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Alien plant invasion on the Agulhas Plain : A detailed description of invasion patterns

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Abstract

Invasive alien species occur within several biodiverse regions of South Africa. It is not yet fully understood the extent to which invasive alien species affect natural vegetation. It is important to classify such species based on abundance and distribution in order to determine invasion patterns and set priorities for management within a region. Such a study was adapted for the Agulhas Plain of South Africa in the Cape Floristic Region. ? *Eucalyptus lehmannii* was recognised as the top invasive alien species, occupying both natural and transformed landscapes at high densities, >130% canopy cover. *Acacia saligna* and *Acacia cyclops* are the most widely distributed species, covering? 41% and 53% of the total area. Effectively determining invasive alien species richness required the use different variables to those used in this study. meaning? Invasive alien species invasion pattern was classified into two groups, namely coastal invasion and * Interior invasion. These characteristics which? differed with regards to vegetation types and species composition. Natural vegetation within the Mountain fynbos (100% invaded), Dune fynbos (91% invaded) and Mountain top fynbos (99% invaded) vegetation types were largely threatened by invasive alien species. Vegetation types largely affected by transformation include Elim asteraceous fynbos (89% transformed) and Renoster fynbos. The invasion patterns described could be used in prioritisation of manageable land.

* Inconsistent use of lower case + caps for several words in the report

Introduction

Biological invasions are a serious threat to natural populations (Schaffelke *et al., 2002;* Richardson *et al.,* 2000) worldwide. In South Africa some 10 million ha has already been invaded (NEL *et al.*, 2004; Richardson *et al.* (2004). Invasions in South Africa have received much attention recently ,because of their impacts in biodiverse parts of the country, such as the Cape Floristic Region (CFR). The impacts on ecosystem function by invading alien species are well documented, yet they are not fully understood (Richardson & van Wilgen, 2004). The invasion patterns of many alien invasive species are also not well known. Recognised invading species within the CFR include Australian *Acacia* spp., *Hakea* spp. and *Pinus* spp. (Richardson *et al.,* 1996; Rouget & Richardson, 2003).

Fighting aliens is an expensive undertaking, and the resources required to do so are not easily at our disposal. A recent national census of invasive alien species led to the classification and prioritisation of the most important invading species (Nel *et al.,* 2004). Nel *et al.* (2004) stress the importance of making informed choices for effective species control. Nel *et al.* (2004) devised a national classification system for major and minor invading species. Such a system also has potential for use at finer spatial scales and could be useful for guiding management interventions. This report sets out to adapt the approach of Nel *et al.* (2004) for regional classification of invading species within a region of the CFR with high biodiversity and high threats from invasive alien species.

The Cape Floristic Region has very high plant species richness and high levels of endemism associated with edaphic heterogeneity, (Cowling *et al.,* 1988; Cowling & Holmes, 1992; Cole *et al.* 2000). The amazing biodiversity of the area is world renowned and is the focus of many conservation efforts (e.g. Lombard *et al.,* 1997; Pressey *et al.,* 2003). The area includes the threatened lowland fynbos and renosterveld vegetation types (Cowling *et al.* 1998).

We focus our regional assessment on the Agulhas Plain within the southeastern parts of the CFR. Threatened by human occupation, heavily utilized land, including farming, and urban developments and the spread of invasive alien species has seen more than 39% of the area transformed. Fragmented landscapes are usually more susceptible to invasion by alien species than are intact systems (With, 2002).

Previous studies have focused on aspects of biodiversity and defining network reserves to conserve representative portions of the regions biodiversity (Lombard *et al.,* 1997; Euston Brown, 1999), while Rouget and Richardson (2003), focusing on modelling at various scales, explored current and future patterns of invasion for several invasive alien tree species (namely A*cacia and Pinus* spp.*)* within the Agulhas Plain.

Vegetation types have proven useful at the scale of identifying invasion (Rouget & Richardson, 2003). We assess the extent to which invasive alien species affect remaining natural vegetation; identify vegetation types which are most invaded and investigate how we can use this data to refine models on alien distribution. This will help to resolve issues regarding alien invasion within the Agulhas Plain and aid conservation planning.

This study has four aims: a) describe spatial patterns of invasion b) to classify invasive species according to abundance and distribution; c) to classify vegetation types/groups by invasion status, and d) to cluster species using co-occurrence and environmental factors.

The survey was done to map aliens – not determine conservation priorities.

Methods

Separate heading for study site would have been good

Mapping land use and invasion pattern

The study area is roughly 215 997 ha in size (Figure 1) and is divided into twelve vegetation groups based on definitions by Cowling *et al.* (1988) These groups were further sub-divided into 36 vegetation types, a useful surrogate for biodiversity in the Agulhas Plain (Cole *et al.* 2000). Details of the vegetation groups and subdivisions are given in Table 1. Since a detailed description was provided in Cole *et al.* (2000) only a brief summary will be presented here. In order to identify priority areas for conservation within the Agulhas Plain an extensive field mapping survey was undertaken. The fieldwork was carried out by Douglas Euston Brown (1999). A total of 39 invasive alien species were recorded at varying densities and across different land use categories. A list of the alien invasive species names and codes can be found in Table 2.

Vegetation groups were mapped in the field on to 1:10 000 orthophotos. The data was then digitised into a Geographic Information System (GIS) database using ARCVIEW.

Transformation was classified into the following categories: *cultivated land* (fallow land, cultivated land, fynbos farms, farm dam, unknown, quarry, dump), *urban areas*, *areas of untransformed natural vegetation* (alien free, aliens) and *areas of mixed land use.* Land use of the mixed category could not be defined in the field; it is a mixture of natural and fallow land. A total of 6307 polygons (referred to as stands from here on) were mapped on the Plain ranging in size from 0.02 – 6912.73 ha (mean 34.28 ha).

Alien vegetation within each stand was mapped according to three criteria: species, density and height. Up to 13 alien species were recorded per stand Species density was calculated based on the percentage canopy cover within each stand. These ranged from 0 - 100%. The absolute density for stands containing several species when summed could result in values > 100%. Original density classes as used in Cole *et al.*, (2000) were modified for this study. Instead of using the lower limits per density class, the middle value was

0 – (No aliens), 1 – (0 - 21%), 2 – (22 - 61%), 3 – (62 - 95%), 4 – (96 - 129%), and 5 – (130 - 224%). Height was ~~excluded from~~ not considered this analysis.

Describing invasion pattern

Most stands contained more than one alien species, ordered from most abundant to least abundant per stand. Species data were arranged to show presence/absence of all 39 species in each ~~per~~ stand. Density values for each species were recorded per invaded stand. It was assumed that each species occupied the whole stand it occurred in. Species occupancy was summarised as a percentage of the study area. Maps of species richness were produced based on the number of species per stand.

Distribution and description of species

The average density for each species was calculated using the middle value of the density class, as described above. The densities were averaged based on the number of the stands a species occupied. A similar approach was used to calculate species distribution. The values for density and distribution were plotted on separate graphs. Both density and distribution were divided into classes, based on the clustering of data points. Three density classes were identified (scattered <20%, common 20% - 37%, and abundant >37%). Three distribution classes were defined according the area a species occupied: localised (< 160ha), widespread (300ha - 10 000ha), and very widespread (>26 600ha) (Table 3). The 39 species were classified according to the three density and three distribution classes (Table 2). The top most important invaders were identified. Species were also classified according to the number of vegetation types they occupied.

Vegetation groups and types

Invasion pattern was summarised per vegetation type/group. The total number of alien species were calculated, as was the percentage of land transformed within each vegetation type/group. The vegetation types/groups were sorted according to alien density. Included in the analysis are the density classes for alien invasion and the percentage of the vegetation type that falls within each class (see appendix).

Clustering alien species & vegetation types according to invasion pattern

Several analysis techniques were applied, in order to understand the spatial pattern of invasion; correlation matrices, modelling with environmental and climatic data and the use of correlation biplots.

Species co-occurrence

Species presence and absence were recorded within each invaded stand to calculate correlations between species. Only the top seven species were used (very widespread/abundant, very widespread/common).

Correlates of alien species richness

In order to identify areas of high alien species richness, environmental variables (biotic and abiotic), provided by M. Rouget, were incorporated in the study. Included variables: aspect, distance to roads, distance to fields, distance to coast and geology, including climatic data, mean annual precipitation (MAP), minimum temperature and growth days. Rouget & Richardson (2003) used these variables to predict the spread dynamics of *Acacia cyclops, Acacia saligna* and *Pinus pinaster* within the Agulhas Plain.

Two models were used to predict alien species richness per stand, a stepwise linear regression model (LM) and a regression tree model (TM). Both models were created in statistical package S-Plus. Results were compared with the existing data set. The results were mapped to produce predicted species richness. How? Too brief!

ref/versi

Determinates of species distribution and invasion pattern

Biplots are useful for identifying correlated variables and the clustering of observations. The program SVDD (~~designed by Les~~ Underhill 1991), was used to develop biplots as a summary for visualising multivariate data. Further details on biplots can be found in Rouget *et al.,* (2002). Biplots were produced for alien species and vegetation. Species variables included 1) the number of vegetation types occupied, 2) total area occupied, 3) average density of alien species across the Plain and the climatic and environmental variables

too cryptic

//

mentioned earlier. Vegetation variables include 1) percentage of area invaded by alien species, 2) number of species present, 3) percentage transformation, 4) average density of alien species, 5) altitude and 6) growth days. insufficient detail here

Results

needs a subheading

Of the 215 997 ha of the Agulhas plain, 54% is classified as natural vegetation, 30% has been cultivated, 15% is classified unknown (all unknown land contained alien vegetation) and <1% is urban. No aliens were recorded in urban sites. Of the 54% natural vegetation only 3% is free of aliens (Figure 2), this mean that 95% of natural untransformed land is invaded by aliens. Almost a third (27%) of the area that has no aliens registered is transformed.
Figure 3 shows the current density classes of alien species on the plain. The majority of the Plain is characterised by low-density invasion. The highest density classes occur in the interior. These areas have an accumulated canopy cover >130%, and are highlighted in green on the map. Covering 4261ha of which 300 ha is untransformed the majority of this class occurs within transformed land. Areas with > 60% canopy coverage include density classes 3, 4 & 5. Patterns of alien plant invasion distinguish two regions: coastal invasion and interior invasion. The coastal regions are less affected by land transformation whereas most of transformed land occurs within the interior invasion area. Coastal invasion is characterised by adjacent stands forming continuous dense canopy cover > 60%. The few high-density areas (> 130%) are irregularly dispersed throughout the entire study area. Interior invasion comprises less of density classes 3 and 4 and more of class 5. There appears to be an East/West profile connecting high-density areas in the middle of the Agulhas Plain (Figure 2). awkward term

Species classification

Species classification has been summarised in Table 2 and 3.
Only one species, *E. lehmannii,* was classified as very widespread/abundant and six were classified as very widespread/common. This study effectively describes the seven top invading species. The top species, *Eucalyptus lehmannii* (spider gum) occurs across 15% of the plain and at an average density of 39% (Table 2). It occupies both natural and cultivated stands at high densities. The

inconsistent use of lower case / caps — used caps.

highest distributions were recorded for *A. cyclops,* covering 53% of the total area, followed by *A. saligna* 41% and *P. pinaster* 36%. Although *Acacia* spp. invade a large portion of the plain (Table2), the densities at which they occur vary. Only 7% of the area occupied by *A. cyclops* has a canopy cover of 87.5% or more. Similar patterns were observed for the other top species.
Sixteen localised (occupying < 1%) invasive alien species were identified, of which 4 were abundant, 1 common and 11 scattered (Table 2). The highest recorded density was for *Eucalyptus grandis,* occupying only 1.9 ha. This localised/abundant species was restricted to Transitional fynbos and Mountain top fynbos vegetation types. *E. grandis* only occurred within one cultivated stand. ?

Classification of vegetation groups and types

a) vegetation groups

The Acid group is the largest vegetation group, covering 24% of the plain. This group contains 34 invasive alien species followed by Elim asteraceous fynbos group with 32 species. The most invaded vegetation group is the wetlands. Covering approximately 10% of the plain it contains 36 alien species. Wetland habitats are shown in Table 1. The invasion pattern is well distributed across all density classes, with 46% occupation density class 1 & 2 and 15% covered by more dense stands, density classes 4 & 5). 25% of the wetlands are univaded by aliens. Important invading species include *Acacia* spp., *Eucalyptus* spp., *Pinus* spp., *Paraserianthes lopantha and Leptospermum laevigatum.* ?

Vegetation groups, Renoster fynbos (with 13 invasive alien species), Elim asteraceous fynbos (with 29 invasive alien species), Renosterveld (14), Transitional fynbos (24), Dry restioid (8), and Elim fynbos (24) have more than 60% of the area transformed, the highest being Renoster fynbos with 84%. The Renoster fynbos falls within the interior invasion region as identified in Figure 2. poor sentence

b) vegetation types

Most species occur ~~in~~ over many vegetation types, ~~whereas~~ but a few~~er~~ species show preference ~~to any~~ for certain vegetation type(s) ~~in particular~~. Of the 36 vegetation types clumsy sentence identified, four (Mountain Fynbos, Dune Fynbos, Elim asteraceous fynbos, and Limesand fynbos) make up almost 60% of the total area covered. The largest vegetation type within this area is Mountain Fynbos (24%) containing 34 alien species, while Berzelia riparian (only 2.2% of area) has 32 species within. The renosterveld vegetation type contains 14 alien species (including *Eucalyptus* spp. *and Acacia* spp.,). The Elim asteraceous fynbos vegetation type is a preferred habitat for many invading species (Table 2).

Species and Vegetation Groups/Types

A. saligna, and *A. cyclops* invade most of the vegetation types (36 and 35 respectively). Figure 4 shows the number of vegetation types that each species occupies. Three groups become apparent; species invading > 20 vegetation types (veg. types), species invading 5 – 20 veg. types and alien species invading < 5. These groups roughly coincide with the species classification. *A. saligna, A. cyclops* and *E. lehmannii* are generalists and can invade in a large portion of the vegetation types present. At the other end of the scale species from *Nerium oleander* to *Pinus patula* occur in few vegetation types. Interestingly these species have high average densities (*Pinus patula* and *Oputina ficus-indica*). *O. ficus-indica* has a small range occurring only in fallow land within Renosterveld and Dune fynbos vegetation groups, while *P. patula* occurs in the Elim asteraceous fynbos vegetation type. As mentioned before the wetlands are particularly ~~well~~ invaded. Acacia species (*A. cyclops, A. longifolia, A. mearnsii* and *A. melanoxylon*) have 40% of their range ~~occur~~ within the wetlands. Similar are *Pinus pinea* and *Pinus pinaster* with 46% while *Paraserianthes lopantha* has 34%.

not clear what this means

strange sentence

lophantha

Acacia mearnsii does not readily occur at low altitudes within the Dune fynbos vegetation type. This area is well invaded by few species such as *A. cyclops* and *A. saligna* (Figure 2).

meaning ??

Species co-occurrence

Correlate species were determined using the top seven species (Table2). *A. cyclops* is likely to be found with *A. saligna* and not necessarily with Hakea's or *Pinus spp*. Other correlations to note include *P. pinaster* with *A. longifolia*, *Hakea gibbosa* and *L. laevigatum.*

Table 4: The species co-occurrence table used for the top seven species as depicted in Table 1. Co-occurrence was based on presence and absence for species per invaded stand.

Explain sp. codes

	ACALON	ACASAL	EUCLEH	HAKGIB	LEPLAE	PINPIN
ACACYC	0.04	0.29	-0.06	-0.21	0.08	-0.11
ACALON		0.30	0.08	-0.01	0.29	0.24
ACASAL			0.04	-0.10	0.26	0.13
EUCLEH				-0.11	0.05	-0.05
HAKGIB					0.04	0.32
LEPLAE						0.25

what are figures in the table. Shading

The top 7 species do not always occur in the same vegetation types. The areas where they are most likely to be found together are Berzelia riparian, Elim fynbos, Elim riparian, Elim asteraceous fynbos, Limesand fynbos, Limestone fynbos, Transitional fynbos, Palmiet riparian and Mountain fynbos (Table 2). Dense stands of *E. lehmannii* usually occur when few other species are present.

not explained

Correlates of alien species richness

Few stands have more than 6 alien species. The maximum number of alien species (13) was recorded, in an actively cultivated field. The stand had a density class of 1. Alien species richness is shown in Figure 5. This map differs slightly to Figure 3.

what has this got to do with "correlates of alien species richness"?

Results of the models used to predict areas of high alien species richness are shown in Figure 6. The LM is more conservative in predicting where high alien species richness will occur, while the TM appears to overcompensate for the distribution of such areas. Both models fail to predict alien numbers over 5. Yet they overlap with current alien species rich areas. Testing the model suitability showed good fit to the original data although increased ranges were observed along the same points.

? meaning

not at all clear

The variables most likely to predict alien species rich areas are: level of transformation, distance to coast/roads and altitude. Distance to field is the most important variable for determining species rich areas. (reference to Table/Figure?)

Determinates for alien species distribution

68

Figures 7 and 8 show the invasion patterns of the top 16 species and vegetation types, respectively, in relation to environmental and climatic factors within the Agulhas Plain. What origin?

Many species cluster around the origin. Interesting to note is the correlation between *Hakea* spp. and *P. pinaster*, which agrees with the correlation matrix results presented earlier. Many species seem to have the same affinity for space. Species with specific habitat requirements are *Casuarina species, Myoporum tenuifolium subsp. montanum* and *Oputina ficus-indica*. This could explain the restricted range of these species within the Plain. *Eucalyptus grandis* is a notable exception as it only occurs within one stand. *Pinus patula* and *Rubus* spp. were excluded from the cluster analysis due to the small area of their distribution. The random points did not coincide with their localities. meaning?

Area and average density (two main classification units used in the study) were negatively correlated. The variables used could not explain invasion pattern sufficiently.

Vegetation types are more distinct from each other (Figure 8). Vegetation types that fall into quadrants 2 and 4 are the most affected with regards to percentage area invaded, the number of specie within each vegetation type etc. Some of these vegetation types include Mountain top, Afromontane forest, Mountain fynbos and Elim asteraceous fynbos. Mountain top fynbos, Afromontane forest and Restio bog are areas where natural vegetation is most under threat. There are several vegetation types that have been transformed to a large extent and are affected by invasive alien species, these include Elim asteraceous fynbos and Renosterveld vegetation groups.

This section is poorly written

mixing Agulhas Plain results with general findings Not a good introduction to the Discussion

Discussion

Invasion pattern

This study was an attempt to describe the extent of alien invasion within the Agulhas Plain. Classification of invading species would ultimately lead to prioritisation for close monitoring. The regional assessment provides a better understanding of invaders within the diverse landscape. Llarge portions of natural land have been invaded and only 3% is pristine. Major threats have been identified as land transformation, having the highest impact, (Latimer *et al.,* 2004) and alien invasion. For example, transformed land aids alien invasion (With, 2002) by hosting some of the densest alien stands on the plain (Figure 3). These areas occur some distance from the coast, where majority of the land has been transformed. Fallow land allows invasive alien species to enter new systems and slowly increase in number.

not in Agulhas Plain

Two invasion groups (interior and coast) have been identified and are based on clustering of high-density areas. The first one is within the Dune fynbos vegetation type situated in the coastal lowlands characterised by areas of moderate to high alien density but with low alien species richness. *Acacia cyclops* and *Acacia saligna* both have dense stands along these areas. This is a result of historical introductions into dune vegetation to stabilise sands. Transformed land is situated on more fertile soils further inland. The interior invasion occurs mainly within the Elim asteraceous fynbos and Mountain fynbos vegetation types. These areas have more invading species with increased invasive alien species richness per stand. This can be attributed to long-term farming and high levels of disturbed land. High-density stands usually fall into the highest density class for transformed land, while lower densities occur within adjacent natural land. A large portion of the mixed land use category also falls within the interior invasion region and adds the moderate density on invasive species. This can be related to the difference between Figures 2 and 5, which indicate that species rich areas do not necessarily form dense stands. The most species rich stand with 13 species has a density class of 1.

very confusing

The top seven invading species are generalist species and are able to invade almost anywhere in the Agulhas Plain. The study highlights *Eucalyptus lehmannii* as the most important invading species within the Agulhas Plain based on species distribution and abundance. This is followed by *Acacia saligna* and *Acacia cyclops,* which have for years been identified as important invaders (MacDonald and Richardson 1986). These two species occur over a larger area but at a lower average density than *Eucalyptus lehmannii*. Spider gum, as it is commonly known, is a well-known invader in the Agulhas Plain (Forsyth *et al.*, 2004). The invasion potential for this species has been proven and should be dealt with seriously. When densities are greater than 100% it usually occurs alone within a stand. ? not really

The homogenisation of flora by alien invasive species has negative impacts for biodiversity. Few areas on the plain contain many alien species at low to high densities. One of the major barriers for aliens to overcome, before settling and establishing, is the geographic and biological barrier. These barriers are virtually removed where cultivated lands are left fallow and provide an excellent opportunity for new species to grow. The level of fragmentation is determined by the ability of an organism to move across a landscape (With, 2002), *Acacia cyclops* seems to have little boundaries and few limitations. The fragmented landscape could be aiding the spread of alien species and retarding that of natural types (Richardson *et al.*, 1996). ?

The incredible biodiversity on the Agulhas Plain is under serious threat. Unless the species are able to cope or co-exist with aliens, then we might be facing some problems with regards to natural species richness. Nel *et al. (2004)* and Rouget and Richardson (2003) both describe the need for finer scale studies to refine that of broad scale initiatives.

Determinant of species invasion

Our understanding of species distribution was not adequate enough to effectively use in the models, as the variables used explained only 67% of original data. Although the models did not replicate the areas of high alien density exactly, the rough similarity could give it some credit. Likewise Rouget and Richardson (2003) concluded that fine scale prediction is not always successful. Thus, other factors beside these environmental ones could ?? what..

determine the spread of aliens. Propogule pressure was excluded from this study but might help to explain instances where environmental data does not. The regression models used revealed areas for invasion beyond that of current distribution patterns. Some reasons for alien invasive species not already occupying these areas include: 1) cultivated lands reduces possible habitat, 2) species have not yet reached their full invasion potential equilibrium. Perhaps refining of the models would produce clearer answers with regards to future invasion. Vegetation types are a good determinate in prediction species occurrence (Rouget & Richardson, 2003) and could be used more effectively in further studies.

Vegetation types were easier to describe regarding invasion, than alien invasive species. The fixed units could easily be summarised based on the number of invaders and area transformed or invaded habitat. A number of habitats are currently severely invaded with more having a high risk of future invasion e.g. Renosterveld as identified by Rouget *et al.* (2002). Vegetation types only appear to be safe from aliens when they are under active cultivation but at the loss of natural vegetation it is not a viable option.

why introduce this abbreviated now??

Biodiversity impact and management implications

Endemism in the A.P. has become restricted to refuge sites due to high levels of transformation. The well-developed edaphic substrata support a number of endemics. Loss of these areas will result in major losses of species. Some 37% of A.P. endemics occur within the limestone-based soils. These soils, although make up a small percentage of the plain are classified among the top invaded vegetation types. It is not yet known what the exact ~~a~~e ffects on endemics are. Like Richardson *et al.* (1996), it would be important to look at natural vegetation in relation to alien spread. This would highlight the vulnerability of fragile species. Few natural areas are left in the Agulhas Plain and this study highlights some areas and species that could be targeted for conservation.

It is important to identify the low-density areas before prop~~o~~a gule pressure increases.

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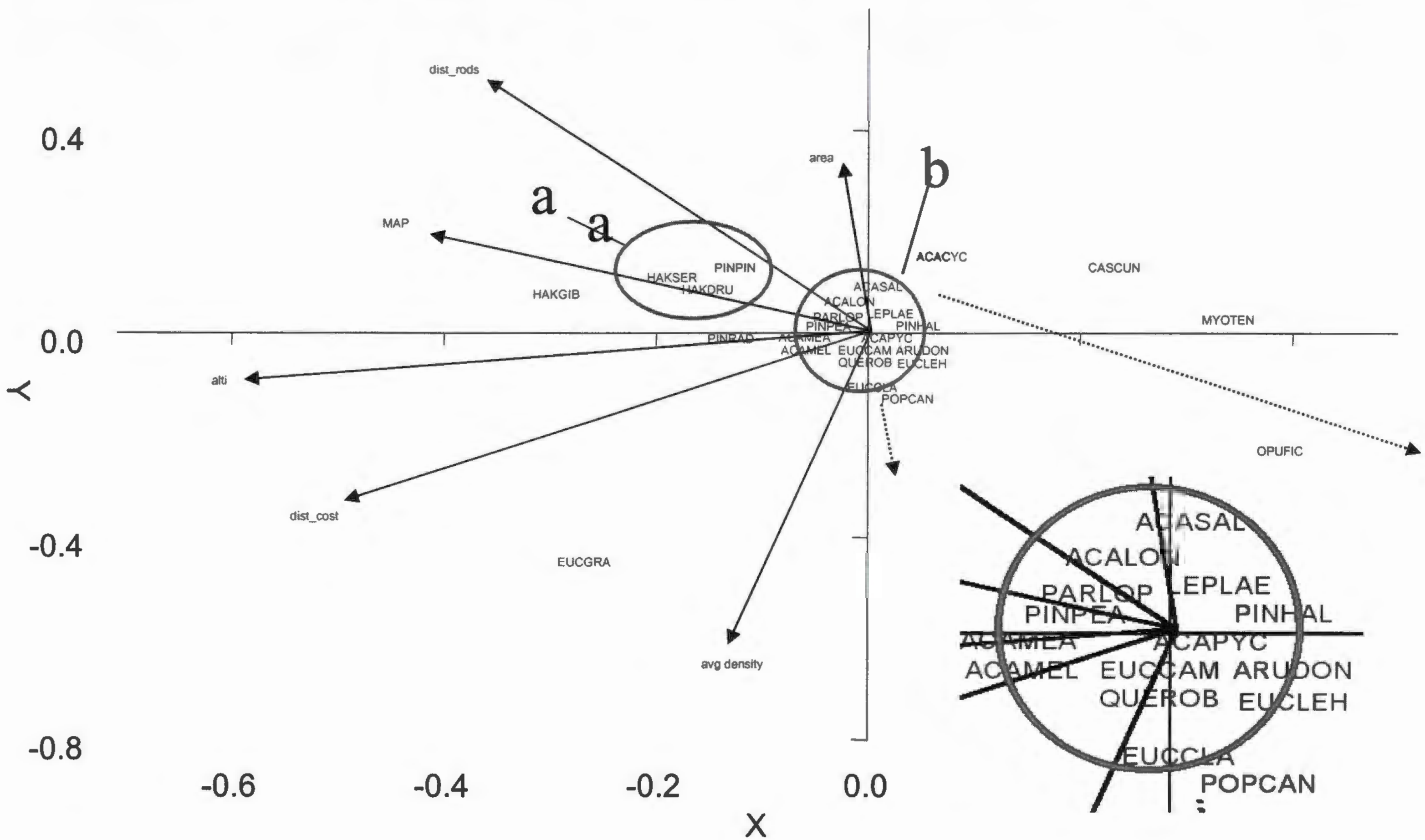


Figure 7 : Biplot showing the distribution of 16 invasive alien species in relation to six environmental variables, including distance to roads (dist_rods), distance to the coast (dist_cost), altitude (alti), the average density of species (table 1),total area invaded by the species (area), and mean annual precipitation (MAP). a) groups species which invade higher altitudes b) species with average values for variables indicating a wide range for potential habitat invasion. (b has been exploded to clarify points)

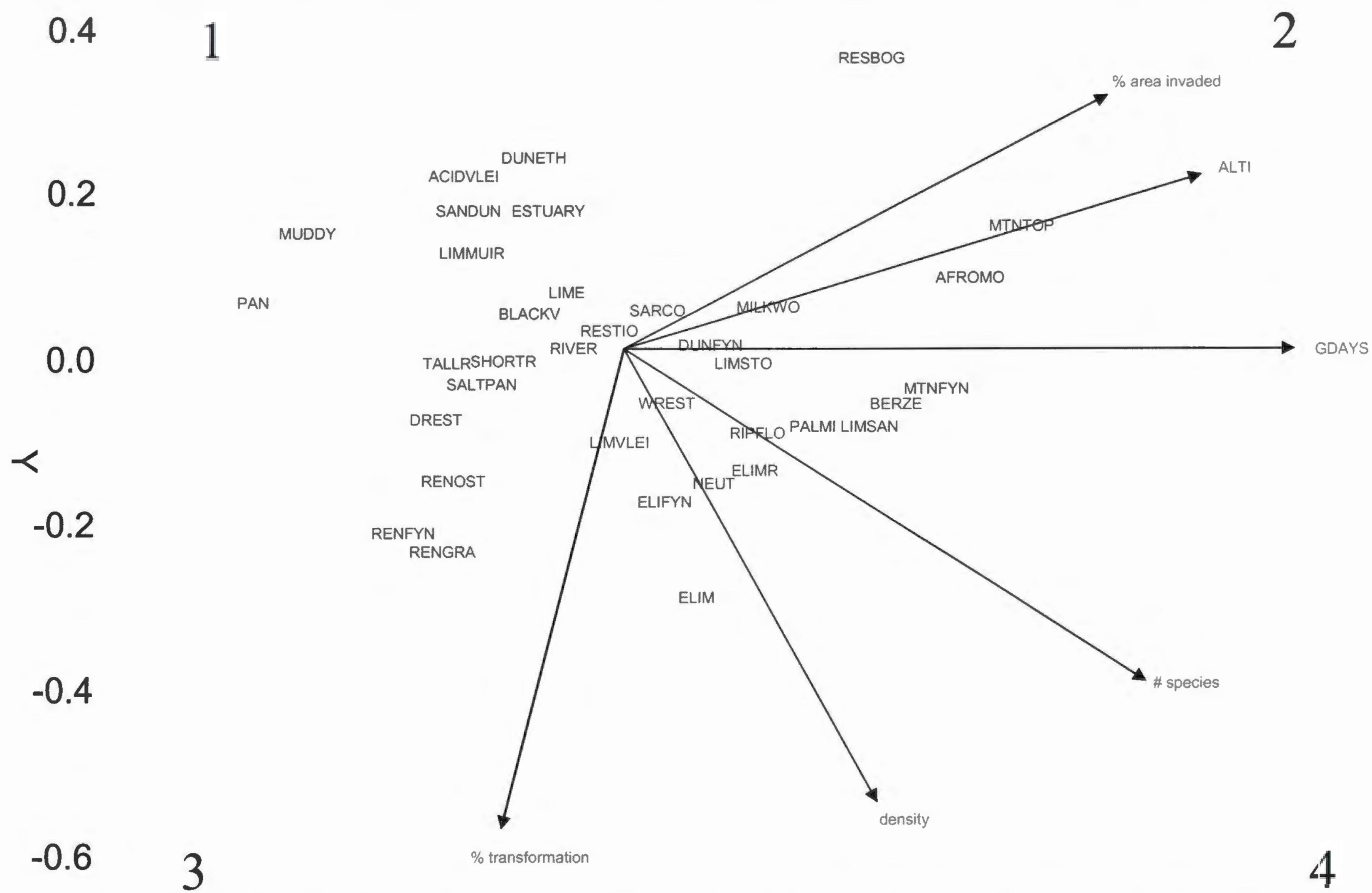
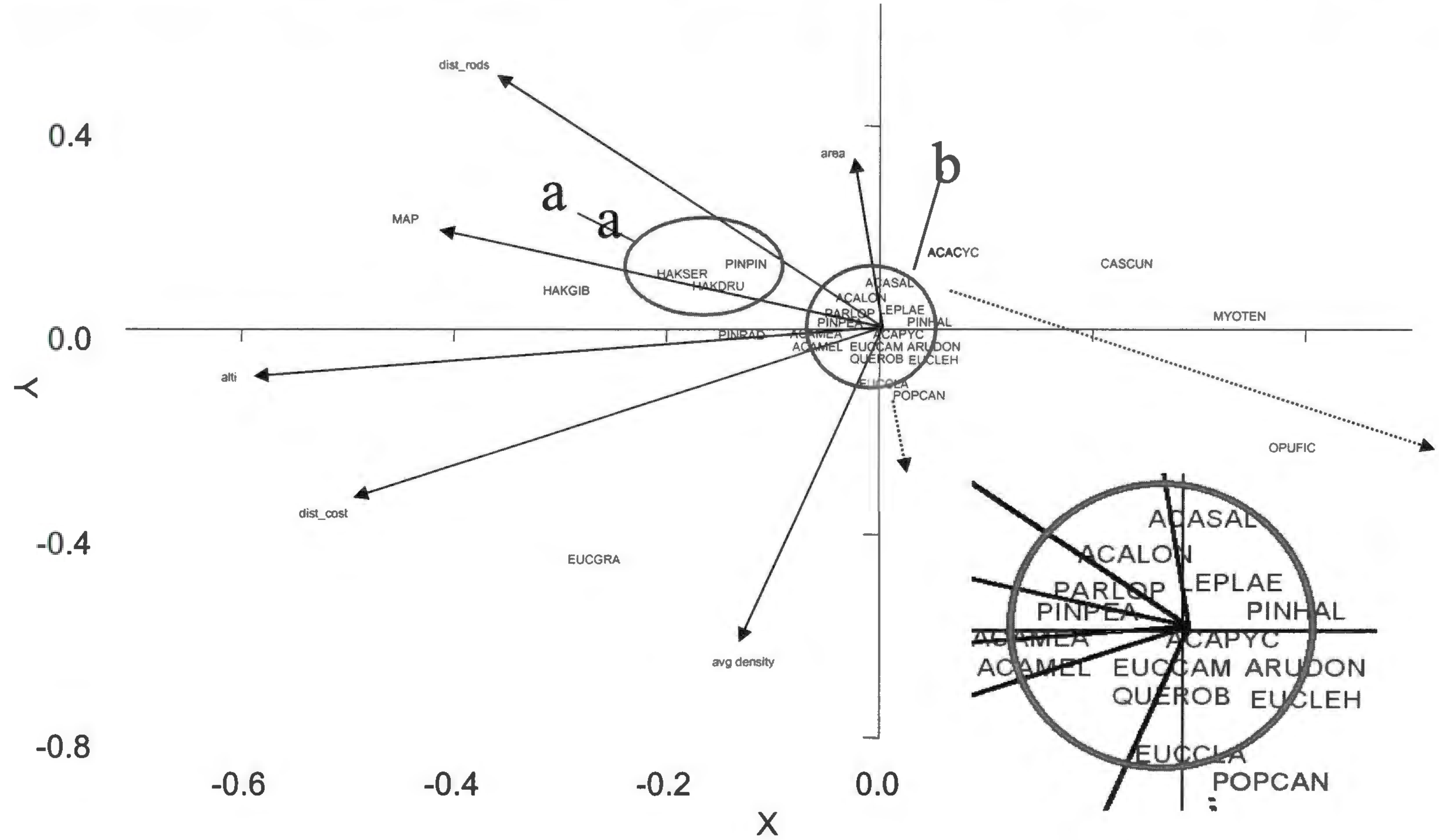


Figure 8: Bipolt showing the distribution of all vegetation types using six variables. The variables include the percentage of vegetation type that has been transformed (% transformation), average density of alien species within the vegetation type (density), the number of species which are present (# species), index of growth days (GDAYS), alitude (ALTI), and the percentage of the total area invaded by invasive alien species (% invasion).



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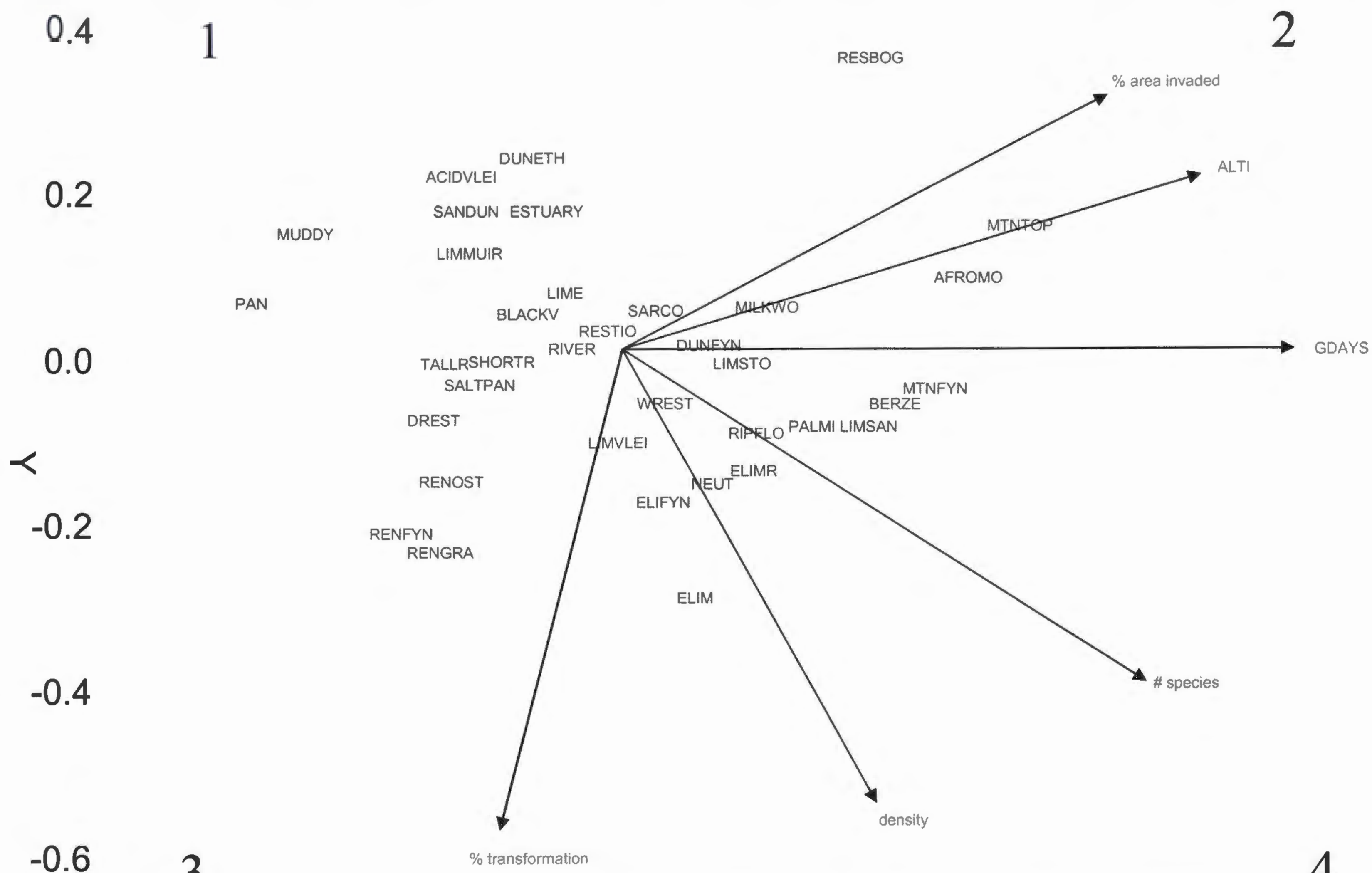

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Table 1: A Summary of vegetation groups and vegetations types described in the Agulhas Plain. Included is the area per vegetation type that has been invaded (total area invaded), the percentage of the total area invaded (% area invaded), the percentage of the vegetation type that is transformed (% trans), the number of species within each vegetation type (# spp.) and the average density of alien species within each vegetation type).

Group	Type	Total area invaded (ha)	% area invaded	% trans	# spp.	Average Density
Acid sand proteoid fynbos (ACID)	Mountain fynbos (MTNFYN)	46989	89	20	34	46
Dune asteraceous fynbos (DUNE)	Dune fybbos (DUNFYN)	27097	91	20	21	37
Elim asteraceous fynbos (ELIM)	Elim (ELIM)	6499	28	84	30	53
	Elim fynbos (ELIFYN)	6249	47	60	23	44
	Renoster fynbos (RENFYN)	1285	15	85	13	43
	Transitional fynbos (NEUT)	2828	57	66	23	46
Ericaceous fynbos (ERIC)	Mountain top fynbos (MTNTOP)	7833	99	5	20	32
Forest and thicket (FOREST)	Afromontane forest (AFROMO)	10	100	14	21	32
	Dune thicket (DUNTH)	87	96	3	4	8
	Milkwood thicket (MILKWO)	901	91	17	23	27
Limestone proteiod fynbos (LIME)	Limestone fynbos (LIME)	9533	92	18	14	29
	Limestone fynbos dominated by *Leuscospermum muirii* (LIMMUIR)	679	93	10	3	33
	Lime sand fynbos (LIMSAN)	14743	92	40	25	47
	Limestone outcrop fynbos (LIMSTO)	1913	94	28	19	41
Renosterveld (RENO)	Renoster grassland (RENGRA)	1492	28	73	16	52
	Renosterveld (RENOST)	854	20	78	14	31
Restioid fynbos	Dry restioid fynbos (DREST)	991	42	64	8	33
	Wet restioid fynbos (WREST)	6882	80	40	22	41
Rivers (RIVER)	Rivers – RIVER	200	80	31	17	31
Sand dunes (SANDU)	Sand dunes (SANDUN)	1598	64	1	8	14
Vleis (VLEI)	Acid vlei (ACIDVLEI)	90	93	0	4	13
	Back vlei (BLACKV)	54	37	19	8	28
	Estuary (ESTUARY)	259	96	1	4	24
	Limestone vlei (LIMVLEI)	0	13	9	6	72
	Muddy vlei (MUDDY)	2	0	4.6	2	5
	Pans (PAN)	6	14	47	2	5
	Salt pan (SALTPAN)	28	8	14	9	43
Wetlands (WETLAN)	Berzelia riparian (BERZE)	3960	91	35	31	41
	Elim riparian (ELIMR)	2318	69	58	25	46
	Palmiet riparian (PALMI)	2787	88	42	26	47
	Restio bog (RESBOG)	33	100	0	3	4
	Restioid wetland (RESTIO)	2938	85	18	14	39
	Riparian flood plain (RIPFLO)	332	84	48	10	58
	Sarcocornia wetland (SARCO)	351	92	42	8	25
	Short reed (SHOTR)	939	47	30	15	29
	Tall reed (TALLR)	1994	51	31	12	38

Table 2: Description and classification of the 39 alien invasive species within the Agulhas Plain. Included is the identification of species codes, the percentage of area invaded by the species (% Invaded), the average density of the species across the Plain (Avg. Density) and the number of vegetation types can be found in (# Veg. Types). The top two, in some cases three, locations where the species occurs are shown in the important vegetation types (NB Veg. types). The Vegetation types are explained in Table 1. Zero's indicate areas of <1 % of area of the Agulhas Plain. The brackets the side of the tables indicate species used for analysis: a) the top seven species, b) the top 16 species for analysis.

Species Code	Species name	% Invaded	Avg. Density	# Veg. Types	NB Veg. Types
Widespread abundant					
EUCLEH	Eucalyptus lehmannii	15	40	32	MILKWO, BERZE, MTNFYN
Very Widespread common					
ACACYC	Acacia cyclops	53	22	35	BERZE, MILKWO
ACALON	Acacia longifolia	23	22	28	BERZE, LIMSTO, MTNFYN
ACASAL	Acacia saligna	41	23	36	BERZE, MTNFYN, LIMESTO
HAKGIB	Hakea gibbosa	12	20	14	BERZE, MTNFYN
LEPLAE	Leptospermum laevigatum	18	14	28	BERZE, LIMSTO
PINPIN	Pinus pinaster	36	15	31	BERZE, MTNFYN
Widespread abundant					
EUCCLA	Eucalyptus cladocalyx	4	38	26	MTNFYN, ELIM, BERZE
POPCAN	Populas canescens	1	39	19	BERZE, MTNFYN, ELIMR
Widespread common					
ACAMEA	Acacia mearnsii	2	11	20	ELIM, ELIMR, MTNFYN
ACAPYC	Acacia pycnantha	1	11	16	ELIM, ELIMR, WREST
EUCCAM	Eucalyptus camaldulensis	4	23	7	ELIM, ELIMR, MTNFYN
EUCSPP	Eucalyptus species	2	23	27	MILKWO, LIMSTO
HAKSER	Hakea sericea	3	12	13	MTNFYN, BERZE
PINRAD	Pinus radiata	2	28	15	BERZE, MTNFYN
QUEROB	Quercus robur	< 1	17	12	MTNFYN, ELIM
Widespread scattered					
ACAMEL	Acacia melanoxylon	< 1	7	12	MTBFYN, PLAMI, BERZE
ARUDON	Arundo donax	< 1	1	14	BERZE, MTNFYN, PALMI
CASCUN	Casuarina species	< 1	1	6	MILKWO, SARCO, ESTUARY
HAKDRU	Hakea drupacea	4	10	18	MTNFYN, BERZE, ELIM
MYOTEN	Myoporum tenuifolium subsp. Montanum	1	5	18	MILKWO, DUNFYN
PARLOP	Paraserianthes lopantha	1	7	17	MTNFYN, MILKWO
PINHAL	Pinus halepensis	1	9	16	MTNFYN, NEUT
PINPEA	Pinus pinea	1	7	16	ELIMR, ELIFYN
Localized abundant					
EUCGRA	Eucalyptus grandis	< 1	88	2	MTNTOP, NEUT
OPUFIC	Oputina ficus-indica	< 1	42	3	RENGRA, DUNFYN
PINPAT	Pinus patula	< 1	63	1	ELIM
POPSPP	Populas species	< 1	43	10	PALMI, MTNFYN
Localized common					
PINSPP	Pinus species	< 1	10	3	DUNFYN, ELIM
Localized scattered					
BANKSP	Banksia species	< 1	9	2	MTNFYN, PALMI
~~BANKPIN~~	~~Banksia piñata~~	~~< 1~~	~~4~~	~~3~~	~~MTNFYN, BERZE, ELIM,~~
EUCDIV	Eucalyptus diversicolor	< 1	1	6	ELIM, WREST, BERZE
HAKSPP	Hakea species	< 1	1	3	MTNTOP, BERZE, MTNFYN
NEROLE	Nerium oleander	< 1	4	4	BERZE, MTNFYN
NOVSPP	Unknown genus	< 1	1	2	BERZE, MTNFYN
PITUND	Pittosporum undulatum	< 1	1	2	BERZE, MTNFYN
RUBSPP	Rubus species	< 1	3	2	ELIM, SHORTR
SALBAB	Salix babylonica	< 1	6	10	ELIM, ELIMR
SESPUN	Sesbania punicea	< 1	3	2	BERZE, MTNFYN

lophantha

? what is this — no such species

Table 3: A summary of the classification of species (Table 2) including the criteria for density and distribution classes.

	Localised	Widespread	Very Widespread
	<100ha	<10 000ha	>26600ha
Scattered (< 20%)	11	8	0
Common (< 27%)	1	7	6
Abundant (> 38%)	4	2	1

Not clear that the figures in the body of the table are numbers of species!

Should refer to Nel et al (2004) for background on this scheme for describing abundance + "widespreadness" of aliens.

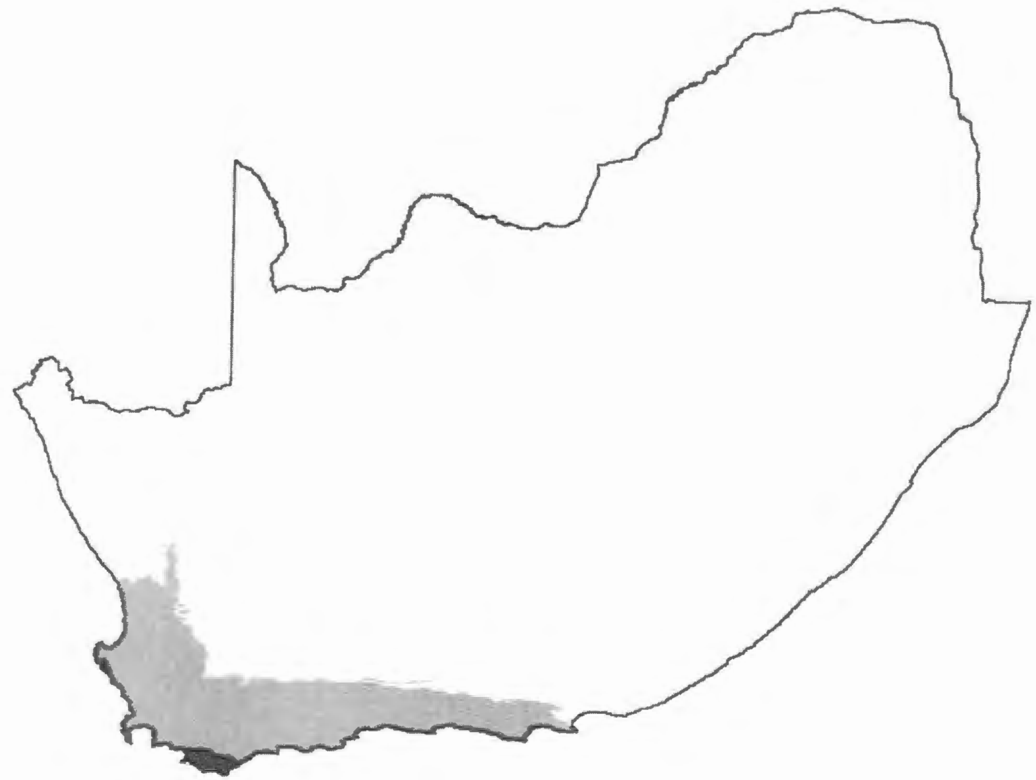


Figure 1: The study ~~site~~ area showing the Agulhas Plain (highlighted in black) within the Cape Floristic Region (highlighted in grey) (Cole *et al.*, 2000)

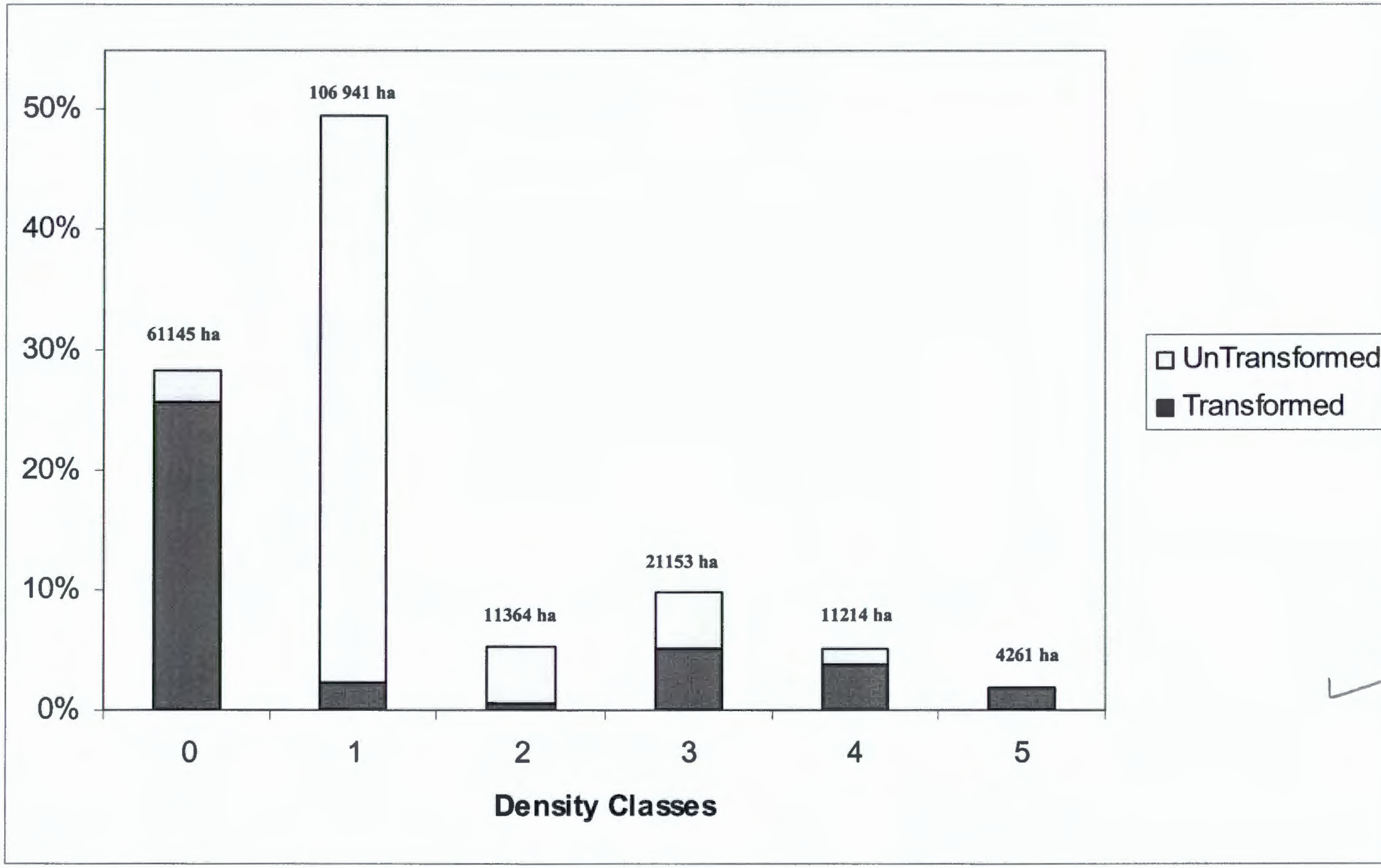


Figure 2: Density classes for invasive alien species across the Agulhas Plain. Within each class the percentage of transformed and untransformed land are shown. The total area of each class is shown ~~in bold~~. above each bar.

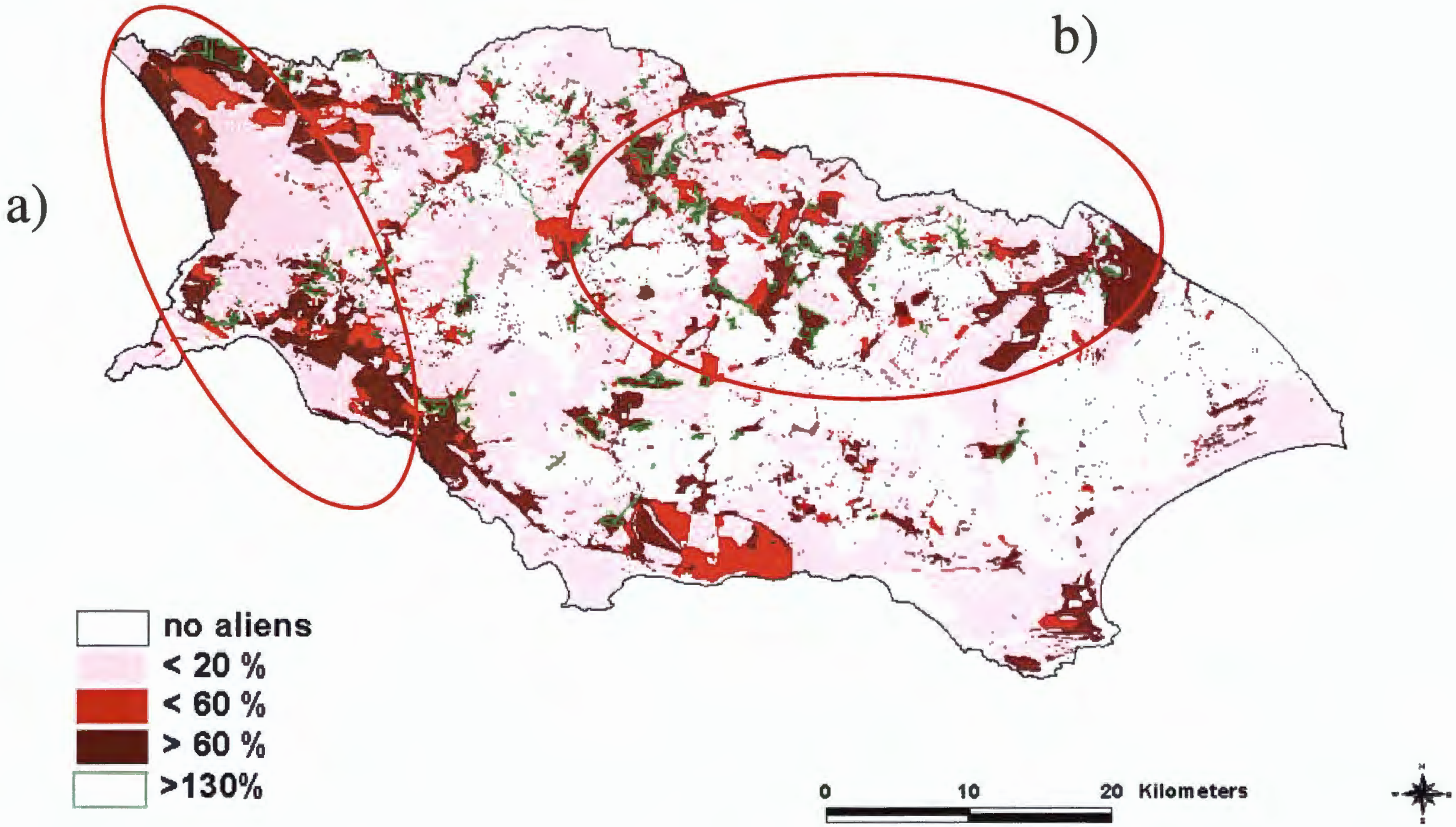
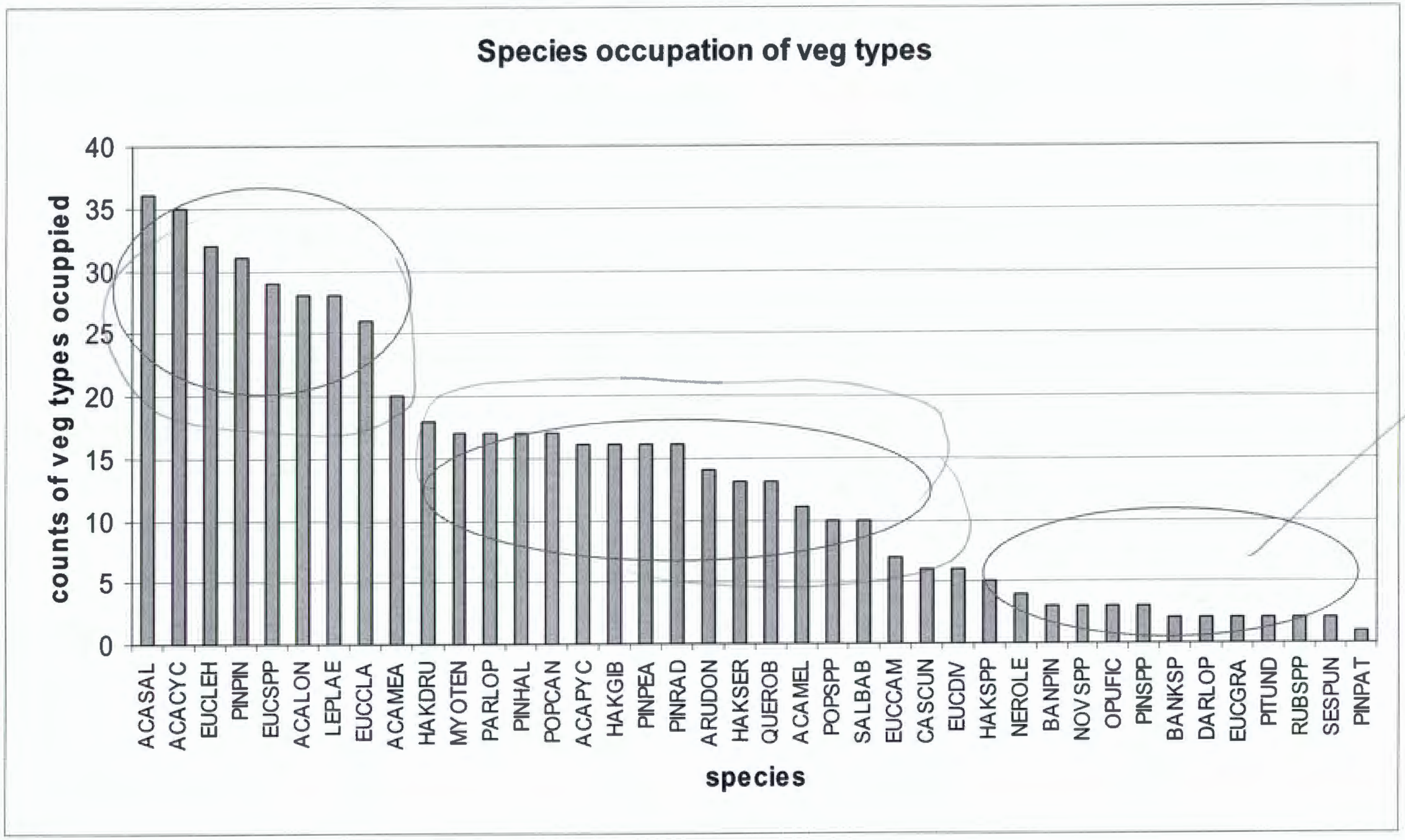


Figure 3: Density classes for mapped stands of invasive alien species on the Agulhas Plain. Areas >130% fall into the highest density class (5) and are shown in green. a) reveals the site for coastal invasion within Dune fynbos vegetation while b) shows interior invasion within Elim asteraceous fynbos and Mountain fynbos vegetation types.



elipses do not conform exactly to groups as defined in the caption

Figure 4: The number of vegetation types invaded by each of 39 species. Three groups can be identified 1) species invading ≥ 20 vegetation types, 2) species invading 5 – 20 vegetation types, 3) species invading < 5 vegetation types. These are similar to the classification method shown in Table 2. The species codes are explained in Table 1.

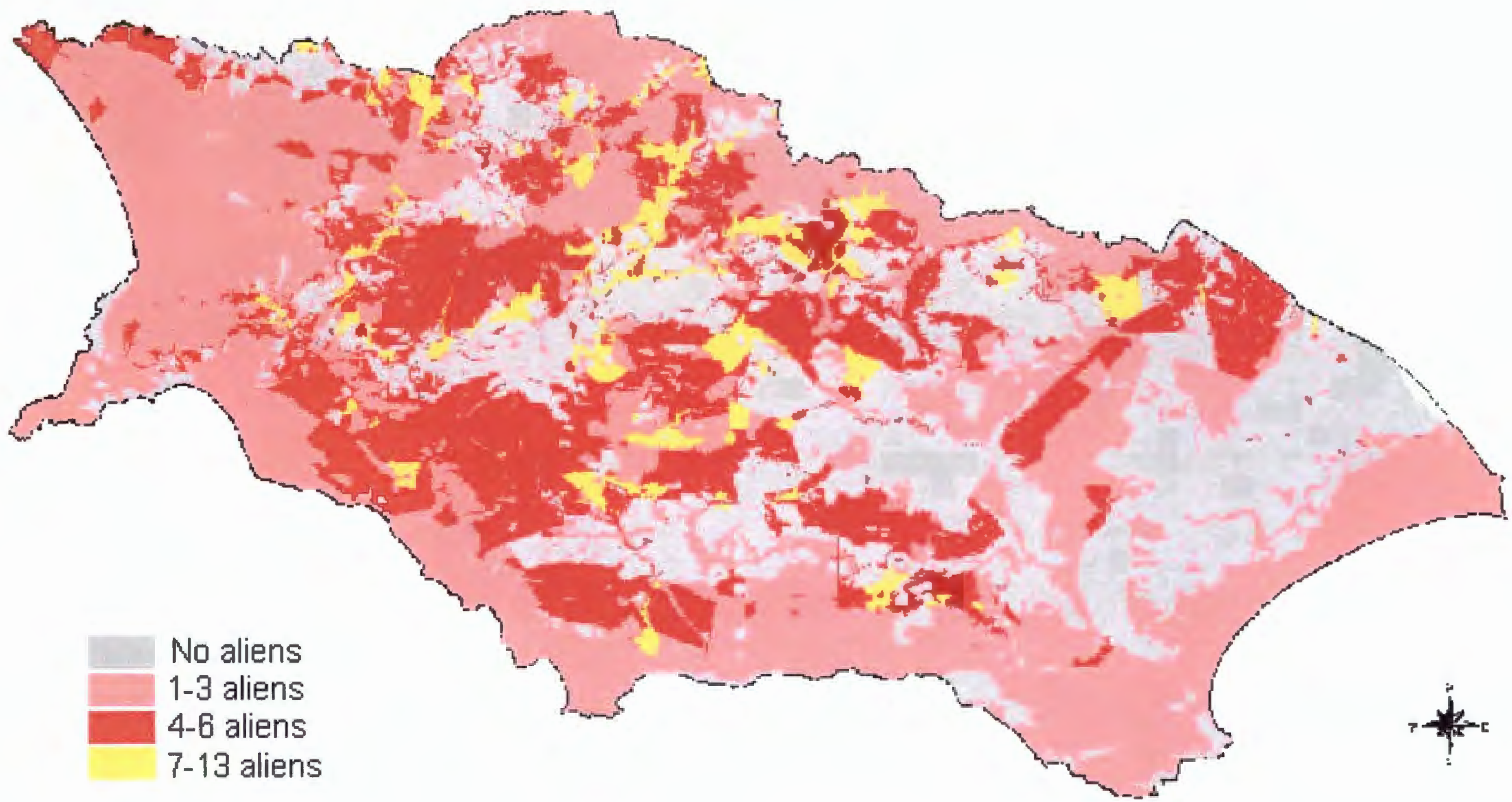


Figure 5 : Species richness map for invasive alien species on the Agulhas Plain. Areas shown in yellow are invaded by the greatest number of species (> 7).

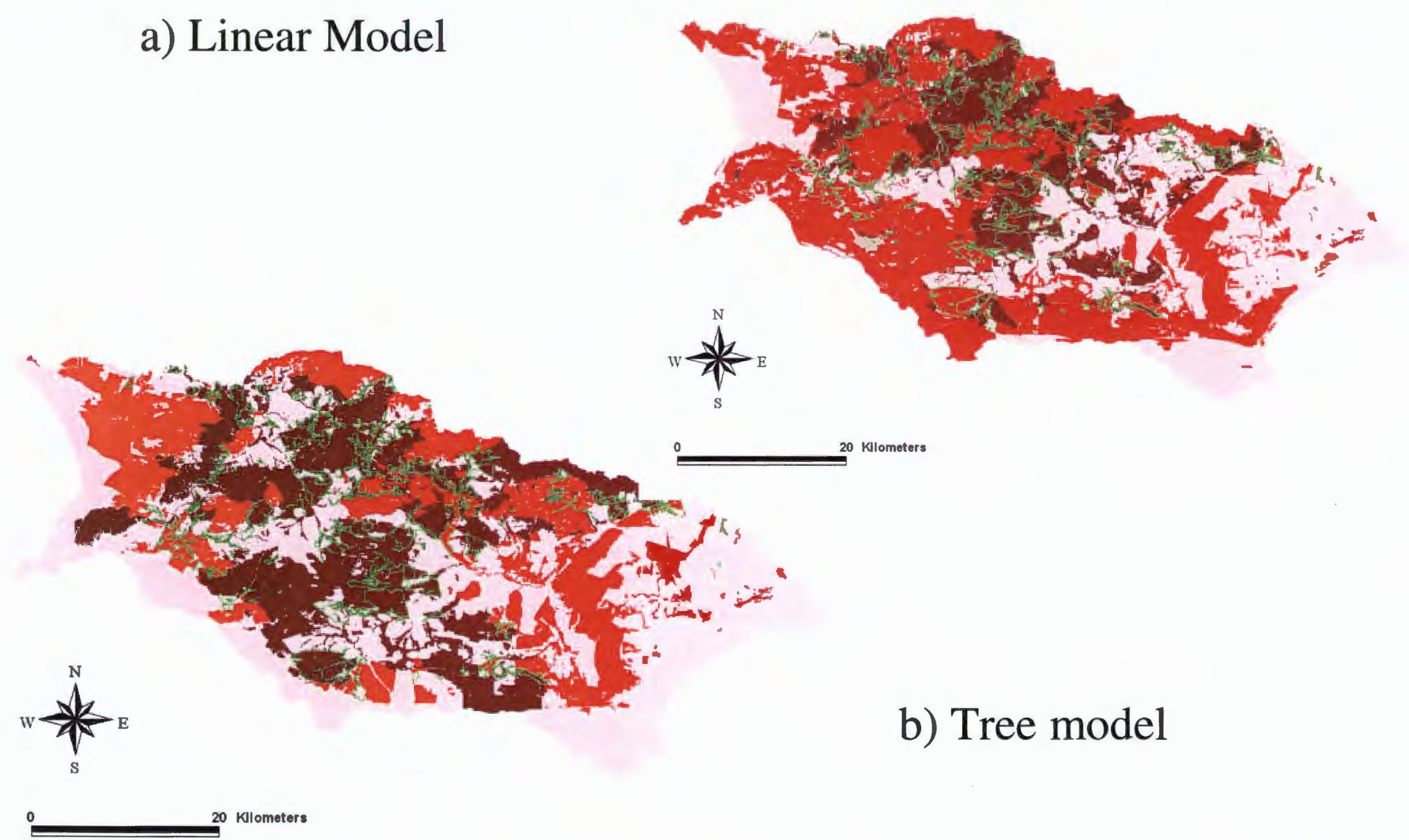


Figure 6: Results of two models for predicting species richness of invasive alien species on the Agulhas Plain: a) linear regression model b) tree regression model (see text). Three classes are identified on each map. Dark red indicates areas of high invasive alien species richness (> 3) while bright red indicates area of lower alien richness < 3. Areas where no aliens are predited are shown in pink. Green boundaries have been overlaid on both maps to show the current distribution of alien species rich stands as shown in Figure 5.

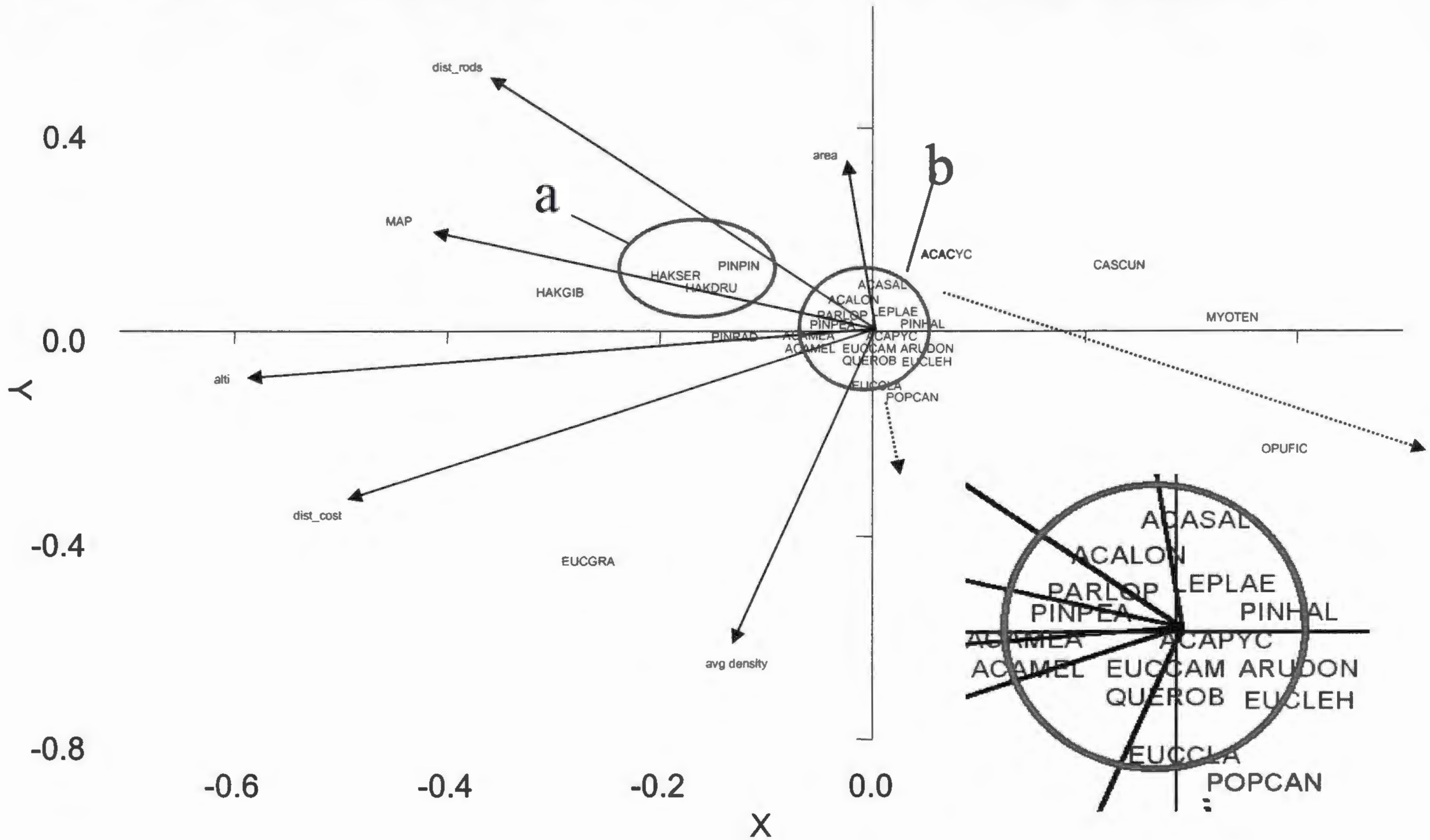
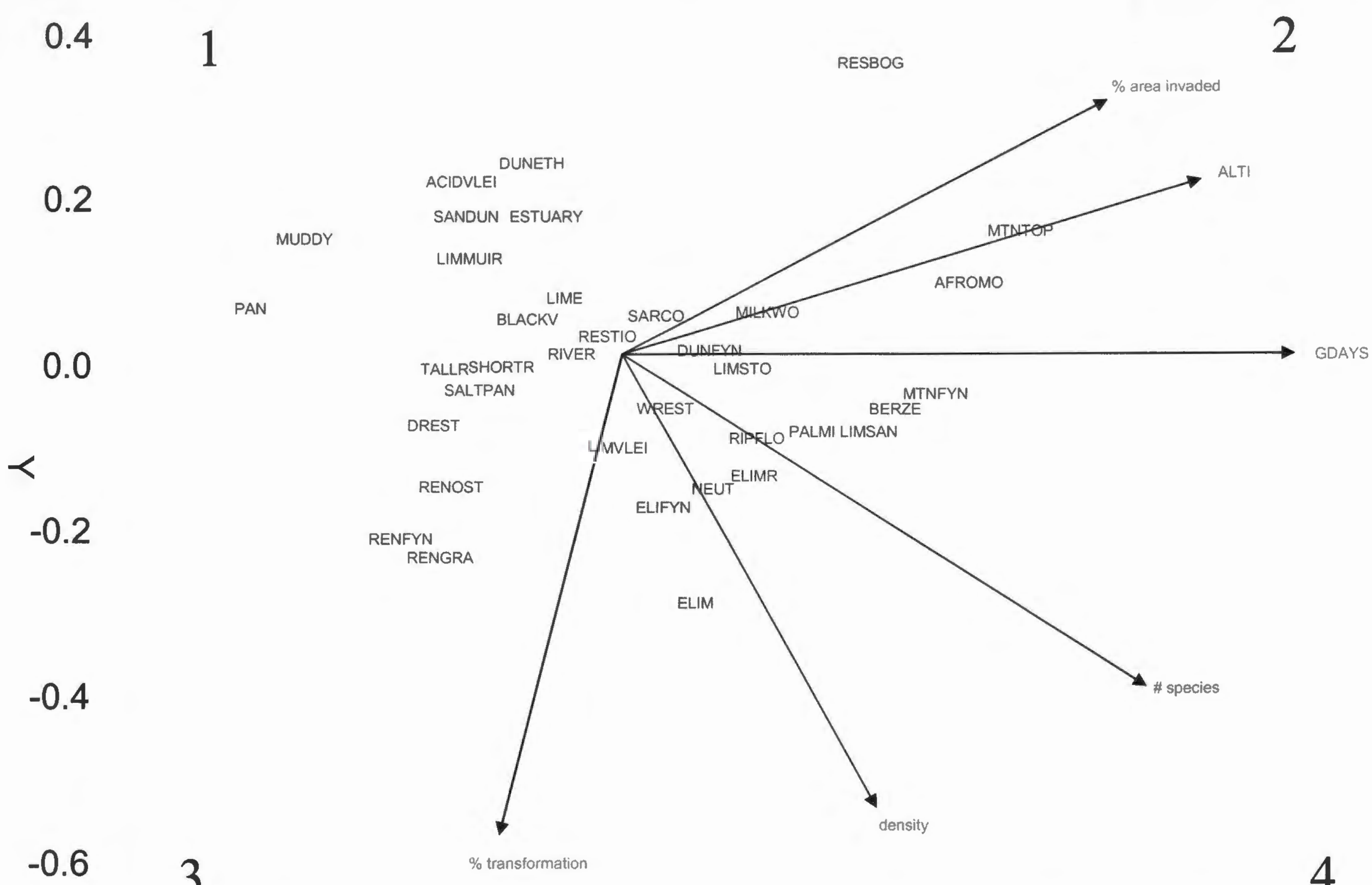


Figure 7 : Biplot showing the distribution of 16 invasive alien species in relation to six environmental variables, including distance to roads (dist_rods), distance to the coast (dist_cost), altitude (alti), the average density of species (table 1),total area invaded by the species (area), and mean annual precipitation (MAP). a) groups species which invade higher altitudes b) species with average values for variables indicating a wide range for potential habitat invasion. (b has been exploded to clarify points)

Not clear – need a dot to show the location of each species.



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Need to cross-refer to Table 1. for veg type codes.