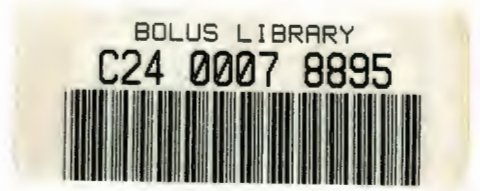


**Long-term vegetation change in response to rest
from grazing at Worcester Veld Reserve**

**Honours Project
Arid Zone Ecology**

**Kate Mc Grath
MCGKAT003**



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Supervisor: M.T. Hoffman

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Abstract

Studies of vegetation change and dynamics in arid areas show that change occurs very slowly. There is a lack of long-term data records. Therefore most studies of vegetation dynamics rely on short-term studies, which are not accurate for arid areas. There is a data set available for Worcester Veld Reserve. The officer in charge at the reserve did the initial sampling in 1937. A subsample of plots surveyed in 1937 was re-surveyed. The area had undergone rest for 40 years. Vegetation change has occurred. The study site is heterogeneous in that heuweltjies (termite mounds) occur throughout the area. Different patterns of change have occurred on heuweltjies and non-heuweltjies.

Introduction

Studies of vegetation dynamics are hindered as their duration is usually not as long as the time scale of vegetation changes. In semi-arid areas (rainfall per annum between 150mm to 500mm (Noy-Meir)) vegetation change is notoriously slow (O'Connor and Roux 1995; O'Connor Morris and Marriott). In semi-arid areas a time scale of 20-60 years is satisfactory (Valone *et al* 2002; Coffin, Lauenroth and Burke 1996, Knapp 1992). That time period allows perennials to recolonise. Studies that are too short may not be able to predict changes. As arid areas are water limited, vegetation dynamics is related to water events (stochastic) (Hoffman and Cowling 1987) not really by other variables. The data sets need to be longer than any temporal patterns of variation

Cyclical or extreme weather phenomena may mask underlying long-term trends. There might be a cyclical nature to rain (18 years) in the Karoo, therefore studies of dynamics need to at least incorporate two cycles. This is because they drive short-term responses that suggest directional change, but there are actually no long-term changes. Semi arid ecosystems are temporally variable and subject to extreme disturbance events.

Equilibrium concepts are thus very relevant. Lack of directional change may be seen as evidence for equilibrium, while directional change can be defined as successional trends (in response to grazing or rainfall) (Walker and Wilson 2002; O'Connor and Roux 1995; Goldberg & Turner 1986.)

There is a lack of representation of dynamics of Karoo plant communities. This is because of the slow rate of population turnover, and the predictable series of replacement is not possible in a system where dynamics are governed by variable climatic events. But predictable patterns do occur (Yeaton and Esler 1990). The question about whether a population or community is in equilibrium or non-equilibrium may be too

simplistic. There may be stabilizing processes present, but weather and invasion of alien plants prevent equilibrium from happening. A definition for equilibrium is: the rate of change in abundance for all species is zero. A population is said to be stable if species return to the equilibrium abundance after perturbation. In the non-equilibrium model populations are constantly subject to environmental perturbation or density dependant mortality events. However there can still be stabilizing processes occurring in these systems. In these systems species composition is influenced by infrequent abiotic events, such as grazing and drought. Among species competition is weak or not important.

Long-term changes in vegetation can be studied using aerial photographs (Carmel and Kadmon) or long-term data records (Goldberg and Turner 1986) or by contrasting grazed versus ungrazed areas (Pettit and Froend 2001, Knapp 1992)

In 1937 Mr van Breda, officer in charge at the Worcester Veld Reserve surveyed 75 ha of the reserve. His data is still available at the reserve. His survey recorded both species and species cover. His data is an excellent source to use in long-term vegetation studies.

The Worcester Veld Reserve is the succulent karoo biome (Rutherford and Westfall 1986). The vegetation in this area is classified as karroid broken veld by Acocks. The vegetation is characterized by short, mostly succulent plants. The landscape is also characterized by circular soil mounds, approximately 1m high and 30m in diameter. These are known as heuweltjies.

Heuweltjies

Heuweltjies are found throughout the western coastal areas of South Africa, from the Orange River in the North to False Bay in the South. The eastern limits of this range are the Cedarberg and the Kouebokkeveld. It also occurs in the inland valleys of the Hex River, Riviersonderend, Witteberg, Langeberg, Swartberg and Outeniqua mountains (Lovegrove and Siegfried 1986). Heuweltjies used to be known as Mima-like mounds, as they were thought to be similar to mounds found in the western parts of the United States. The type locality for these mounds was the Mima prairie, Washington State (Lovegrove 1991). However this is unlikely because mima mounds have rodent origin, but African mounds have termite origin (Moore and Picker 1991).

Many hypotheses were about that discussed the origins of these mounds. These included as wide-ranging sources as the limestone faulting hypothesis, wind-action hypothesis, termite molerat hypothesis and the termite hypothesis. The most accepted hypothesis now is the termite hypothesis. The termites involved are *Microhodotermes viator*. *M. viator* is endemic to the Western Cape (Lovegrove 1991). These termites are territorial insects (Swift 1994). Therefore heuweltjies are symmetrically spaced in the landscape, and have a density between 232 -388 km⁻². Intermound distances are usually between 44 and 55m (Lovegrove 1991). *Microhodotermes viator* has only one hive per colony. Heuweltjies are no different from mounds elsewhere in Africa, which are also formed by termites. The other animals that are associated with heuweltjies , apart from *M. viator*, are thought to actually help spread the mound, not help to create it (Milton and Dean 1990). Mounds have three layers, a calcified basal zone that is resting on bedrock, a partially lithified central zone and a upper sandy layer. *M. viator* tunnels dominate the entire subsurface portion of the intact mound in Clanwilliam. Fossil termite structures

were found in calcified layers. Dating samples from calcified areas gave result of 4000 yrs (Moore and Picker 1991).

Heuweltjies have a different substrate than the surrounding intermound areas. They have higher organic matter, significantly more nutrients, higher pH and lower salinity (Smitheman 1990; Midgley and Musil 1990). Similar conditions to those on heuweltjies were found by Smitheman (1990) in area of *Euclea undulata*, however *Euclea undulata*, and other tree like plants such as *Rhus*, *Lycium* and *Asparagus* were not found on heuweltjies. On heuweltjies the soil is finer, having more silt, and clay, while intermound areas are more pebbly (Moore and Picker 1991; Lovegrove 1991, Midgley and Musil 1990). There is better soil aeration on heuweltjies. The soil water content is higher on heuweltjies, though only in winter and spring. In summer there is no difference in soil water content between heuweltjie and non-heuweltjie (Midgley and Musil 1990)

Heuweltjies support a different vegetation type. This is because of different soil water content, increased soil nutrients and increased disturbance. The presence of heuweltjies increases the beta and gamma diversity of an area. There is usually more species diversity in the intermound areas, than on the heuweltjie. The vegetation on heuweltjies is usually more succulent, asteraceous and deciduous (Knight, Rebelo and Siegfried 1989; Midgley and Musil 1990). The increased deciduousity has been linked to the higher nitrogen concentration, but not to higher water content (Midgley and Musil 1990). The deciduousness is debatable, as it depends on what is classified as deciduous. For example, *Euphorbia mauretanica* is seen to be deciduous (it does have small leaves, which are lost), however the main photosynthetic organ is the stem. Therefore *Euphorbia mauretanica*, *Euphorbia burmanni* and *Sarcostemma viminale* can be seen to be

evergreen stem succulents (Boshoff 1989). There is low similarity of species within heuweltjies (18%, versus 27% intermound) (Knight *et al* 1989). There is more plant cover on heuweltjies, therefore the plant turnover on heuweltjies may increase the concentration of nutrients further (Yeaton and Esler 1990).

There is high alpha species diversity on heuweltjies. This could be because of random colonization of plants and non-uniform disturbance regimes. There are more nutrients available on heuweltjies, therefore there can be selective grazing on heuweltjies. This would lead to more trampling, and therefore more disturbances.

Disturbance

Disturbances are relatively discrete events that disrupt ecosystems, community or population structure and change resources, substrate availability or physical environment. Termites create disturbances by consuming the vegetation, altering the soil fertility and drainage, attracting herbivores to nutrient enriched and more productive vegetation. Different termites create different disturbances, for example *Trinervitermes trinervoides* a grass-eating termite, while *Microhodotermes viator* is not (Smith and Yeaton 1998). It has been found that they eat mostly dried leaf material (*Rhus incisa* and *Pteronia ciliata* being the favorites), not grass or poisonous shrubs such as *Galenia africana* and *Euphorbia burmanni* (Scarola, 1995). Heuweltjies undergo much disturbance. *Pteronia incana* is an indicator of lightly disturbed heuweltjies, *E mauretanica* indicator of highly disturbed heuweltjies (Helme 1990). Apart from termites, which burrow in the heuweltjie, other animals that are found on heuweltjies are the ostrich (which use it as a nest site), whistling rat *Parotomys brantsii* (folivore), striped rat (which are granivores), aardvark (*Orycteropus afer* – high intensity disturbance, episodic and severe) and the

mole rat -family Bathyergidae –regular disturbance, and buck. Heuweltjies are actually hotspots of animal activity. The high soil fertility, and therefore high plant fertility encourage animals to feed there. Other animals that are found on heuweltjies include porcupines, foxes, moles, mongooses, rats, shrews, snakes scorpions, lizards, beetles (Milton and Dean 1990; Knight *et al* 1989). Herbivory by termites is important (Swift 1994).

Specifically at Worcester Veld Reserve there is *Cryptomus hottentotus* (molerat), *Raphicerus melanotis* (grysbok- shaded by the dense vegetation on the heuweltjies), *Microhodotermes viator* and *Rhabdomys pumilio* (striped field mouse) (Helme 1990).

Heuweltjies continue to affect the soil even when the termite colony has died. Nutrients leach out of 'dead' heuweltjies. Therefore the pH and chemical composition changes in the intermound areas. This effects what species establish first in succession of the intermound area (Yeaton and Esler 1990).

At the study site there are essentially two different systems: the intermound system, and the heuweltjie system. The heuweltjie system is characterized by high disturbance and increased soil moisture and soil nutrients. A competitive hierarchy (non-random sequence) of species on heuweltjie suggests that succession is happening (Helme 1990).

The aims of this study were to investigate vegetation change in response to rest from grazing. As disturbance is more prevalent on the plots, a hypothesis would be that the heuweltjies would change more than the non-heuweltjie area. This survey will also be

able to see more clearly if trees are the climax vegetation (Olivier 1966, Smitheman 1990)

Study site

The study was conducted at Worcester Veld Reserve. It is approximately 140 km away from Cape Town. It lies in the Worcester Roberstson Valley, 33°39` S and 19°27` E. The soils are Malmesbury shale derived. The soils are shallow; but on the heuweltjies and the bottom of the slope the soil is deeper. Bedrock is often exposed (Boshoff 1989). It has a Mediterranean climate, with most of the rain falling between April and September (Boshoff, 1989). No rain falls in December and January. The valley lies in a rainshadow surrounded by the Sonderend, Wemmershoek, Du Toits, Slanghoek, Heks rivier and Witzenberg Mountains. The highest rain falls in August (Smitheman 1990). It has approximately 238mm of rain per year. The reserve has had no livestock on it for at least 40 years. The area is 75 ha, with two small hills in it, Meiringskop, and Rondekop. The exposition is mostly northwest and southeast. The northwest is relatively drier, warmer and the southeast side is relatively cooler and moister. The gradient varies from between 0 and 30 degrees. The elevation above sea level is 260m, with Rondekop at 361 m and Meiringskop at 396 m above sea level. A small portion of it has been cultivated for crop development (Olivier 1966).

The reserve was previously commonage. In January 1935 the area was declared a reserve. The main function of the reserve was to study pasture, however, as the pasture was too bad, and the area too small, this was not done. Instead the northern part of the reserve was set aside to study succession, the effect of fire and phenology; and the southern part was for experiments for growing pasture plants (Olivier 1966).

Methods

Two assumptions in this study are: Mr van Breda used the same nomenclature as we do now, and that he sampled thoroughly – that he included even small insignificant plants. We can assume these things to be true because he left herbarium samples (at the Worcester Veld Reserve), therefore we can know that he was referring to the same plants. He included species that are small and insignificant, as well as plants where there was only one plant in a plot.

Another assumption we have to make is that we used the same method for sampling the plots that he used. Fortunately he did publish a paper in the South African Journal of Science in 1937. From this we can be sure that we used the same method.

Refinding the same plots for sampling was the most difficult thing to do. Although van Breda marked out the plots, these markings were stolen during the war. After the war someone attempted to refind the plots, but had no success. In order to find the plots we had to assume that what he had labeled as *E. mauretanic*a populations were in fact heuweltjies. This is a valid assumption. Smitheman (1990) and Olivier (1966) (who both did research in the Worcester valley) found that *E. mauretanic*a grows on predominately on heuweltjies. To determine the plots we used aerial photographs from 1949 and 1997. We superimposed van Breda's survey map onto the aerial photo. Using heuweltjies as a guide we could determine where his plots were. Then using the aerial photograph from 1949 we could identify the plots in the most recent aerial photograph. From there we could identify the plots on the ground.

van Breda divided the reserve into one morgen plots. Each one morgen plot was then divided into nine squares, each approximately 34 X 34 yards. This is equivalent to 30.1 m. We therefore made our plots 30 X 30 m. We marked out the plots with 50 m tape (for our non -heuweltjie plots). For the heuweltjies plots we just recorded the heuweltjie, and not the surrounding area. For the non-heuweltjie plots we tried specifically to get plots that included no heuweltjies. If a small part of a heuweltjie was present on a plot, we excluded it from the study.

In each plot we walked around for approximately ten minutes noting all the species that were present. The percentage cover of total plant, moss, rocks, stones, lichens, and plant cover per species were recorded.

Topography has an effect on vegetation. Although slope and aspect is often combined into one measurement, radiation, both have an effect individually (Carmel and Kadmon 1999). A study done at the Worcester Botanical Garden (Smitheman, 1990) found that the difference between the north and south slope was quite marked. On the south slope the vegetation is taller, there is more plant cover and there was a higher seasonal ground cover of mosses, annuals, geophytes and ferns. On the northern slopes there was lower species richness, the vegetation was sparser and shorter, there was no seasonal change in ground cover. In a study done over 18 months at the Worcester Veld Reserve (Boshoff, 1989) it was found that the southern slope received approximately 100mm more rain the northern slope. The south slope also had generally lower temperatures. We therefore sampled at both the northern and southern slopes. On each slope we sampled five heuweltjies, and five non-heuweltjie quadrats. These are, according to van

Breda's survey: northern aspect, non-heuweltjie: 10c, 23a, 38b, 38c, 55b; northern aspect, heuweltjie: 10e, 23d, 38e, 39h, 55e; southern aspect, non-heuweltjie: 57f, 65h, 65d, 65b, 65f: southern aspect, heuweltjie: 57e, 65i, 65e, 65c, 65a.

Analysis

Correspondence analyses (CA) were done on all the data and on heuweltjie and non-heuweltjie plots separately. Unconstrained correspondence analysis was chosen as the data had a unimodal model. CANOCA for windows was used to do all the analyses, and EXCEL was used to plot the ordinations, using values from the first two axes. The data could have been noisy as many species were either only found in one plot, or were found at very low abundance levels. Ordinations work well with noisy data (ter Braak 1988).

To determine differences in number of species per plot, paired t-test (ZAR 1974) were calculated for the plots, using Statistica (ver.5.5 1999-2000)

To see whether there were changes in percentage cover in growth form; species were allocated to growth forms, namely: tree, deciduous shrub, evergreen shrub, stem succulent, large leaf succulent (> 10cm), small leaf succulent (<10cm) and grasses. Total percentage cover was calculated for each growth form, for non-heuweltjie and heuweltjie plots respectively.

Results

In the correspondence analysis that used all the plots and species, (figure 1), a number of patterns are evident. The heuweltjies on the right hand side of the analysis show

separation between the old (1937) and the new (2002) plots. The 1937 plots are grouped more closely together, indicating that there was less difference among them when the first survey was done. The 2002 heuweltjie plots are more widely spread. There are also differences between the north and the south side, with the heuweltjies on the southern slope forming a cluster, and the heuweltjies on northern slope more scattered. The new plot, 10e that is more like the old plots, than the other new plots, has the same plants, namely *Euphorbia mauretanica*. The plants that define it as a group are *Sarcostemma viminale*, *Kedrostis nana* and *Hermannia desertorum*. Of these, *Kedrostis nana* and *Hermannia desertorum* are not found on any of the other plots. *Sarcostemma* is found on other plots, though with less cover.

The non- heuweltjie plots are separate from the heuweltjie plots. The non- heuweltjie plots do not separate into groups, corresponding to old and new surveys. They also do not separate according to slope (north or south).

The separate correspondence analyses for the heuweltjie and non- heuweltjie areas were done in order to more clearly see the ordination. In the heuweltjie ordination (Figure 2) one can clearly see the pattern of change. In all the plots, except, 10e, there is a definite pattern from left to right, changing from old to new plots. The plants that define the outlying group are *Hermannia desertorum* and *Sarcostemma viminale*.

Figure 3 shows the correspondence analysis for non- heuweltjie plots. As opposed to the heuweltjie plots there is no clear pattern of change. The two plots that have changed the most are 10c and 38c. Both of these plots are found on the northern aspect. Two of the old plots, 55b and 65d, change in a different direction altogether.

The lack of change in grass cover may another indicator that grass is a supposed climax state, not a real one (Mitchell 1991).

Change has occurred, but as it has been a change in unpalatable plants it is not really an improvement of the vegetation. A change that has occurred that is good is the decrease of *Galenia africana*.

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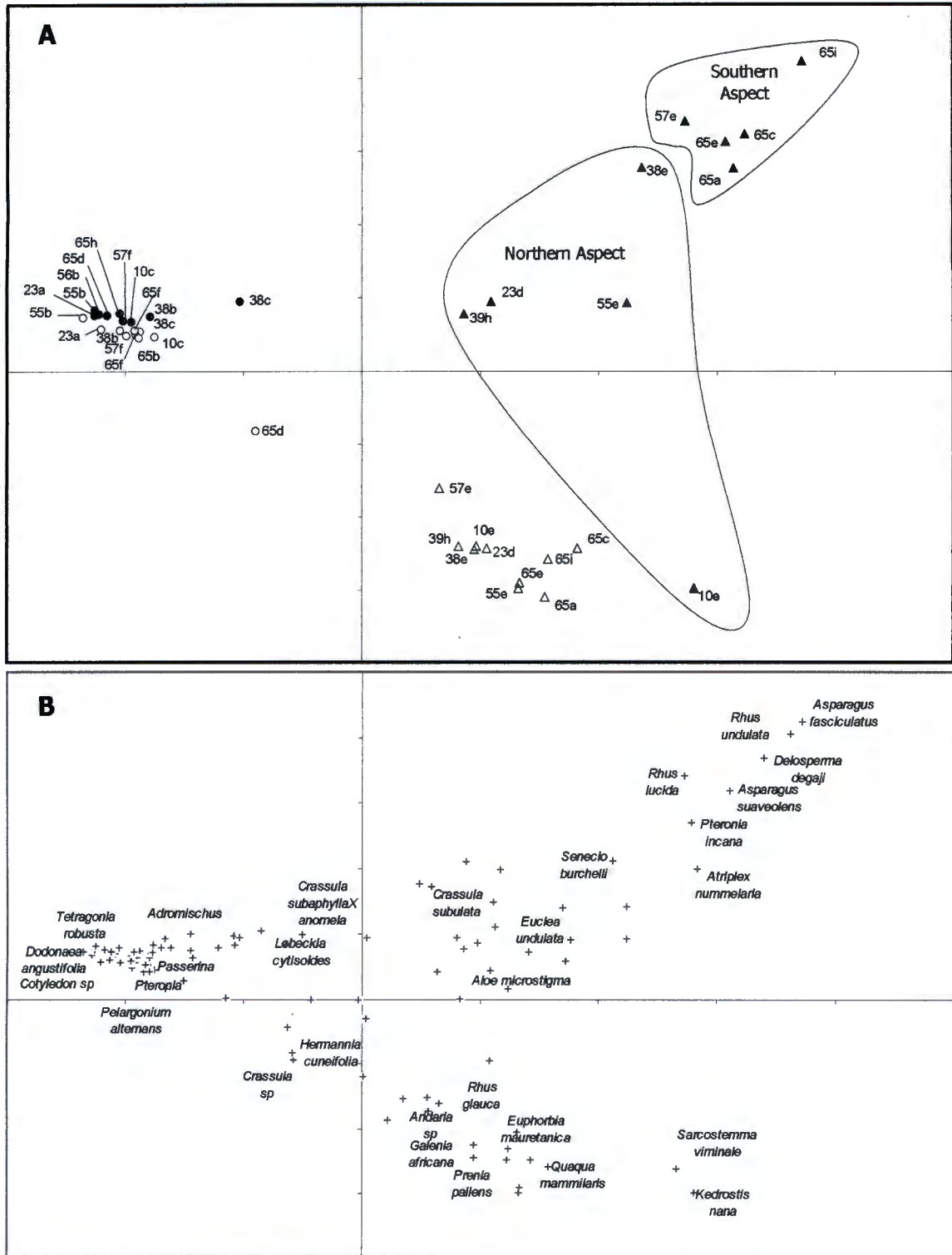


Figure 1: Graph of correspondence analysis scores, from both heuweltjie and non-heuweltjie plots. Fig 1A is the graph of all plots. Open triangles represent heuweltjie plots surveyed in 1937, filled triangles represent heuweltjie plots surveyed in 2002. Open circles represent non-heuweltjie plots surveyed in 1937, while dots represent non-heuweltjie plots surveyed in 2002. Figure 1B is the ordination of all species (N=113). Each species is represented by a '+' sign.

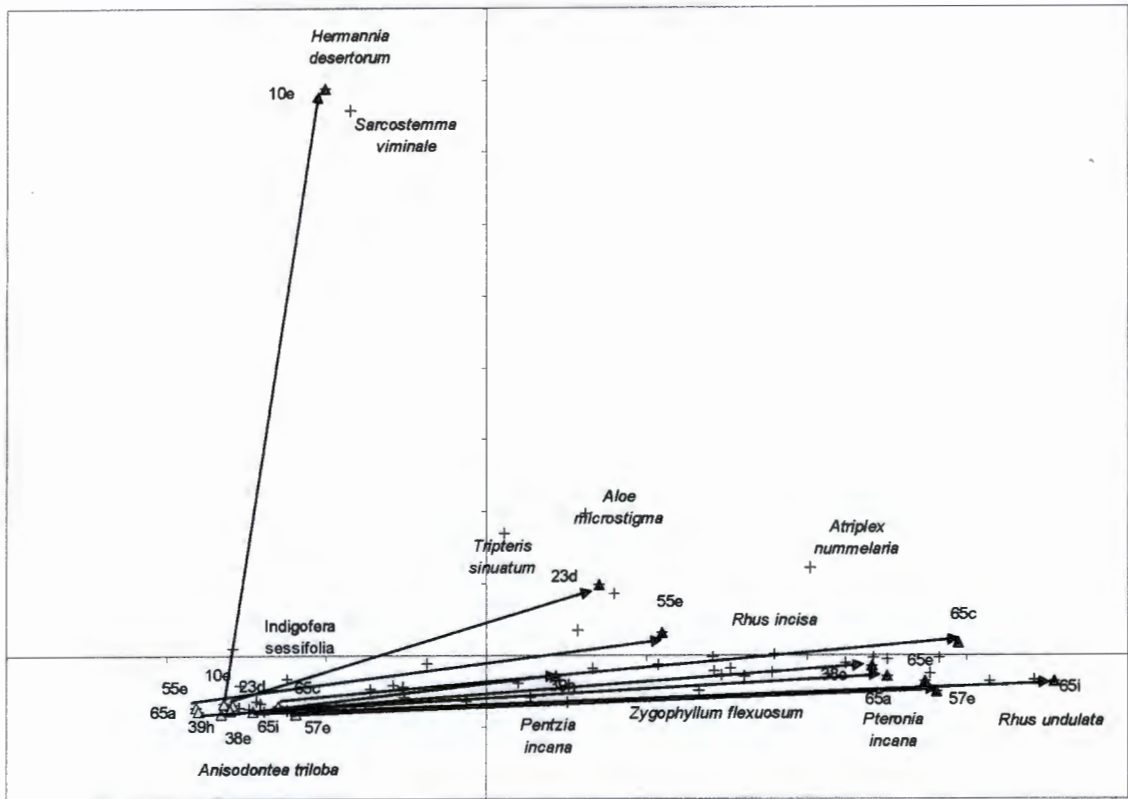


Figure 2: Correspondence analysis ordination of heuweltjie plots and species. Filled triangles represent plots surveyed in 2002. Unfilled triangles represent plots surveyed in 1937. A '+' denotes a species point, key species names have been provided. Arrows are drawn to show the extent and direction of change from 1937 to 2002.

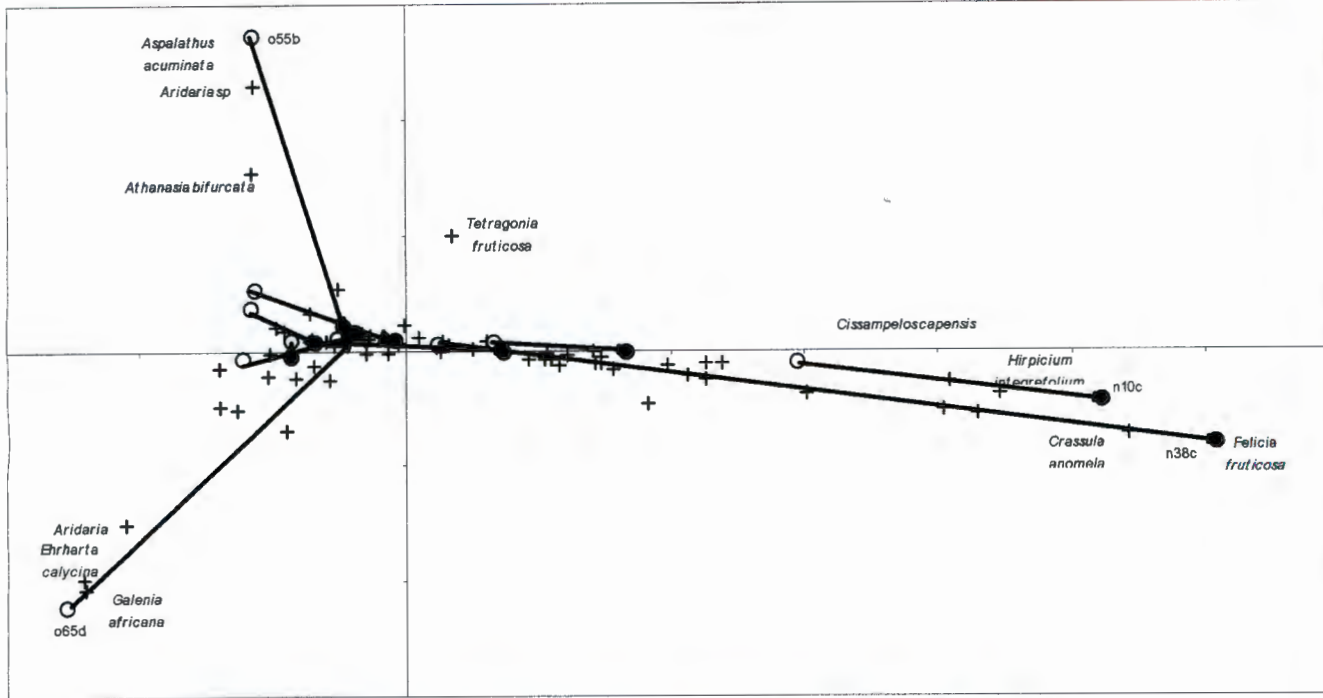


Figure 3: Correspondence analysis ordination of non-heuweltjie plots and species. Dots represent plots surveyed in 2002, while circles represent plots surveyed in 1937. Arrows show the extent and direction of change from 1937 to 2002. A '+' denotes the position of a species in the ordination. Species which indicate the location of the plots are indicated.

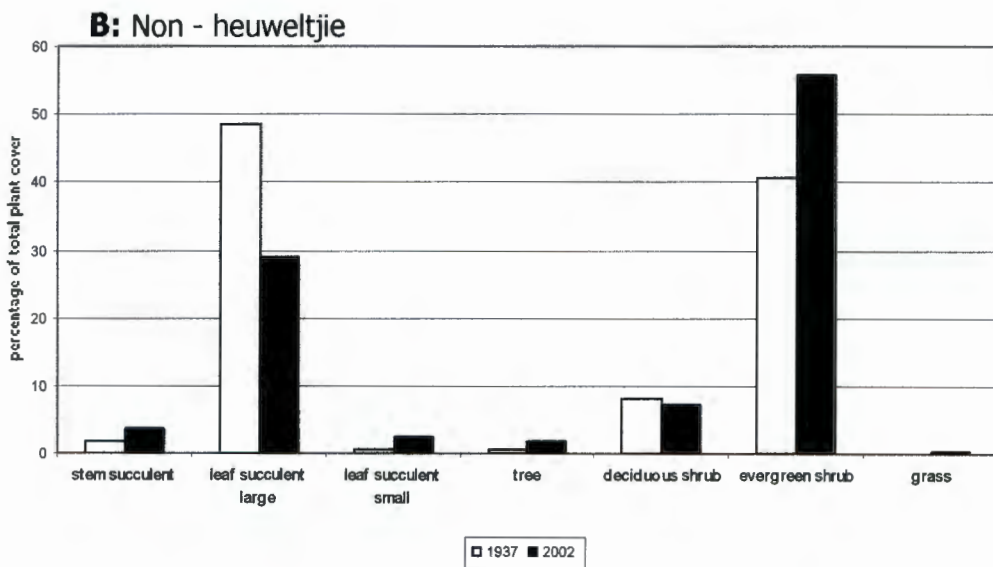
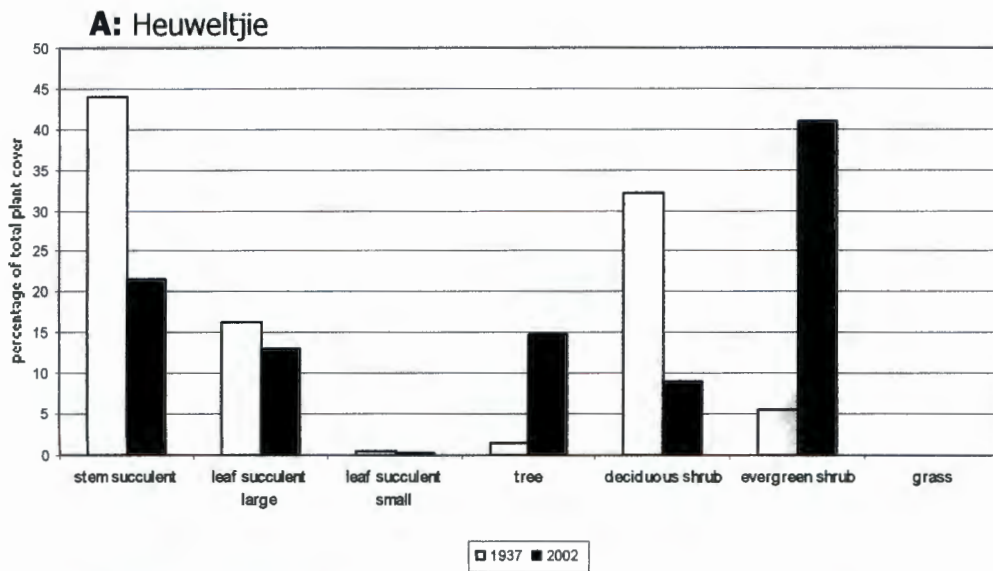


Figure 4: Total percentage cover, for each growth form. Figure 4A represents changes in growth form cover in heuveltjie plots. Figure 4B represents the change in growth form cover in non-heuveltjie plots.

Table 1: Paired t-test (ZAR) for number of species per plot. Plots were grouped according to aspect, and whether the plot was on a heuweltjie or not. N= 5, d.f. = 4, significant values are in bold ($p < 0.05$).

Plot type	Aspect	No. of species (\pm std dev)		t	p
		1937	2002		
Non-heuweltjie	N	11.6 (\pm 1.5)	28.2 (\pm 4.5)	- 11.6	0.0003
Non-heuweltjie	S	21.4 (\pm 6.1)	32.0 (\pm 4.6)	-3.3	0.029
Heuweltjie	N	14.4 (\pm 2.7)	19.8 (\pm 4.8)	-2.0	0.10
Heuweltjie	S	13.4 (\pm 2.3)	18.6 (\pm 2.2)	-3.1	0.037