comm.). Subsequent analysis showed that plots sampled in a fire break did not differ significantly in either species numbers or the number of underground storage organs from the natural vegetation sites. A few grass species and one alien species were found to be common to both the fire break site and the post-plantation site, but no forb species co-occurred. For these reasons, I used the fire break site as the eighth reference site. Post-plantation sites were compared to reference sites to address the first question of whether biodiversity has been affected by afforestation. Species richness, community composition and plant functional types were used to determine the difference between treatments. Plant underground storage organs were used as the main focus to investigate functional trait differences between vegetation treatments.

The five low lying post-plantation sites were selected in sequence of clearance dates, giving seventeen years of restoration efforts in four different clearance stages starting from 1991 and ending in 2004. These sites could therefore be explored for whether there is any successional trajectory in post-plantation sites converging towards natural vegetation with time and for changes in the prevalence of different plant ecological attributes associated with each successional stage.

DATA SAMPLING

At each of the sixteen sites, four plots were located, usually within 50 to 200 meters of each other. Plots were located randomly using a co-ordinate system or a spun stick.
General information recorded for all plots included the soil colour at ten centimetres depth, recent burning activity, GPS co-ordinates in decimal degrees and photos of the site and surrounding area. Plantation clearance dates for each post-plantation site were recorded using an Arcview shape file supplied by the iSimangaliso Wetland Authority. Bearing and aspect were included for all slope treatment sites.

Each plot consisted of a nested one by one meter, one by two meters and two by two meters quadrat all nested in a circular quadrat of five meters radius centred from the middle of the full two by two meter plot (Figure 1).
The numbers of plant species were recorded in the one by one meter plot and additional species added with successive quadrat sizes

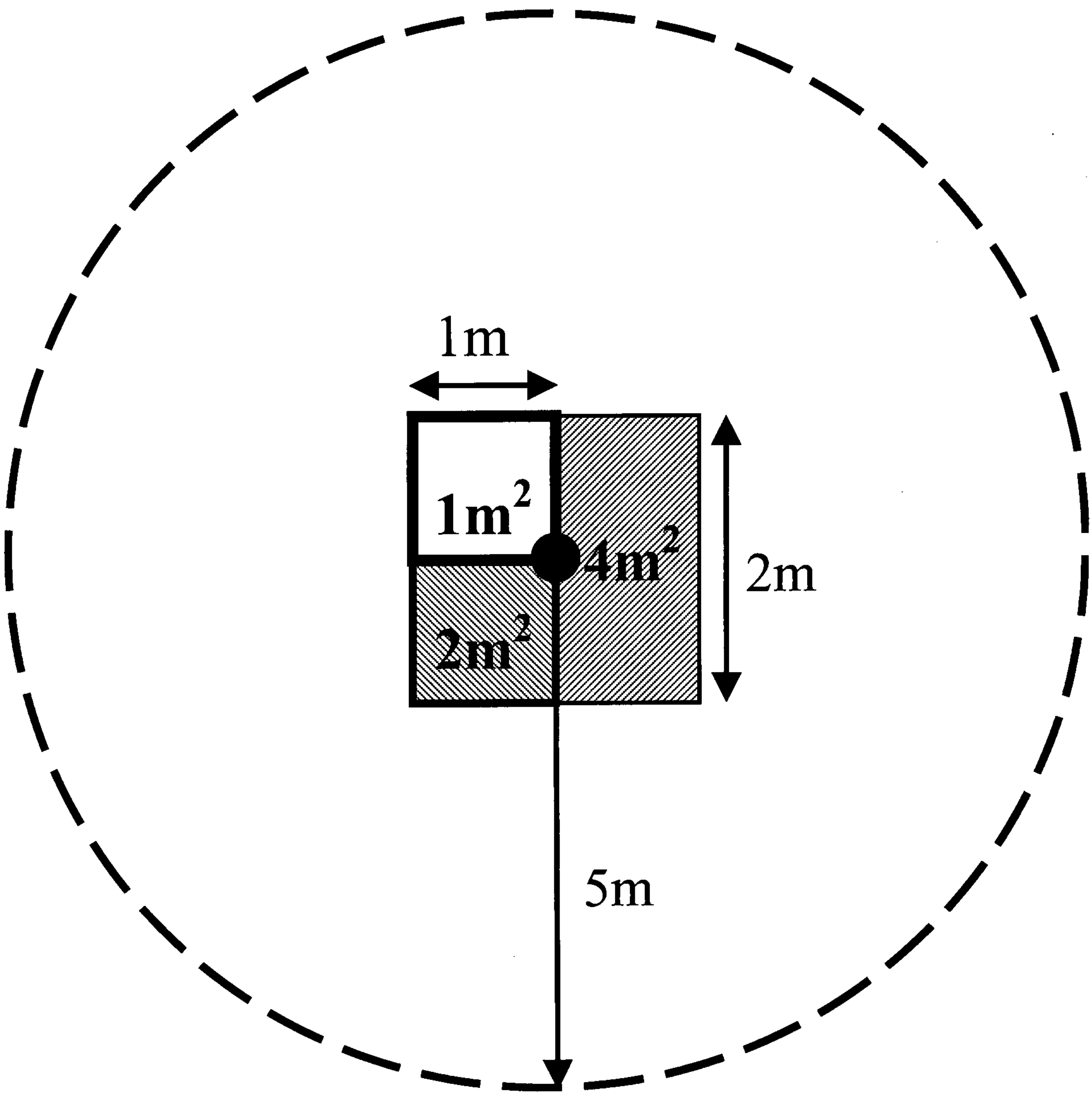


Figure 1: Nested quadrat method of sampling at each plot

The first individual encountered for all grass, sedge and forb species were excavated and the whole plant structure tagged and placed in a large plastic bag allocated for the plot that it was recorded in. This was to be used for recording the plant characteristics including any underground storage later. These samples were also to help as references in identifying the species. Each floral and root structure was then photographed for a reference to help identify the species. When possible, dispersal structures of a species were noted and the size of the structure measured.

Species were identified with the help of two identification guides (Pooley, 1998; Van Oudtshoorn, 1999), and the small herbarium at the St. Lucia EKZN research offices. Staff members from both EKZN Research and The Wetland Authority were very helpful in assisting with the identification process where and when they could. The guides were then used to record the dispersal characteristics of the identified plants while indicating whether the plant was used for traditional medicine, was an alien and occurred in disturbed areas or was a pioneer species. Species were regarded as resprouters if they had any underground storage in the form of thickened root stocks (Uys, 2006).

For the analysis when forbs are mentioned, they include common woody shrubs such as *Heliochrysum kraussii* and *Smilax anceps*.

DATA ANALYSIS:

Species Richness

Differences in species richness of both total species and forb species for vegetation, burnt and sloped treatments were assessed using a factorial ANOVA test. Burnt and slope treatments were assessed separately with the vegetation treatments.

Intra-plot Diversity

Using a similar method to in Schwilk *et al.* (1997) I measured intra-site diversity and turnover by regressing species richness to quadrat size in each plot. This was done for both total species and for forb species comparing vegetation treatments. Burnt vegetation treatments were then compared to un-burnt vegetation treatments.

Community Composition

A Detrended correspondence analysis (Decorana) plot was used to ordinate plot composition for forbs and grass species separately. Rare species were down weighted to lessen their effect on the spatial configuration of the plots. Decorana plots calculate a species score for each species along the ordination axes. The species score is then used to determine the position of each species based along the ordination axis representing community differences between the vegetation treatments. Decorana plots are designed to remove the quadratic distortion of the second ordination axis thereby avoiding the arch problem in other ordination plots (Hill, 1997). Axis two can therefore be used to determine additional variability within vegetation treatments or site differences.

Common and rare species were separated categorising species that occurred in less than eight percent of the total 64 plots as rare as these species would only have occurred in a maximum of four plots. The resulting list of species was used to determine where the majority of rare species were found.

Plant Functional Traits

195 forb species were separated into Natural Vegetation (NV), Post-plantation (PP) or both vegetation treatments and their resprouting ability determined. Using the exclusive non-resprouter and resprouter species to the two vegetation treatments (NV and PP) I then performed a two by two table Chi-Squared test, expecting resprouting species to be significantly distributed within the NV treatment. This assessed and compared the distribution of resprouting and non-resprouting species between vegetation treatments.

The same was done to organize exclusive disturbance and pioneer or weedy associated species into their vegetation treatment. I used the Chi-squared tests again however there was very little data available to perform the test on a large enough sample with only 10 exclusive species in total. Plant species with medicinal properties and uses were tested for association with either vegetation treatment. Again exclusive species were used and a Chi-squared test assessed their distribution between the equal number of NV and PP plots.

Similarity and Beta-diversity

Post-plantation communities may differ not only in alpha-diversity, but also in beta-diversity (species turnover) from one location to another. I tested for possible differences in beta-diversity by comparing the similarity in species composition between sites with the distance separating them. Adjacent plots would be expected to have more similar composition then distant plots.

Sørensen's method was used to measure similarity between all sixteen sites. The Sørensen's method uses indices that weight all species equally (Condit *et al.*, 2002). To measure distance between two sites, a central point was selected for each site and then the distance between these two points measured. These distances were recorded in the same format as the similarity matrix. Vegetation treatments were separated to compare average similarity within each treatment. Using the distance measured for these sites a correlation and regression analysis was performed for each treatment separately to determine the level of Beta-diversity across the Eastern Shores. All inter-treatment (NV with PP) similarity calculations and measurements were not included in these assessments, these were significantly lower than Intra-treatment similarities ($F_{(2, 117)} = 81.38$, $p < 0.0001$).

Succession

To determine whether PP grassland composition changed with time since clearing of pines, I analyzed various measures of succession restricting my analysis to lowland topography sites. The five LPP sites had four separate ages of clearing, 2004, 2002, 1998 (for two sites) and 1991. Mean species richness was regressed against age since clearance and. The same was done for the number of resprouting species at each age. The ratio of resprouters to non-resprouters was calculated and compared against age since clearance. Species composition was investigated by placing the sites into two age categories, less than ten years and greater than ten years, and common to both. The total, exclusive and reprouting (and NV co-occurring species) species were separated into younger (<10 years) and older (>10 years) sites. Species at younger sites were then compared to older sites for changes in community composition with age.

Statistical analysis was performed using the STATISTICA 8 (Statsoft, 2007) package and ordination and similarity analysis was performed in Community Analysis Package 2.13 (Henderson & Seaby, 2002). ArcView 3.2 was used for all GIS work and distance calculations(Applegate, 1992).

RESULTS:

Species Richness

306 different plant species were sampled during the two weeks of collection. The total number of Forb species was 201 (just over 65% overall). 50 woody and tree species were sampled along with 36 grass species. The two biggest forb families sampled included Asteraceae, with 29 species and Fabaceae with forty two species. 122 species could not be identified to species level and when woody and tree species were removed along with species identified to family level only 50 grass, sedge and forb species, the later being the majority, could not be identified.

The number of plant species sampled differed greatly within the two different vegetation treatments. The 32 natural vegetation (NV) plots had far higher species numbers than that sampled in the 32 post-plantation (PP) plots, 220 versus 141. Forb species within NV treatment sites made up 74% of the total number of plant species sampled in the treatment, while the percentage of forbs in PP treatments only made up 51% of the total number of species in that treatment. 128 forb species only occurred in the NV treatment, while 37 species were exclusive to the PP treatment and 35 were common to both (Appendix 1-3). The average species richness was statistically significantly higher in NV sites, 28.9 species per site, than in PP sites, 14.1 species per site ($F_{(1, 60)} = 178.55$, $p < 0.0001$). The difference in forb species richness was proportionally much higher in NV plots, 20.0 per site, verse PP sites, 7.2 ($F_{(1, 60)} = 221.54$, $p < 0.0001$).

Fire showed a significant interaction effect with vegetation treatments for species averages per plot (Figure 2, $F_{(1, 60)} = 6.83$, $p < .02$). The results indicate that burnt NV sites statistically had *significantly higher species* numbers on average than un-burnt NV sites but that burnt PP sites had *significantly fewer species* than un-burnt PP sites. A similar interaction was seen for both vegetation treatments when comparing only forb species, however there was an increase in the difference in the average number of forb species in burnt NV sites versus un-burnt sites, 3.96 to 4.71, and a decrease in the difference between burnt and un-burnt PP sites, 2.58 to 0.54 ($F_{(1, 60)} = 7.65$, $p < .01$).

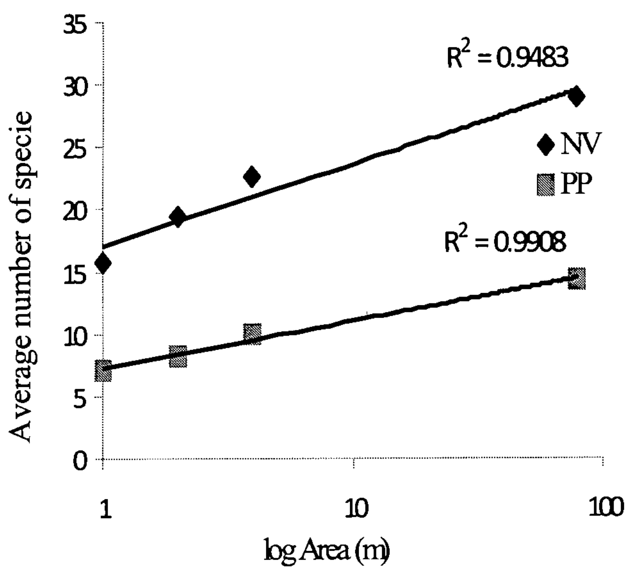


Figure 3a: Mean species richness versus log sample area for NV and PP treatment plots.

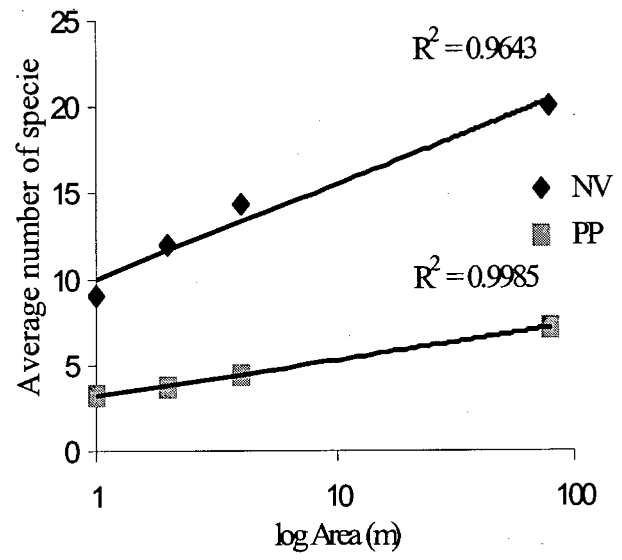


Figure 3b: Mean forb species richness versus log sample area for NV and PP treatment plots.

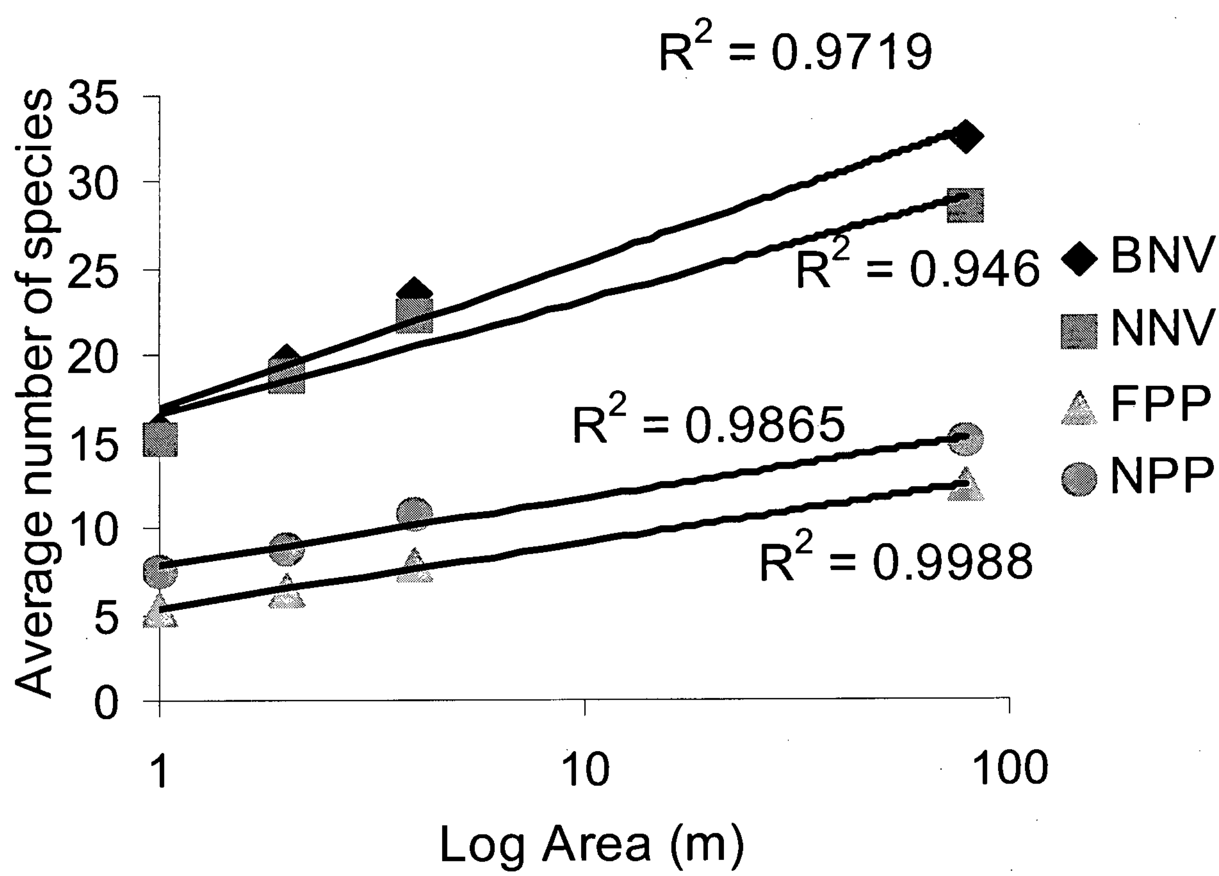


Figure 3c: Mean species richness versus log sample area for burnt and un-burnt vegetation treatments. BNV and FPP are burnt treatments while NNV and NPP are un-burnt treatments. NV= Natural Vegetation, PP = Post-Plantation

Community Composition - Ordination:

Forb species composition showed higher variation within NV plots compared to PP plots (Appendix 4). NV plots are slightly more spaced out along both axes, creating less of a clump when compared to PP plots. Two distinctly separate communities can also be distinguished for two NV sites, LNV4 and SNV2. No distinguished communities can be clearly seen for PP sites. Four outlier plots are visible for the vegetation treatments one NV plot, LNV1 and three PP plots, LPP4, SPP2 and SPP3. A closer look at site vegetation composition shows a distinct separation of NV and PP treatment sites (Appendix 6).

54 forb species occurred in five or more plots (Appendix 1-3). 22 were restricted to NV sites and four to PP sites while 18 were found in both. 147 forbs occurred in less than five plots of which 106 were restricted to only NV plots and 34 to PP plots, while only seven were found in both treatments.

There was a higher number of grass species found in PP sites, 26, of which 17 were exclusive to PP sites, compared with 10 for NV sites. This lower diversity for NV sites is shown in Appendix 5, where little variation in species composition between NV plots is seen along Axis 2, compared to the high variation in PP plots. There were select grass species that were frequently found within each vegetation treatment. Grass species that only occurred within NV sites frequently included *Aristida junciformis* and *Themeda triandra*. There were three species, *Cymbopogon validus*, Unknown spp 1(Long Leaf stem grass) and Unknown spp 2 (Broad leaf deep) which were found far more frequently within NV sites than within PP sites. Two grass species, *Dactyloctenium germanatum* and *Eragrostis ciliaris* were common in PP sites but also occurred within a few NV sites. *Dactyloctenium aegyptium, Panicum natalense* and Unknown spp 3 (Large sheath) were restricted to PP sites and occurred frequently. These ten species were all sampled within at least eight plots with the remaining 26 species making less than six occurrences. Grass was abundant at all sites and grass biomass was observed to dominate most, with exception to recently burnt, sites.

Plant Functional Traits:

Resprouting species were not distributed equally between vegetation treatments with a statistically significant association found between the frequency of resprouting species and NV treatments ($\chi^2_{(2)} = 34.73$, $P < 0.0001$). This indirectly tested the distribution of non-resprouting species which was found to be equal between treatments. 107 resprouting (19 non-resprouting) forb species were found only in NV sites, 23 (10 non-resprouting) were common to both and 13 (23 non-resprouting) found only in PP sites. For every non-resprouting forb species there were 4.48 resprouting species within NV sites, while in PP sites the ratio was 1:1.12. Appendix 6 shows the distribution of sprouting species behaviour in ordination space. This shows that resprouting species were far more common in the NV treatment than in the PP treatment.

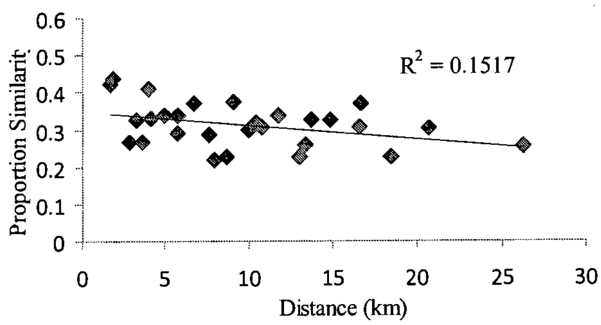
All but seven of the total 42 Fabaceae species were found in NV sites, where only five species were common to both vegetation treatments and two species were found only found in PP sites.

Although more plants with weedy characteristics and disturbed landscape preferences were exclusively found in PP sites (nine compared to one in NV), no statistically significant association was found.

A plant with medicinal properties was more likely to be found in NV sites than within PP sites where the number of plants used for traditional medicine was much higher, of which 26 occurred only in NV sites and only six in PP sites ($\chi^2_{(2)} = 15.71$, $P < 0.0005$).

Similarity and Beta-diversity

Similarity between sites decreased slightly but significantly with increasing distance apart for NV sites (Figure4a). No statistically significant correlation was found for the PP sites (Figure 4b). On average, similarity between NV sites was slightly lower than for PP sites, but this was not significant.



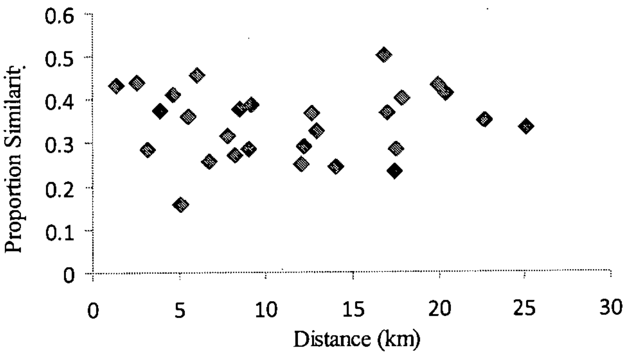


Figure 4a: Negative correlation between site similarity and increasing distance for Natural Vegetation sites ($r^2 = .15$, $P < .05$). Similarity was measured using a Sørensen's similarity matric.

Figure 4b: Similarity compared to increasing distance between Post-Plantation sites showing no relationship ($r^2 = .00$, $P = .87$).

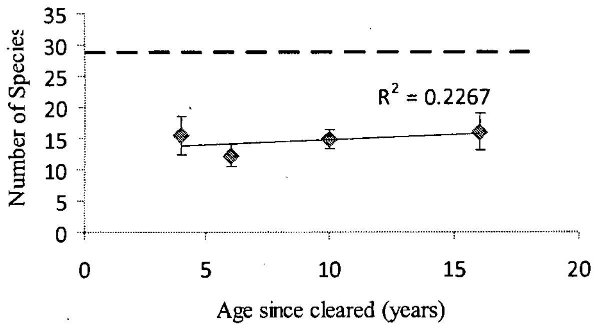
Succession:

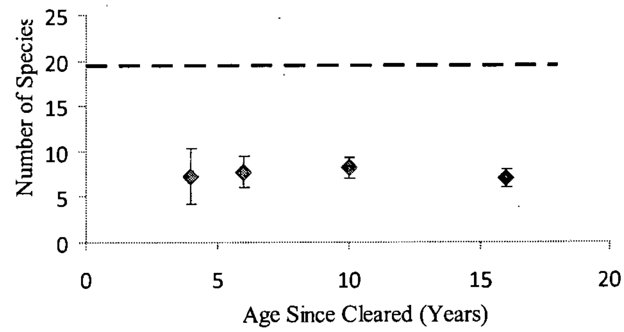
Succession analysis for the five lowland PP sites showed no significant trend in total and forb species numbers with increasing age since clearing although there was a slight positive correlation when comparing total species sampled with age (Figure 5a, $r^2 = 0.23$, $P > .5$ and Figure 5b). No significant trend was found for the number of resprouters per site (6) compared to clearance age. Besides an outlier site with equal resprouter to non-resprouter forb species, there was generally an increase in the ratio of resprouters to non-resprouters with increasing age since clearance (Figure 6).

When site forb species composition was assessed for differences in younger and older clearance treatments, older sites not only had a higher total number of species, but these species were mostly exclusive to these old sites (Table 1). The difference in the number of resprouters and NV treatment plants did not increase proportionally for the older sites.

Table 1: Total, exclusive and resprouter species composition for younger versus older sites. Total and % resprouter columns show both exclusive and total respectively.

Occurance	Age of sites	Total Species	Exclusive species	Exc (Total) resprouters
Young sites	< 10	30	16	5(12)
Old site	>= 10	40	26	8(15)





gure 5a: Average number of species in lowland PP tes compared with clearance age. The dashed line dicates average species number for lowland NV sites $^2 = 0.2267, P > .5$)

Figure 5b: Average number of forb species in lowland PP compared with clearance age. The dashed line indicates average species number for lowland NV sites

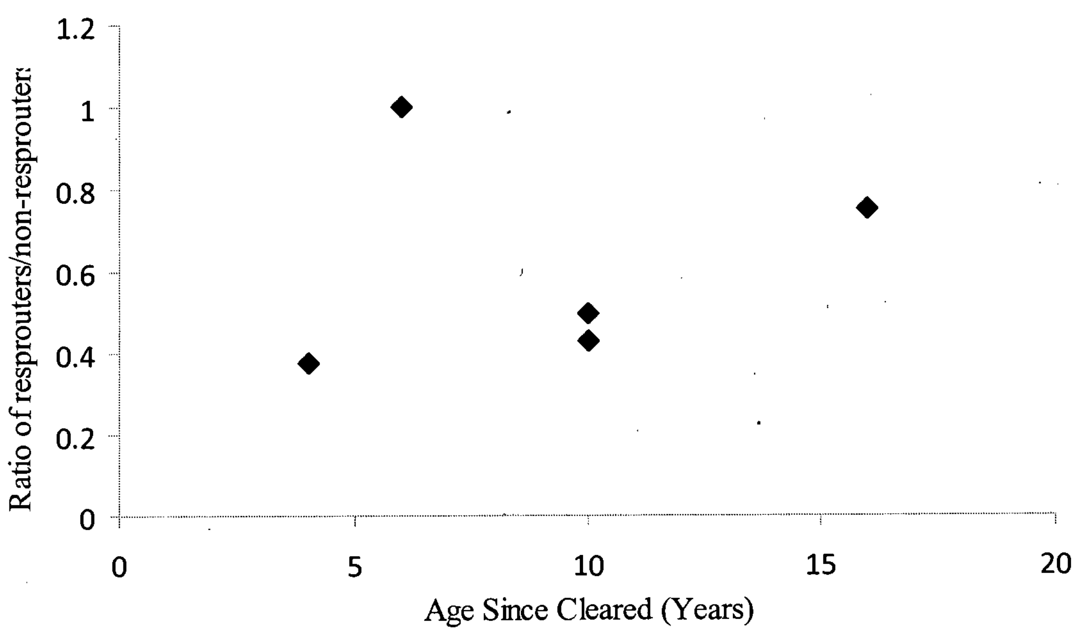


Figure 6: Ratio of resprouting to non-resprouting forb species with increasing age since clearing.

DISCUSSION:

HOW AFFORESTATION HAS AFFECTED BIODIVERSITY

Comparing vegetation treatments at two scales using methods for both alpha- and beta-diversity, it was found that plant diversity and particularly that of grassland forb species is greatly affected by afforrestation.

Not only were species numbers far lower in previously afforested sites but they supported a woodier shrubby community. Intra-community species turnover was found to be far lower in post-plantation plots. Natural grassland plots were found to have a high intra-community turnover rate reflecting the high level of species heterogeneity at a small scale. Species composition differed between treatments with natural and plantation sites showing a distinct divergence in communities. Species turnover also differed with natural sites having a much higher proportion of rare species and hence showing a high level of variation between plots. Plantation featured few rare species and showed little variation as a result. Ten grass species dominated sites in abundance for both treatments, particularly in biomass for un-burnt sites. However, particular grass species could be used as indicators for plantation disturbance or natural grasslands. It was interesting to find higher grass species richness in previously afforested sites than in natural grasslands which could have been due to the wind dispersal trait of the family, but further investigation into grass succession is needed.

Further analysis of inter-community turnover (or beta-diversity) showed that post-plantation sites across the Eastern Shores were homogenous in nature with about half the species likely to be found at most sites. In contrast, the natural grassland of the Eastern Shores showed more heterogeneity at this scale with decreasing similarity of species with increasing distance apart. This provides some support for Hubbell's Neutral theory which has so far only been tested and supported in rainforests and assumes, among other things, that dispersal is the only limiting factor for plant distribution (Hubbell, 2001).

FUNCTIONAL DIFERENCES

A massive difference was seen in the number of resprouting forb species between vegetation treatments. Compared to non-resprouting species, which have recovered in the species richness (but not in species composition), large numbers of resprouters were missing from the post-plantation treatment and were nowhere near the numbers of resprouting species found in the natural vegetation treatment. It was also very interesting to find a similar pattern for legume species. Legume richness declined steeply in afforested areas, with most of the species being hardy dwarf shrubby plants. The loss of herbaceous legumes could be due to changes in the soil properties and microbial abundance following afforestation. A study by James (1998) found some initial short term differences, especially in pH, where previously afforested soils were found to be more acidic in nature.

Weedier, pioneer species were more abundant in post-plantation sites, which also had higher numbers of species noted as characteristic of disturbed areas in wildflower identification manuals(Pooley, 1998; Van Oudtshoorn, 1999). However more investigation is needed to show which traits are associated with species colonising post-plantation sites.

Lastly, Medicinal plants almost don't feature the post-plantation treatment and therefore indicates the loss of potentially valuable species within these disturbed sites.

DIVERSITY RESPONSE TO TREATMENT AND FIRE

Treatments showed different responses to recent fire activity. Natural sites were able to recover very quickly after such a disturbance and even surpass un-burnt sites in species richness, while the opposite was seen for post-plantation sites. The different response is probably because of the loss of resprouting species from afforested areas, which are adapted to fire disturbance (Uys *et al.*, 2004). The combination of weedier and woodier non-sprouting species that featured mostly in post-plantation sites are all killed during a fire. Only hardy shrubs such as *H. Krausii*, *S. anceps*, a few resprouting species present at the site and other pioneer grass and forb species were quick to return.

Intra-community species turnover in recently burnt natural vegetation was also greater than in un-burnt plots, showing higher heterogeneity within recently burnt communities. Turnover in post-plantation however did not change in response to fire.

ARE THERE ANY SUCCESSIONAL TRENDS

Trends in succession were tested by comparing species richness, composition and resprouting numbers at various clearing intervals up to a maximum of 17 years. No successional trend was found in species richness, particularly forb species richness or with the number of resprouting species. Combining younger and older sites showed that there was at least a change in species composition. However resprouting species and those found in natural vegetation sites did not make up the majority of the older sites species and that the composition shift from younger to older did not indicate any recovery. The soils of the area are known to be nutrient poor (Dalton, 2007; Taylor, 2004) and it has been suggested for highveld grasslands that low nutrients effect plant recolonisation negatively (Mentis, 2006). Low nutrient status is unlikely to have influenced secondary succession at ST Lucia since plants have colonized post-plantation sites and produced abundant biomass. Other factors (such as increased acidity in recently cleared sites (James, 1998)) or poor colonizing ability has caused the very divergent communities of native versus post plantation grasslands.

A strong pattern was that resprouting species were not able recolonize post-plantation sites from which they had been eliminated. This is consistent with the persistence niche theory described by Bond & Midgley (2001) that the most persistent species adapted to high levels of defoliation have poor colonizing ability. James (1998) suggested that rates of succession would vary with proximity to natural communities, and that plantations next to native coastal forest would have supported more forest forb species as the plantations would have mimicked their growing conditions. However, except for tree species associated with the early stages of forest succession, the species richness of plantation sites near natural forest showed no significant difference in numbers of forb species compared to sites adjacent to native grassland.

GRASSLAND COMPARISON WITH TALL GRASS PRAIRIES

Grasslands in Southern Africa show a tendency to differ from the general rules that have been found in North American (Fynn *et al.*, 2004; Uys, 2006; Uys *et al.*, 2004). Fynn *et al.* (2004) and Uys *et al.*(2004) found forb species in South African grassland to be unaffected to high fire frequency. This is because they have adapted such defoliation events by developing large storage organs below the ground (Uys, 2006; Uys *et al.*, 2004). They both also showed that grass species richness declines under such conditions. Differences were found in fire exclusion treatments, where Fynn *et al.* (2004) showed no effect on forb species richness, but suggested that forb species have a higher degree of phylogenetic diversity and therefore species with higher shade tolerance had replaced fire adapted species. Uys *et al.*(2004) showed a loss of forb species after 10 years or more which was often due to being shaded out and replaced by woody species. Forb species in tall grass prairies have a negative response to high fire frequency which is mediated by the grazing of herbivores while frequent fire enhances grass species ability to dominate (Collins, 1992; Collins *et al.*, 1998; Knapp *et al.*, 2004; Leach & Givnish, 1996; Olff & Ritchie, 1998). As the majority of forb species along the Eastern Shores are resprouting and therefore fire adapted species, the implications of both Fynn *et al.* (2004) and Uys *et al.(2004)* are important for management practices of the area and is included its management plan (Taylor, 2004). There is also a need to establish general rules for Southern African grasslands, because they tend to differ from the American prairie examples they will require differing conservation management strategies.

RESTORATION IN GRASSLANDS

In grasslands pine stands change the structure and some of the physical and chemical attributes (such as in the soil) of the habitat in which they are planted. This and disturbances such as ploughing eliminate the underground biomass (plant storage organs and seed pools) of the grasslands, which for this area is considerable with a massive number of forb species with storage organs (In this Study). Once such species have been removed, it would potentially be very difficult for them to recolonize and this has been shown in this study. Therefore it can be considered that any other disturbance that removes or kills or displaces the biomass from the soil (such as open cast mining) will have huge detrimental effects on the species richness in the area and under such diverse conditions who knows what species would be lost or already have been lost. This therefore exposes major flaws to any previous statements concerning the Lake St. Lucia dune system and whether it could be successfully rehabilitated.

The passive rehabilitation method used on the Eastern Shore clearance site is showing no evidence of success. This is most certainly a result of the colonizing traits of the natural grassland species and the lack of propagating sources. It is obvious that the current rehabilitation method is not working and that some sort of active facilitation effort is needed. It would be unpractical to actively re-introduce the number of species that would be missing from this diverse grassland, but it could be considered that some rare species either get reseeding or planted as seedlings.

CONCLUSIONS:

In striking contrast to rehabilitation studies on the coastal forest systems around Richards Bay, there is no indication of succession towards a natural grassland state. These "restored" grasslands may look like recovering natural grassland, but in truth there is little similarity. This implies that the rehabilitation of coastal grasslands and possibly grasslands within Southern Africa is a lot more difficult than originally though and could be near impossible. Further investigation into possible active rehabilitation methods are needed to look at a way forward. This also emphasizes the need to conserve the remaining portion of this threatened ecosystem as what we have already lost may be irrecoverable, at least at a far longer time scale than previously thought. These natural grasslands hold a number of medicinal plants and the potential value to society in both pharmaceutical and horticultural worth in enormous. Grasslands should be actively promoted for public interest as there is a lot more to them than what first meets the eye.

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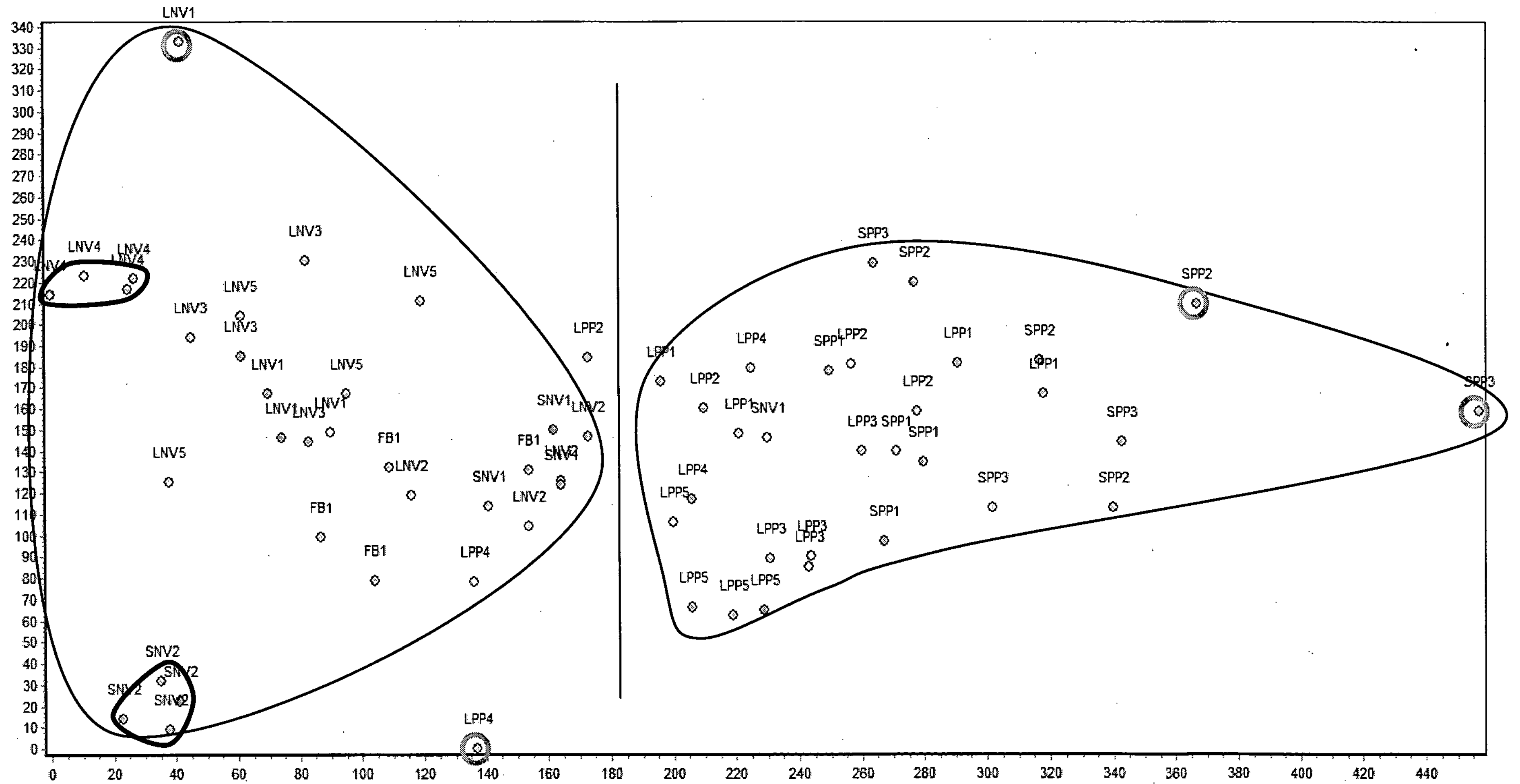
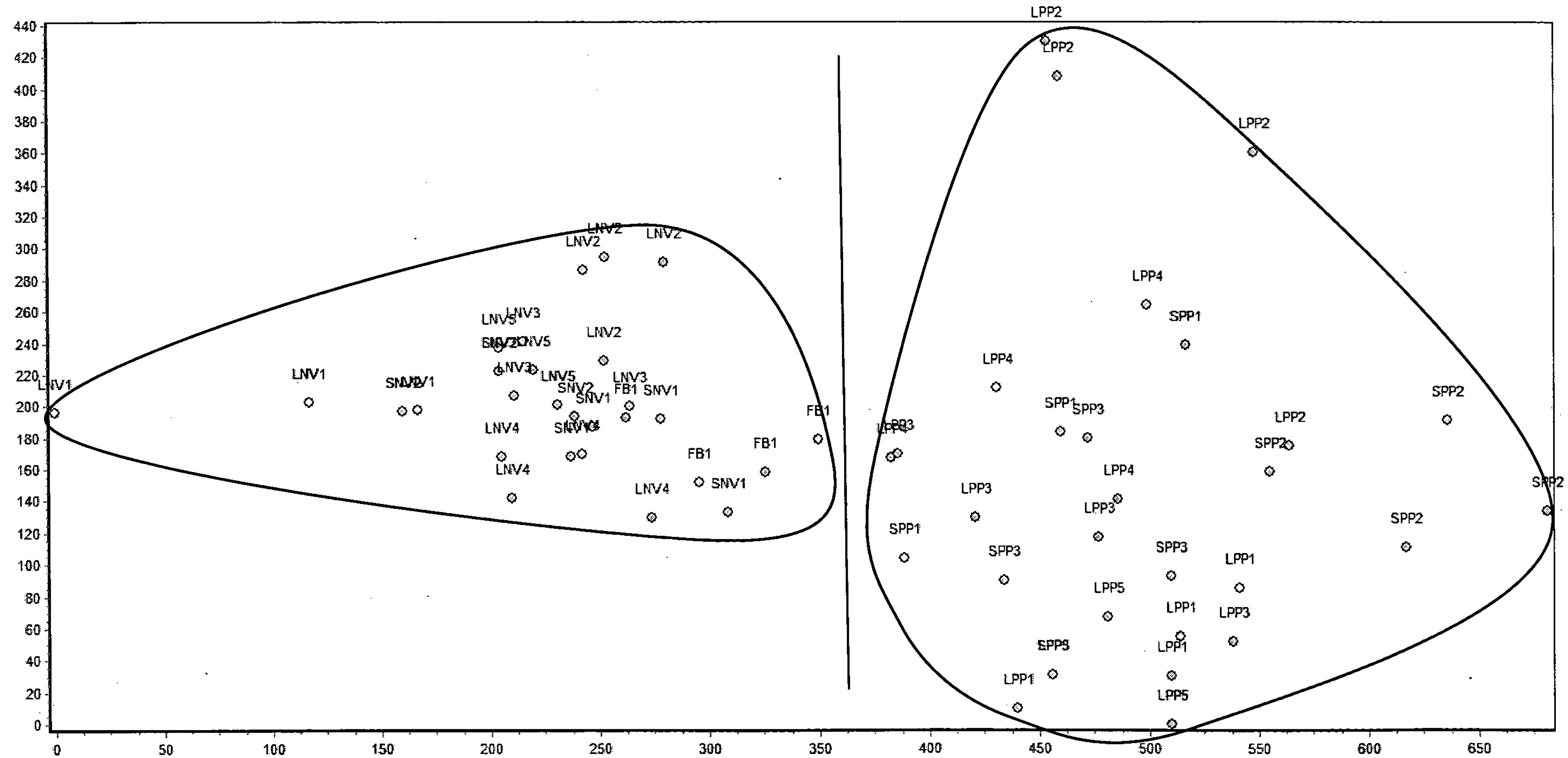
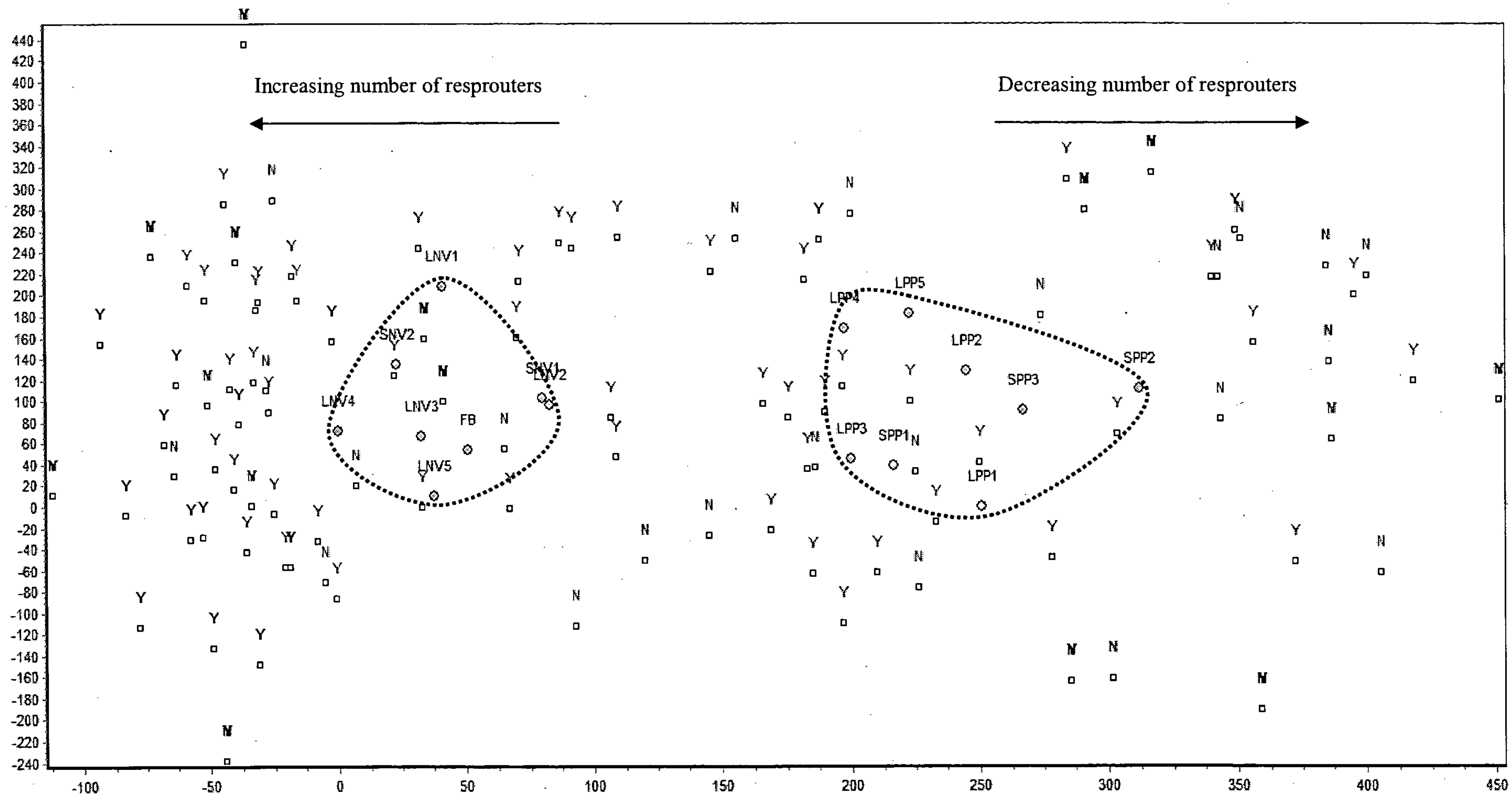


APPENDIX 4: Detrended correspondence analysis (Decorana) plot showing relative similarity in forb species composition for sampled vegetation plots within both Natural Vegetation and Post-Plantation treatments. LNV, SNV and FB are all NV treatment sites while LPP and SPP are PP treatment sites, each site consisting of four sampled plots (Axis 1, Eigenvalue = 0.5092 and Axis 2, Eigenvalue = 0.2867).



APPENDIX 5: Detrended correspondence analysis (Decorana) plot showing relative similarity in grass species composition for sampled vegetation plots within both Natural Vegetation and Post-Plantation treatments. LNV, SNV and FB are all NV treatment sites while LPP and SPP are PP treatment sites, each site consisting of four sampled plots (Axis 1, Eigenvalue = 0.7947 and Axis 2, Eigenvalue = 0.4308).



APPENDIX 6: Detrended correspondence analysis (Decorana) plot showing relative similarity in site forb composition (within dotted circles) and the spatial distribution of resprouting forb species (Y = Resprouter and N = Non-resprouter) compared to Natural Vegetation and Post-Plantation treatments. LNV, SNV and FB are all NV treatment sites while LPP and SPP are PP treatment sites, each site consisting of four sampled plots (Axis 1, Eigenvalue = 0.5067 and Axis 2, Eigenvalue

APPENDIX 1: Forb species composition exclusive for Natural Vegetation sites showing Common (C) and Rare (R) species

No.	Species	C/R
1	*Acalypha peduncularis*	C
2	*Acrotome hispida*	R
3	*Alectra sessiliflora*	R
4	*Alectra spp*	R
5	*Aloe Krausii*	R
6	*Ancylobothrys capensis*	R
7	*Aristea abyssinica*	R
8	Asr: Cluster ast leafs	R
9	Ast: 2 hairy jagged	R
10	Ast: *Callilepis laureola*	R
11	Ast: complete margin weed	R
12	Ast: Dandilion	R
13	Ast: *Gazania krebsiana*	C
14	Ast: red serated outline	R
15	Ast: saw leaves	R
16	Ast: *Sonchus* spp	R
17	*Boophane* spp	R
18	*Bulbine asphodeloides*	R
19	*Cabbea Hirsuta*	R
20	*Commelina* blue spp	R
21	*Crinum acaule*	R
22	*Crinum macowanii*	R
23	*Cyanotis speciosa*	R
24	*Drimia elata*	R
25	Euphorb/ast	R
26	*Euphorbia ericoides*	R
27	*Euphorbia quenzii*	R
28	*Euphorbia* spp	R
29	*Euphorbia* spp 1: linear leaf	C
30	*Gerbera ambiqua*	R
31	*Gladiolus longicollis*	R
32	*Gnidia calocephala*	R
33	*Gnidia kraussiana*	R
34	*Gnidia* spp(*calocephala*)	R
35	*Hebenstretia comosa*	R
36	*Helicrysum spp*	R
37	*Heliochrysum spiralepsis*	R
38	*Heliotropium steudneri*	R
39	*Hypoxis angustifolia*	C
40	*Hypoxis argentea*	R
41	*Justica protracta*	R
42	*Kohautia amatymbica*	R
43	*Ledebouria apertiflora*	R
44	*Ledebouria* spp	C
45	*Ledebouria* spp (*sandersonii*)	R
46	Leg : *Abrus laevigatus*	R
47	leg: 2/1 trifoliate	C
48	Leg: 2-3 leaf	R
49	leg: 5/6 compound creeper	R
50	Leg: *Aeschynomene micrantha*	C
51	leg: *Chamaecrista comosa*	R
52	Leg: compound	C
53	leg: Compound legume	R
54	leg: *Crotalaria monteiroi*	R
55	Leg: *Desmodium dregeanum*	R
56	leg: erect shrub compound	R
57	Leg: *Eriosema salignum*	R
58	Leg: *Eriosema* spp (*codatum*)	R
59	leg: large pink sweat pea	C
60	Leg: *Ligna sp. Aff. Trileba*	C
61	Leg: Long creeper	R
62	Leg: *Lotononis* (*flarifera*)	R
63	Leg: *Lotononis corymbosa*	R
64	leg: *Macotyloma axillare*	R
65	leg: mini compound	R
66	Leg: pink sweet pea	R
67	leg: pink yellow	R
68	Leg: *Rhynchosia* spp	R
69	Leg: rounded trifol shrub	R
70	Leg: *Stylosanthes fruticosa*	C
71	Leg: *Tephrosia macropoda*	R
72	Leg: *Tephrosia polystachya*	R
73	Leg: tiny tri leaflet	R
74	Leg: Trifoliate 3	R
75	leg: yellow? Compound creeper	R
76	*Nemesia denticulata*	R
77	*Oxygonum dregeanum*	C
78	*Pelargonium schlechteri*	R
79	*Pentanisia prunelloides*	C
80	*Polygala capillaris*	R
81	*Polygala sphenoptera*	C
82	*Polygala* spp	R
83	*Raphionacme galpinii*	R
84	*Raphionacme lucens*	C

APPENDIX 1 - continued

85	*Rhoicissus tridentata*	R
86	*Scabiosa columbria*	C
87	*Senecio* (*discodreggeanus*)?	R
88	*Senecio* spp	R
89	*Sisyranthus virgatus*	R
90	*Sopubia simplex*	R
91	*Stachys natalensis*	C
92	*Thunbergia atriplicifolia*	C
93	*Thunbergia*: heart creeper ?	R
94	*Trachyandra asperata*	R
95	*Trachyandra saltii*	C
96	*Tragia glabrata* (*durbanensis*)	R
97	Ukn spp: Cluster round leaf	R
98	Ukn spp: greenflower	R
99	Ukn spp: Hairy simple leaf	C
100	Ukn spp: hairy stem linear leaf	R
101	Ukn spp: jaged simple leaf 3 white	R
102	Ukn spp: little white round flower	R
103	Ukn spp: Microflower	C
104	Ukn spp: Monocot 2	R
105	Ukn spp: Nettle Like	R
106	Ukn spp: Opposite Simple	R
107	Ukn spp: orange stem micro white flower	R
108	Ukn spp: Purple hairy stem	R
109	Ukn spp: purple white cluster serated	R
110	Ukn spp: Resample check with LPP5	R
111	Ukn spp: Serated Succulant	R
112	Ukn spp: Serated weed	R
113	Ukn spp: Serated weed 2	R
114	Ukn spp: Shrub: Bristly heart	R
115	Ukn spp: Shrub: hairy heart	C
116	Ukn spp: Simple 4	R
117	Ukn spp: Simple leaf 1	R
118	Ukn spp: Simple leaf 2	R
119	Ukn spp: simple opp stipule	R
120	Ukn spp: Small white flwr shrub	R
121	Ukn spp: Tall linear	R
122	Ukn spp: very fury large leaves	R
123	Ukn spp: Wavy velvet leave	R
124	Ukn spp: White fury toothed	R
125	Ukn spp: White purple floresence	C
126	Ukn spp: Whorled cluster node	R
127	Ukn spp: Whorled cream	R
128	Ukn spp: Wild garlic?	R
129	*Zaluzianskya* (*natalensis*?)	R

APPENDIX 2: Forb species composition exclusive for Both vegetation treatments sites showing Common (C) and Rare (R) species

1	Alien: *Asystasia gangetica* (alien?)	C
2	Alien: *Cassytha filiformis*	C
3	Alien: *Centella asiatica*	C
4	*Aneilema cyanotis*	R
5	*Asparagus spp. Cf. Falcatus*	C
6	*Asparagus virgatus*	C
7	Ast: *Senecio*, Thistle purple	C
8	Ast: *Sonchus* spp c.a *nanus*	R
9	ASX	R
10	*Commelina africana*	C
11	*Commelina eckloniana*	C
12	*Commelina erecta*	C
13	*Euphorbia (natalensis)*	C
14	*Gladiolus crasifolius*	C
15	*Heliochrysum appendiculatum*	C
16	*Heliochrysum auriceps*	C
17	*Heliochrysum kraussii*	C
18	leg shrub: red inflorence compound	C
19	leg shrub: red trifoliate	C
20	Leg: creep 1(tri)	C
21	Leg: *Tephrosia* spp (c.a *multijuga*)	C
22	Leg: *Zornia capensis*	C
23	*Lobelia coronopifolia*	C
24	*Manulea parviflora*	C
25	*Polygala sphenoptera*	C
26	*Schizoglossum codifolium*	R
27	*Selago tarachodes*	C
28	*Smilax anceps*	C
29	*Thunbergia dregeana*	R
30	*Tricliceras (mossambicense)*?	C
31	Ukn spp: green flower heart creeper	C
32	Ukn spp: Soft spike leaves	C
33	Ukn spp: White purple	R
34	*Vernonia oligocephala*	C
35	*Wahlenbergia grandiflora*	R

APPENDIX 2: Forb species composition exclusive for Post-Plantation sites showing Common (C) and Rare (R) species

1	Alien: *Bidens pilosa*	R
2	Alien: *Catharanthus roseus*	R
3	Ast: *Senecio* yellow	C
4	Asteraceae weed	R
5	*Gomphocarpus physocarpus*	R
6	*Helichrysum spp side*	R
7	*Heliochrysum aueonitens*	R
8	*Heliochrysum spirotus*	R
9	*Hibiscus calyphyllus*	R
10	*Hibiscus trionum*	R
11	*Hypoxis* spp?	R
12	leg: Beenstalked creeper	R
13	Leg: *Eriosema* spp?	R
14	Leg: *Rhynchosia cooperi*	R
15	leg: trifoliate shrub	R
16	leg: trifoliate shrub 2	C
17	Leg: Trifoliate shrub 3	R
18	leg: whorled leaves	R
19	*Ornithogalum* spp*: green flower bulb*	R
20	*Polygala* spp: funky wing florets	R
21	*Scadoxus multiflorus* subsp. *multiflorus*	R
22	*Senecio madagascarensis*	R
23	*Senecio* spp 2	R
24	Ukn spp: Assymtrical simple	R
25	Ukn spp: Bulb 1	R
26	Ukn spp: cluster no stem	R
27	Ukn spp: Creeper: weed, compund white	C
28	Ukn spp: fleshy woody creeper	R
29	Ukn spp: Jagged simple leave	R
30	Ukn spp: linear leaf serated bottom	R
31	Ukn spp: Linear sickle shrub	R
32	Ukn spp: Resample	R
33	Ukn spp: Resample, leafy small stipules	R
34	Ukn spp: Serated weed fury	R
35	Ukn spp: Unknown shrub 2	R
36	Ukn spp: Weedy woody spike shrub	R
37	Ukn spp: Whorled weed	R

The large pictures are of different roots structures for legumes species (Fabaceae).
The last picture is of a *Crinum acaule*, a rare species with a lovely perfumed flower.