Chapter 11

General discussion and synthesis

11.1 Introduction

This chapter provides a discussion and synthesis on the findings of the study and aims to provide insight on the Succulent Karoo and Fynbos Biome affinities of the Hantam-Tanqua-Roggeveld subregion.

11.2 Vegetation mapping of the Hantam-Tanqua-Roggeveld subregion

Although the entire Hantam-Tanqua-Roggeveld subregion was included in the SKEP (Succulent Karoo Ecosystem Plan) planning domain, such a delineation is not universally accepted. According to Low and Rebelo (1996) and Mucina et al. (2005) the vegetation of the subregion falls within both the Succulent Karoo and Fynbos Biomes. The Two Way Indicator Species Analysis (TWINSPAN) on the entire data set of 390 relevés resulted in two phytosociological tables supporting the clear difference in species composition of the Fynbos Biome related vegetation and the Succulent Karoo Biome related vegetation. The first data set of 107 relevés, characterised the vegetation of the predominantly Mountain Renosterveld with Fynbos Biome affinities, while the second data set of 283 relevés, characterised the Succulent Karoo Biome vegetation. Within the Succulent Karoo Biome vegetation there was another split at a lower level separating the Tanqua Karoo and Loeriesfontein plots (association 7 and association 8) from associations 4, 5 and 6. These two large vegetation groups within the Succulent Karoo vegetation were referred to as the Tanqua Karoo and Winter Rainfall Karoo respectively.

The phytosociological tables were used to describe the eight major associations and 25 subassociations found in the Hantam-Tanqua-Roggeveld subregion in terms of their species composition, environmental parameters and relationship to one another as well as to map their geographical distribution. Various map outputs were generated including: a) a vegetation map of the Fynbos Biome related vegetation (Van der Merwe et al. 2008a), b) a vegetation map of the Succulent Karoo Biome related vegetation (Van der Merwe et al. 2008b), c) a detailed vegetation map of the entire subregion including vegetation mosaics (Figure 11.1), and d) a simplified vegetation map of the entire subregion (Chapter 6, Figure 6.1).

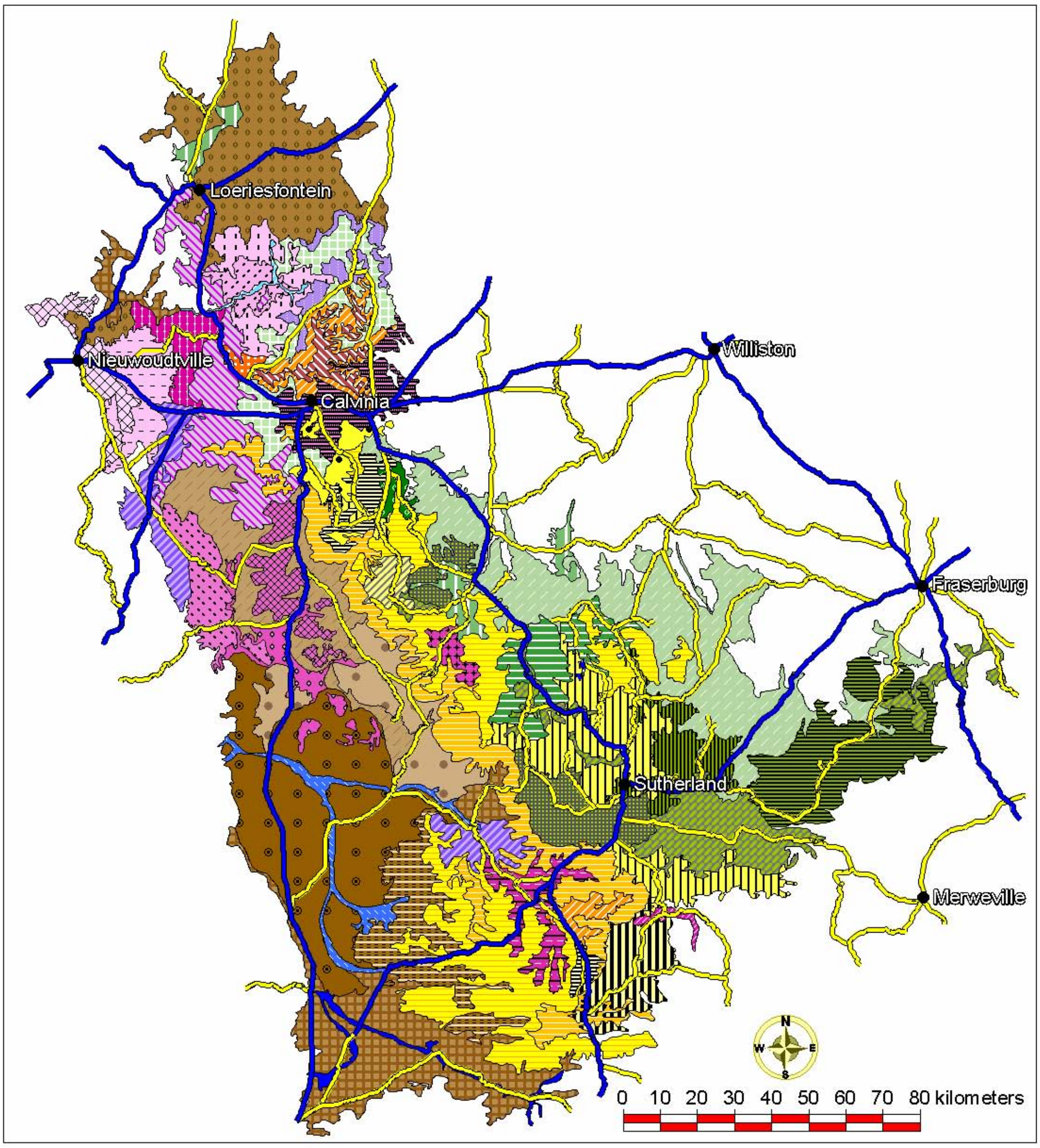

Figure 11.1 A detailed vegetation map of the entire Hantam-Tanqua-Roggeveld study area showing both the Fynbos Biome related and Succulent Karoo Biome related vegetation.

Figure 11.1 (continued)

Previous maps published by Acocks (1953, 1988), Low and Rebelo (1996) and Mucina et al. (2005) show interesting similarities and some dissimilarities to the map generated in this study (Figure 11.1). Since the scale of these maps and the current map differ and the reasons for compiling the maps also differ, only generalisations can be made when comparing the maps. The current study found the Sutherland area, a region classified by Acocks (1953, 1988) as Western Mountain Karoo and Low and Rebelo (1996) as Upland Succulent Karoo, was more closely related to the Mountain Renosterveld vegetation of the Fynbos Biome than to the Succulent Karoo vegetation. Mucina et al. (2005) identifies this area as Roggeveld Karoo (SKt3) whereas this study incorporated the area into the Mountain Renosterveld vegetation of plant association 1.

The Succulent Karoo Biome related vegetation included two of Acocks's (1953, 1988) veld types. Associations 4 (Escarpment Karoo), 5 (Hantam Karoo) and 6 (Roggeveld Karoo) combined form part of the Western Mountain Karoo (Veld Type 28) which is incorporated into Low and Rebelo's (1996) Upland Succulent Karoo (Unit 56) while associations 7 (Tanqua and Loeriesfontein Karoo) and 8 (Central Tanqua Grassy Plains) are both included into Acocks's (1953, 1988) Succulent Karoo (Veld Type 31) which relates to Low and Rebelo's (1996) Lowland Succulent Karoo (Unit 57). Approximately ten vegetation units were mapped by Mucina et al. (2005) within the Succulent Karoo Biome related vegetation as identified by this study. There was a good agreement between the Tanqua Escarpment Shrubland (SKv4) of Mucina et al. (2005) and association 4 (Escarpment Karoo). Generally, the delineation of the Hantam Karoo (association 5), Roggeveld Karoo (association 6) and Tanqua Karoo (association 7) in this study was more restricted than that of the Hantam Karoo (SKt2), Roggeveld Karoo (SKt3) and Tanqua Karoo (SKv5) of Mucina et al. (2005). The maps of Acocks (1953, 1988) and Low and Rebelo (1996) differ appreciably in the van Rhynsdorp/Doorn River region, however, the Mucina et al. (2005) map was more closely related to the map presented in this thesis. This region is situated in the transition between the Succulent Karoo Biome (Tanqua Karoo and the van Rhynsdorp Succulent Karoo) and the Fynbos Biome, and requires additional study to determine the boundaries of each different vegetation type.

Grazing and cropping are the main land uses in the Mountain Renosterveld vegetation of the Fynbos Biome related vegetation, while grazing is the main land use in the Succulent Karoo Biome related vegetation since this area receives less rainfall for growing crops. A major threat to the vegetation of the study area, identified by the farming community, Northern Cape Department of Agriculture and through personal observations during field surveys was the less than ideal farming practises due to a lack of infrastructure, especially fencing, for optimal farm management. Although damage happens fast, recovery in the Karoo is very slow, as it depends mainly upon unpredictable rainfall events (Esler et al. 2006). Sustainable farm management planning is critical for ensuring a productive, profitable future in the region (Esler et al. 2002, Millennium Ecosystem Assessment 2005).

The second threat is that of invasive alien species, especially *Prosopis* species. *Prosopis glandulosa* was introduced to the Karoo to aid in fodder production for small stock in the drier months of the year when little natural vegetation is available (Zimmerman 1991). Unfortunately, more than one species of *Prosopis* was introduced resulting in hybridisation between the species. These hybrids have invaded large tracts of land and are a serious threat especially in the Hantam and Tanqua Karoo areas. Other invasive alien species include *Nerium oleander* and *Nicotiana glauca* which are also found mostly in the Hantam and Tanqua Karoo areas and are usually restricted to drainage lines. Invasive annual grasses such as *Hordeum murinum* and *Bromus pectinatus,* commonly occurring in the Hantam and Roggeveld areas, have a naturalised status.

Large scale transformation of natural vegetation, especially along drainage lines, into flood irrigated lands has taken place in the past. Few of these lands, especially in the Tanqua Karoo, are still utilised for cropping and now lie barren with little vegetation cover to combat erosion or the lands are infested by invasive species, usually *Prosopis* species.

Large tracts of the Mountain Renosterveld vegetation of the Roggeveld are dominated by the unpalatable renosterbos, *Dicerothamnus rhinocerotis*, which is considered an encroacher by most farmers with its dominance being blamed on centuries of incorrect farming practices in the region (Marloth 1908, Acocks 1988, Cullinan 2003). Overgrazing and incorrect burning practices are thought to have had a substantial effect on the grassy component of the vegetation, reducing it to the current state (Marloth 1908, Acocks 1988, Cullinan 2003), with grazing pressure given as a reason for the near extinction of the indigenous rye grass (*Secale strictum* subsp. *africanum*) (Van Wyk & Smith 2001, Rebelo et al. 2006).

Formal conservation of the Hantam-Tanqua-Roggeveld subregion is limited. Two local municipal reserves, the Akkerendam Nature Reserve (230 ha) and the Nieuwoudtville Wildflower Reserve (115 ha) are located within the study area. Akkerendam Nature Reserve protects a part of the plateau and slope of the Hantam Mountain, while the Nieuwoudtville Wildflower Reserve protects a combination of the Fynbos and Succulent Karoo Biome related vegetation on the western extreme of the study area. The Tankwa Karoo National Park has expanded its boundaries considerably over the last few years protecting large parts of the Tanqua Karoo and small areas of the Roggeveld escarpment and Roggeveld plateau, however, large tracts of land especially in the Tanqua Karoo are highly degraded. The latest addition (12 December 2008) to the protected area network is the 6200 ha of the Hantam National Botanical Gardens situated just south and east of Nieuwoudtville. This area protects Succulent Karoo and Fynbos Biome related vegetation. Private nature reserves and conservancies are few and are generally found within the Tanqua Karoo. Most of them are located at the southern end of the Tanqua Basin, close to the town of Ceres.

Formal conservation on a plant association level in the Hantam-Tanqua-Roggeveld subregion is highly inadequate. Large areas of association 7 (Tanqua Karoo) and association 8 (Central Tanqua Grassy Plains) are protected within the borders of the Tankwa Karoo National Park, with small areas of association 4 (Escarpment Karoo) and association 2 (Mountain Renosterveld) being conserved along the Roggeveld escarpment into the Mountain

Renosterveld vegetation of the Roggeveld plateau. An extremely small area of association 3 (Mountain Renosterveld) is conserved within the Akkerendam Nature Reserve since it forms part of the town of Calvinia's water catchment area. Association 2, located as an outlier mosaic vegetation unit close to Nieuwoudtville, and association 5 have recently been conserved with the proclamation of the Hantam National Botanical Gardens. The Roggeveld Karoo (association 6) is not formally conserved in any way. Currently, the largest threats to the unprotected associations within the Hantam-Tanqua-Roggeveld subregion are incorrect management of grazing land as well as alien invasive trees, especially *Prosopis* species. This reinforces the general view that livestock grazing has been identified as a major threat to biodiversity in the Succulent Karoo (Mucina et al. 2006).

11.3 Plant diversity studies

11.3.1 Species-area relationships

Analysis of the data collected using 40 Whittaker plots scattered throughout the Hantam, Tanqua and Roggeveld areas revealed an array of species-area curves. Significance levels of the untransformed linear function, exponential function and power function varied greatly, however, better r–values and p-values were obtained for the exponential and power functions with the exponential function performing marginally better.

A comparison of plant associations along a west to east transect from the Tanqua Karoo across the escarpment into the Roggeveld crossing five different associations, generally revealed significant differences in slope values between the associations, except for the *Dicerothamnus rhinocerotis* Mountain Renosterveld which did not differ significantly from associations bordering it on either side. Generally, the Tanqua Karoo had a low vegetation cover, low species richness values and species-area curves with shallow slopes. The Roggeveld Escarpment Karoo vegetation, which falls within the Winter Rainfall Karoo vegetation group, is transitional between the Tanqua Karoo and the Mountain Renosterveld of the Roggeveld Mountains and produced the highest species richness values and steepest species-area curves.

11.3.2 Diversity parameters

The species richness in the 1000 m^2 (0.1 ha) plots ranged from nine to 100 species per sampled 1000 m^2 among the 40 Whittaker plots. Mean species richness was significantly higher in the Mountain Renosterveld than in the Winter Rainfall Karoo, which in turn was significantly higher than in the Tanqua Karoo. However, the low mean species richness values for the Tanqua Karoo compared poorly to Succulent Karoo values cited in the literature (Cowling et al. 1989, Cowling & Hilton-Taylor 1994, Anderson & Hoffman 2007). Species richness values obtained for the Fynbos Biome, and in particular for the renosterveld vegetation type within this biome, compared well with Mountain Renosterveld vegetation values found in this study (Cowling et al. 1992, Cowling & Holmes 1992, Richardson 1995, Procheş et al. 2003, Kongor 2009). However, the year in which the survey was conducted was a poor rainfall year, which would have had a negative influence on the annual and geophyte species that make up a large component of the Succulent Karoo and Fynbos diversity and the values presented in this study probably underestimated the potential diversity in the region. Evenness, Shannon and Simpson indices were found not to differ significantly between the Mountain Renosterveld and Winter Rainfall Karoo but these values were significantly higher than for the Tanqua Karoo.

Comparisons of species richness at seven different plot sizes (1 m^2, 5 m^2, 10 m^2, 20 m^2, 50 m^2, 100 m^2, 1000 m^2) produced significant differences between the Winter Rainfall Karoo and Tanqua Karoo and between the Mountain Renosterveld and Tanqua Karoo at each plot size. A significant difference between the Winter Rainfall Karoo and Mountain Renosterveld was only obtained at the 1000 m^2 plot size indicating the importance of surveying relatively large plots that enable researchers to pick up differences in species richness between different regions not evident at smaller plot sizes.

This relationship between the broad vegetation groups was visually summarised and illustrated when a Principal Co-ordinate Analysis was conducted with the diversity data for the seven plot sizes producing three ordination clusters. The Tanqua Karoo cluster was characterised by a low plant cover, shallow slopes and low y-intercept values. At the other extreme a cluster of a selection of high-lying Mountain Renosterveld plots was produced, generally possessing steep species-area curve slopes and high y-intercept values, and representing a 'true' Mountain Renosterveld vegetation. The central cluster consisted of Winter Rainfall Karoo plots as well as several transitional Mountain Renosterveld plots indicating that the Mountain Renosterveld vegetation of the Hantam-Tanqua-Roggeveld consists of 'true' Mountain Renosterveld as well as a transitional form between the Mountain Renosterveld and Winter Rainfall Karoo vegetation groupings.

Despite changing fashions and preoccupations, diversity has remained a central theme to ecology (Magurran 1988). In spite of various criticisms, diversity indices have sparked renewed interest in handling problems associated with the conservation of natural heritage or the changes in global ecology (Mouillot & Leprêtre 1999). Diversity indices determined in this study indicate that ironically, the two most species poor associations (association 7 and association 8), with the lowest diversity values, are well conserved within the Tankwa Karoo National Park and that two associations (association 2 and association 4) with high levels of diversity are included to a very limited extent. The importance of conserving mountain communities, such as associations 2 and 4 in this study, has been emphasised (Burke et al.

2003) since altitude is an important contributor to explaining species diversity (Körner 2000). Altitudinal gradients have also been recognised as an important buffer in the event of climate change (Bond & Richardson 1990) because mountain habitats could provide refugia for species during climate change (Midgley et al. 2000). This further emphasises the importance of conserving especially association 4 (Escarpment Karoo) and association 3 (Mountain Renosterveld). The Tankwa Karoo National Park boundaries could therefore be extended to include a larger area of association 2 and association 4 and should even, potentially, be extended to include areas within association 1 and association 6, two additional associations with relatively high diversity values.

Diversity measures should, however, only be used as an indicator of which areas should be conserved but these potential areas of conservation importance must be considered together with information on the floristic relationships in the region in order to ensure a functioning ecosystem is conserved. Low diversity areas should also be considered and conserved since in many cases species or species combinations in these areas are unique to the region.

11.3.3 Life form spectra

Comparisons of the various life forms, between the associations and vegetation groups, produced different results when studied at a species or vegetation cover level. Generally, the eight plant associations were dominated by chamaephyte, cryptophyte (geophyte) and therophyte (annual) species.

At the species level, phanerophyte contributions were significantly higher in the Mountain Renosterveld than both the Winter Rainfall Karoo and Tanqua Karoo. Hemicryptophyte contributions were significantly higher in the Tanqua Karoo than the Winter Rainfall Karoo, while cryptophyte and therophyte contributions were significantly lower in the Tanqua Karoo than the Mountain Renosterveld. Therophyte contributions also differed significantly between the Winter Rainfall Karoo and the Tanqua Karoo. No significant differences were found between the vegetation groups for chamaephyte, liana and parasite species. At a vegetation cover level, the phanerophyte cover contribution was found to be significantly higher in the Mountain Renosterveld than the Winter Rainfall Karoo and the Tanqua Karoo. Chamaephyte contributions were significantly higher in the Mountain Renosterveld and Winter Rainfall Karoo groups than the Tanqua Karoo vegetation group. No significant differences were found for hemicryptophytes, cryptophytes, therophytes, lianas or parasites.

It was found that, generally, the succulent species were chamaephyte, hemicryptophyte and therophyte species. The percentage contribution of the succulent species was low in Mountain Renosterveld, intermediate in Winter Rainfall Karoo and highest in the Tanqua Karoo while, succulent vegetation cover was generally lowest for the Mountain Renosterveld, with higher cover values found for the Winter Rainfall Karoo and Tanqua Karoo. This confirms the inclusion of the Winter Rainfall Karoo and Tanqua Karoo into the Succulent Karoo Biome. But, the higher than expected succulent cover for one strongly Mountain Renosterveld (Fynbos Biome) association (association 1), indicates its transitional nature between the Succulent Karoo and Fynbos Biomes. Another Succulent Karoo site, Goegap Nature Reserve, produced similar patterns to this study, yet, these patterns were found to be very different from the pattern encountered in the winter rainfall Mojave Desert. In this study, life form spectra for Mountain Renosterveld did not compare well with a Fynbos Biome site where therophyte contributions were much lower and phanerophyte contributions much higher. The low degree of succulence in the Winter Rainfall Karoo association, association 6, could be due to its transitional nature since it is situated between the Mountain Renosterveld of the Fynbos Biome and the Nama Karoo Biome and is probably more closely related to the Nama Karoo Biome vegetation.

11.4 Life forms and species diversity on abandoned croplands in the Roggeveld

The Roggeveld, located within the Fynbos Biome (Low & Rebelo 1996, Mucina et al. 2005, Van der Merwe et al 2008a), has a higher rainfall than the surrounding areas and has been used to cultivate wheat and fodder crops for hundreds of years. Many of these lands now lie barren as a result of an increase in production costs.

The most abundant life forms on abandoned croplands of all ages were chamaephytes and therophytes. Therophyte species were most abundant on young abandoned croplands and decreased in number from 10-years of age to values similar to those encountered in the natural vegetation. Phanerophyte species did not differ much across the age range of the surveyed plots and numbers remained low. Chamaephyte, cryptophyte and hemicryptophyte species increased in number with an increase in age of abandoned croplands with the highest values found for the natural vegetation. Chamaephytes made an overwhelming contribution to the relative cover on abandoned croplands while, phanerophytes, cryptophytes and therophytes contributed significantly less. Hemicryptophyte and liana cover contributions were negligible.

In all instances, slope or intercept values of the exponential function species-area curves differed significantly between the abandoned croplands and the natural vegetation. An increase in age of abandoned cropland leads to an increase in species richness, with species richness values highest for the natural vegetation. Evenness, Shannon and Simpson indices did, however, not reflect the same increase. Only 15 species contributed to the highest cover on the abandoned croplands with eight of these also contributing to the high cover of the natural vegetation.

A regression of species richness against age of abandoned croplands predicted that an abandoned cropland of about 33-years in age should be as species rich as the natural vegetation, however, a Principal Co-ordinate Analysis of the floristic data indicated that floristically there is an extremely large gap between the abandoned croplands and the natural vegetation. The recovery rate of the various life forms varies and an important component of the flora, the geophytes (cryptophytes), still remain greatly underrepresented after 20-years of abandonment.

The pattern of recovery on abandoned croplands in the Mountain Renosterveld of the Roggeveld seems to differ from those of the West Coast Renosterveld of the Cape Floristic Region (CFR) where remnant renosterveld vegetation and abandoned croplands were studied on the Elandsberg Private Nature Reserve. These studies indicated the apparent slow return of indigenous renosterveld vegetation on abandoned croplands (Midoko-Iponga et al. 2005). Annual weedy alien grasses arrest the whole recovery process in the West Coast Renosterveld, however, this was not the case in this study in the Mountain Renosterveld of the Roggeveld. Current restoration efforts in the West Coast Renosterveld aim to reduce the cover of the introduced grasses while, at the same time, maintaining or even increasing species richness and diversity of indigenous target species (Krug & Krug 2007). The recovery in the Roggeveld probably occurs under harsher environmental conditions yet, species richness steadily increases and evenness values, Shannon and Simpson indices of diversity on abandoned croplands from approximately 10 years after abandonment are similar to those of the natural vegetation.

The recovery of vegetation on abandoned croplands in the Roggeveld could be left to continue at its natural pace with no management interventions. This will quickly lead to some form of perennial vegetation cover to primarily combat soil erosion, which is a major problem on abandoned croplands due to the mountainous topography of the area and occasional summer thunderstorms that produce large volumes of runoff. This is, obviously, the cheapest option for the land owner. A second, more costly option, would be to establish perennial shrubs and grasses that are of a higher forage value than those that initially colonise and later dominate abandoned croplands. However, it is suggested that this be initiated on abandoned croplands that are in the initial stages of vegetation recovery. The pioneering species will be able to provide some sort of protection against the harsh environmental conditions on an abandoned cropland by providing windbreaks, shade, humus, breakage of the soil crust or collection of water runoff. These advantages to a newly sown seed or planted seedling should outweigh the negative influences of competition in the initially hard and barren soil. Old abandoned croplands with high densities of *Dicerothamnus rhinocerotis* will have to be thinned before attempting to establish other vegetation since these dense stands will out-compete other vegetation.

11.5 Vegetation trends following fire in the Roggeveld

Establishment of vegetation began within nine months following a fire in the Roggeveld (Mountain Renosterveld vegetation) with only the first two years after the fire being marked by a low vegetation cover. The study found different vegetation trends on the two land types present at the sites (Land Type Da and Land Type Fa). Species richness was highest within three years after the fire with chamaephyte species contributions the most except on Land Type Fa where therophyte species often contributed more. Generally, all except one plot, had the lowest Shannon values in year 9 and year 10 and the highest Shannon values in year 1 to year 3.

Phanerophyte and chamaephyte species contributions were generally higher on Land Type Da than Land Type Fa, while therophyte species contributions were higher on Land Type Fa than Land Type Da. On a vegetation cover level, phanerophyte cover was highest on the two Land Type Da plots and one Land Type Fa plot due to the dominance of *Dicerothamnus rhinocerotis*. Chamaephyte vegetation cover was highest on Land Type Da and therophyte vegetation cover highest on Land Type Fa. A large difference in species composition between the first two years following fire and the subsequent years was illustrated using a Principal Co-ordinate Analysis.

Quick community recovery after fire in Mediterranean-type ecosystems has been reported in various studies with species richness highest soon after fire (Keeley et al. 1981, Bond & Van Wilgen 1996, Schwilk et al. 1997, Guo 2001, Potts et al. 2001, Capitanio & Carcaillet 2008). In all instances species richness was reported to decline in the following years. When studying the species composition after a fire it becomes evident that all, or the majority of, species present during the succession are in place at the beginning of the recovery phase. These data seem to support Egler's (1954) 'initial floristic composition' model.

The removal of *D. rhinocerotis* by one of the farmers in order to limit their establishment and later dominance of the area produced interesting results, namely: 1) therophyte species percentage contribution to the vegetation cover was higher than in a comparable site; 2) species richness was more than twice as high where *D. rhinocerotis* was removed compared to a similar site; 3) perennial vegetation cover contributed to 35.5% of the total vegetation cover of 79% while at the comparable site, perennial vegetation cover contributed to 54.5% of the total vegetation cover of 47%; 4) the biomass of the site which is primarily composed of small annual vegetation is probably much lower than in the comparable site, however, the biomass at the second site is comprised mainly of *D. rhinocerotis*, which is of limited value to the farmer since it is not a palatable species; and 5) the fact that *D. rhinocerotis* did not establish in large numbers after being initially removed by the farmer seems to indicate that this species is unable to compete with other species once the other species have established, even if comprised of predominantly annual species. This has important management implications, indicating that if the farmer can establish plant species of forage value *D. rhinocerotis* will not be able to establish and dominate at a location.

11.6 Succulent Karoo and Fynbos Biome affinities: a synthesis of results

A synthesis of all the data provides a clearer understanding of the broad vegetation groups and how they are related to one another and provide some clarity on how they are affiliated to the Succulent Karoo and Fynbos Biomes. A summary table is presented as Table 11.1.

11.6.1 Phytosociology

The Mountain Renosterveld vegetation group consists of three associations (1. *Rosenia oppositifolia* Mountain Renosterveld, 2. *Dicerothamnus rhinocerotis* Mountain Renosterveld, 3. *Passerina truncata* Mountain Renosterveld), similarly the Winter Rainfall Karoo consists of three associations (4. *Pteronia glauca* Escarpment Karoo, 5. *Eriocephalus purpureus* Hantam Karoo, 6. *Pteronia glomerata* Roggeveld Karoo) and the Tanqua Karoo of two associations (7. *Aridaria noctiflora* Tanqua and Loeriesfontein Karoo, 8. *Stipagrostis obtusa* Central Tanqua Grassy Plains).

11.6.2 Environmental parameters

The mean annual precipitation for the Mountain Renosterveld vegetation ranges between 200 mm to 400 mm per year with a coefficient of variation of between 25% and 40%. Winter Rainfall Karoo has a slightly lower mean annual precipitation and a higher coefficient of variation while the Tanqua Karoo has the same coefficient of variation for annual precipitation as the Winter Rainfall Karoo but a much lower mean annual precipitation. Mean maximum and minimum temperatures for the warmest and coldest months of the year are cooler for Mountain Renosterveld than for Winter Rainfall Karoo or Tanqua Karoo, with Winter Rainfall Karoo temperatures intermediate and Tanqua Karoo temperatures the highest. Snow is six times more common in the Mountain Renosterveld than Winter Rainfall Karoo, with no snowfall occurring in the Tanqua Karoo.

The concept of the heat unit (or degree day) revolves around the development of a plant or organism being dependent upon the total heat to which it was subjected during its lifetime, or else during a certain developmental stage (Schulze 1997). Heat units are expressed as degree days, where these are an accumulation of mean temperatures above a certain lower threshold value (below which active development is considered not to take place) and below an upper limit (above which growth is considered to remain static or even decline) over a period of time (Schulze 1997). The degree days above 10 °C for April to September are the lowest in the Mountain Renosterveld, some of the lowest values for the entire South Africa, intermediate for the Winter Rainfall Karoo and highest for the Tanqua Karoo.

Some plants, which have a dormant season during winter, may have to accumulate chill units with temperatures below a threshold in order to stimulate growth, develop leaves, flowers or set fruit (Steyn et al. 1996, Schulze 1997). The required amount of chilling for completion of the rest period varies between species, cultivars and different locations. Chill units have been derived from models using threshold temperatures. The accumulated positive chill units from May to September for Mountain Renosterveld are some of the highest values for the entire South Africa, these values are much lower in the Winter Rainfall Karoo and even lower for the Tanqua Karoo.

Soils underlying Mountain Renosterveld are shallow stony lithosols and duplex soils in the occasional lowlands. The soils of the Winter Rainfall Karoo are shallow lithosols and duplex soils but where dolerite occurs soils are red structured and red vertic clays. Tanqua Karoo soils are shallow lithosols that often include a desert pavement and deep unconsolidated deposits in the alluvial parts. Generally, Mountain Renosterveld is found at high altitudes, Winter Rainfall Karoo at lower altitudes and Tanqua Karoo vegetation at the lowest altitudes. Fire is an important disturbance in Mountain Renosterveld vegetation and not in Winter Rainfall Karoo and Tanqua Karoo vegetation.

11.6.3 Diversity parameters

All the diversity parameters and species area relationships could separate the Tanqua Karoo from the Mountain Renosterveld and the Winter Rainfall Karoo, however only the species richness at 1000 m^2 could show a significant difference between the Mountain Renosterveld and the Winter Rainfall Karoo. The ordination diagram partially separated the Mountain Renosterveld from the Winter Rainfall Karoo.

11.6.4 Life forms

When analysing the classic life form spectra at a species level, phanerophyte contributions for the Mountain Renosterveld were significantly higher than for the Winter Rainfall Karoo and Tanqua Karoo. No significant difference was found between chamaephytes, lianas or parasites at the species level. Contributions by hemicryptophyte were significantly higher for the Tanqua Karoo than the Winter Rainfall Karoo whereas those of cryptophytes were significantly higher in the Mountain Renosterveld than in the Tanqua Karoo. Significantly higher therophyte contributions were found in Mountain Renosterveld vegetation compared to the Tanqua Karoo vegetation. Upon extraction of succulent species, Mountain Renosterveld vegetation held significantly lower succulent species contributions than Winter Rainfall Karoo or Tanqua Karoo vegetation.

At a cover level, phanerophyte cover was significantly higher in Mountain Renosterveld than Tanqua Karoo or Winter Rainfall Karoo, with Winter Rainfall Karoo values intermediate and significantly different from the low Tanqua Karoo values. Chamaephyte cover was significantly higher in the Mountain Renosterveld and Winter Rainfall Karoo than in the Tanqua Karoo. No significant differences in cover were found between the vegetation groups of the hemicryptophyte, cryptophyte, therophyte, liana and parasite life forms. Succulent species cover was significantly higher for the Winter Rainfall Karoo and Tanqua Karoo than for the Mountain Renosterveld.

The above-mentioned results clearly indicate that in the majority of cases the vegetation of the Tanqua Karoo is different from the vegetation of the Mountain Renosterveld and Winter Rainfall Karoo. These results also indicate a close relationship between the Mountain Renosterveld and Winter Rainfall Karoo vegetation in that clear differences between them are few, yet, differences were found on a species richness level and especially at the 1000 m^2 plot size.

In the early 1900s, Marloth (1908) and Diels (1909) both recognised the Tanqua Karoo as an area where vegetation was sparse and characterised by succulents. Marloth (1908) provided a detailed description of the *Dicerothamnus rhinocerotis*, renosterbos, dominated Roggeveld while Diels (1909) suggested that the Hantam Mountain, with its Mountain Renosterveld, was an outlier of the Cape flora but also linked it to Marloth's (1909) description of the Roggeveld. Weimarck (1941) treated the Hantam-Roggeveld as a subcentre of his North-Western Centre however, hesitantly stated that the subcentre constituted the last outlier of the Cape element in the inner parts of the western South Africa.

Acocks's (1988) map of the vegetation in A.D. 1950 places the Hantam (Winter Rainfall Karoo) and Roggeveld (Mountain Renosterveld) within the Karoo veld type and the Tanqua Karoo in the Succulent Karoo and Desert veld types. Rutherford and Westfall (1994), however, place both the Hantam and Tanqua Karoo within the Succulent Karoo Biome but agree on the Roggeveld as part of the Nama Karoo Biome. They state that the Roggeveld shows some floristic affinities to the Fynbos Biome, but the life form combination precludes it from being considered as part of the Fynbos Biome. Low and Rebelo (1996) also place the Hantam and Tanqua Karoo in the Succulent Karoo Biome however include the Roggeveld within their renosterveld group of the Fynbos Biome stating that the Cape Floral Kingdom traditionally does not include the fynbos and renosterveld outliers to the north and east. Jürgens (1997) placed the entire study area within the Succulent Karoo Biome while, Mucina et al. (2005) and Mucina et al. (2006) place the Hantam and Tanqua Karoo within the

Succulent Karoo Biome and the Roggeveld within the Fynbos Biome (Rebelo et al. 2006) clearly stating that they did not apply the explicit and globally derived definition of a biome and only considered botanical elements (Rutherford et al. 2006). Born et al. (2007) placed the entire region within the Succulent Karoo Biome using the Succulent Karoo Ecosystem Plan (SKEP) defined subregions as the unit of their study. This study however, indicated stronger links to the Fynbos Biome than the Succulent Karoo Biome for some of the subregions.

This study of the Hantam-Tanqua-Roggeveld subregion clearly indicates that the Tanqua Karoo is very different from the Winter Rainfall Karoo and the Mountain Renosterveld and that it belongs to the Succulent Karoo Biome. There is a relationship between the Mountain Renosterveld and Winter Rainfall Karoo vegetation within the study area, however, these two groups differ in various aspects. The floristic data support a closer relationship between the Winter Rainfall Karoo and Tanqua Karoo, yet, the Roggeveld Karoo does seem to differ the most and is likely to be more closely related to the Nama Karoo Biome than the Succulent Karoo Biome, but this will have to be researched in more detail. The Mountain Renosterveld is clearly different from the Winter Rainfall Karoo and Tanqua Karoo but does not fit the classic Fynbos Biome delimitations. How this arid Mountain Renosterveld links to other renosterveld vegetation types in the 'true' Fynbos Biome will have to be investigated in more detail on a study of renosterveld vegetation.

Table 11.1 A summary of the prominent relationships between the three main vegetation groups

	Attribute	Mountain Renosterveld	Winter Rainfall Karoo	Tanqua Karoo
1.	**Phytosociology (floristics)**	Associations 1, 2 and 3	Associations 4, 5 and 6	Associations 7 and 8
2.	**Environmental parameters**			
	Mean annual precipitation	200 mm – 400 mm	100 mm – 400 mm	<100 mm – 200 mm
	Coefficient of variation for mean annual precipitation	35% to 40%, higher-lying areas 25% to 35%	35% to 40%	35% to 40%
	Mean daily minimum and maximum for the coldest months (June and July)	Minimum: -2°C to 2°C Maximum: 12°C to 14 °C	Minimum: 2°C to 4°C Maximum: 16°C to 18°C	Minimum: 4°C to 6°C Maximum: 18°C to 20°C
	Mean daily minimum and maximum for the warmest months (January and February)	Minimum: 10°C to 14°C Maximum: 28°C to 30 °C	Minimum: 12°C to 14°C Maximum: 30°C to 32 °C	Minimum: 14°C to 18°C Maximum: 32°C to >34 °C
	Snow	6 snow days per year over a 24-year period	1 snow day per year over a 20-year period	No snow
	Heat units (degree days)	<200 - 400	400 – 800	600 - 1000
	Accumulated positive chill units (May to September)	1250 - >1750	750 – 1000	250 - 500
	Soils	Shallow stony lithosols and duplex soils in the occasional lowlands	Shallow lithosols and duplex soils, but where dolerite occurs soils are red structured and red vertic clays	Shallow lithosols often including desert pavement and deep unconsolidated deposits in the alluvial parts
	Altitude	High-lying, generally 700 – 1600 m above sea level	300 – 1400 m above seal level	Low-lying, generally 200 – 800 m above sea level
	Fire	Fire	No fire	No fire

Table 11.1 (continued)

3.	**Diversity parameters**			
	Species-area curves	No significant difference found between the slopes of the Mountain Renosterveld and Winter Rainfall Karoo		Significantly shallower slopes than for the Mountain Renosterveld and Winter Rainfall Karoo
	Species richness in 1000 m^2	Significantly higher values than for the Winter Rainfall Karoo and Tanqua Karoo	Significantly higher values than for the Tanqua Karoo	Significantly lower values than for the Mountain Renosterveld and Winter Rainfall Karoo
	Species richness across six plot sizes (1 m^2, 5 m^2, 10 m^2, 20 m^2, 50 m^2, 100 m^2)	No significant difference between the Mountain Renosterveld and Winter Rainfall Karoo at plot sizes less than 1000 m^2		Significantly different from the Mountain Renosterveld and Winter Rainfall Karoo for all plot sizes less than 1000 m^2
	Evenness	Evenness values significantly higher than for the Tanqua Karoo		Evenness values significantly lower than for the Mountain Renosterveld and Winter Rainfall Karoo
	Shannon index of diversity	No significant difference found between the Shannon index values of the Mountain Renosterveld and Winter Rainfall Karoo but values significantly different from the Tanqua Karoo		Significantly lower Shannon index values than for the Mountain Renosterveld and Winter Rainfall Karoo
	Simpson index of diversity	Simpson index values generally higher than for the Tanqua Karoo but, no significant difference between the Mountain Renosterveld and Winter Rainfall Karoo		Significantly lower Simpson index values than for the Mountain Renosterveld and Winter Rainfall Karoo
	Principal Co-ordinate Analysis of floristic data for seven plot sizes	A cluster representing a selection of high-lying plots generally with steep species-area curve slopes and high y-intercept values = 'True' Mountain Renosterveld vegetation	Central cluster of Winter Rainfall Karoo vegetation plots and several transitional Mountain Renosterveld plots	A cluster representing Tanqua Karoo vegetation with a low plant cover, shallow species-area curve slopes and low y-intercept values

Table 11.1 (continued)

4. **Life forms**			
Classic life forms at a species level expressed as a percentage of the total number of species			
Phanerophytes	Significantly higher values than for the Winter Rainfall Karoo and Tanqua Karoo	Significantly lower values than for the Mountain Renosterveld	
Chamaephytes	No significant difference between the three vegetation groups		
Hemicryptophytes	Low species values	Significantly lower values than for the Tanqua Karoo	Significantly higher values than for the Winter Rainfall Karoo
Cryptophytes	Significantly higher values than for the Tanqua Karoo	Intermediate cryptophyte species numbers	Significantly lower values than for the Mountain Renosterveld
Therophytes	Significantly higher therophyte species numbers		Significantly lower therophyte numbers
Lianas	No significant difference between the three vegetation groups		
Parasites	No significant difference between the three vegetation groups		
Succulents (combined)	Significantly lower succulent species contributions than for the Winter Rainfall Karoo and Tanqua Karoo	Significantly higher succulent species contributions than for the Mountain Renosterveld	

Table 11.1 (continued)

Classic life forms at a vegetation cover level expressed as a percentage of the total cover			
Phanerophytes	Significantly higher phanerophyte cover	Intermediate phanerophyte cover	Lowest phanerophyte cover
Chamaephytes	Significantly higher cover than the Tanqua Karoo		Significantly lower cover than the Mountain Renosterveld and Winter Rainfall Karoo
Hemicryptophytes	No significant difference between the three vegetation groups		
Cryptophytes	No significant difference between the three vegetation groups		
Therophytes	No significant difference between the three vegetation groups		
Lianas	No significant difference between the three vegetation groups		
Parasites	No significant difference between the three vegetation groups		
Succulents (combined)	Significantly lower succulent cover than for the Winter Rainfall Karoo and the Tanqua Karoo	Significantly higher cover than for the Mountain Renosterveld	

References

ACOCKS, J.P.H. 1953. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 28, 1-192.

ACOCKS, J.P.H. 1988. Veld types of South Africa. 3rd edn. Memoirs of the Botanical Survey of South Africa 57, 1-146.

ANDERSON, P.M.L. AND HOFFMAN, M.T. 2007. The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa. Journal of Arid Environments 70, 686-700.

BOND, W.J. AND RICHARDSON, D.M. 1990. What can we learn from extinctions and invasions about the effects of climate change? South African Journal of Science 86, 429-433.

BOND, W.J. AND VAN WILGEN, B.W. 1996. Fire and plants. Chapman & Hall, London.

BORN, J., LINDER, H.P. AND DESMET, P. 2007. The Greater Cape Floristic Region. Journal of Biogeography 34, 147-162.

BURKE, A., ESLER, K.J., PIENAAR, E. AND BARNARD, P. 2003. Species richness and floristic relationships between mesas and their surroundings in southern African Nama Karoo. Diversity and Distributions 9, 43-53.

CAPITANIO, R. AND CARCAILLET, C. 2008. Post-fire Mediterranean vegetation dynamics and diversity: A discussion of succession models. Forest Ecology and Management 255, 431-439.

COWLING, R.M., GIBBS RUSSEL, G.E., HOFFMAN, M.T. AND HILTON-TAYLOR, C. 1989. Patterns of plant species diversity in southern Africa. In: B.J. Huntley (Ed.). Biotic diversity in southern Africa. Concepts and Conservation, pp. 19-50. Oxford University Press, Cape Town.

COWLING, R.M. AND HILTON-TAYLOR, C. 1994. Patterns of plant diversity and endemism in southern Africa: an overview. In: B.J. Huntley (Ed.). Botanical diversity in southern Africa. Strelitzia 1, pp. 31-52. National Botanical Institute, Pretoria.

COWLING, R.M. AND HOLMES, P.M. 1992. Endemism and speciation in a lowland flora from the Cape Floristic Region. Biological Journal of the Linnean Society 47, 367-383.

COWLING, R.M., HOLMES, P.M. AND REBELO, A.G. 1992. Plant diversity and endemism. In: R.M. Cowling (Ed.). The Ecology of Fynbos: Nutrients, fire and diversity, pp. 62-112. Oxford University Press, Cape Town.

CULLINAN, P. 2003. Robert Jacob Gordon 1743 – 1795. The man and his travels at the Cape. http:// web.uct.ac.za/depts/age/people/Gordon/frameset.htm

DIELS, L. 1909. Formationen und Florenelemente im nordwestlichen Kapland. Botanische Jahrbücher 44, 91-124.

EGLER, F.E. 1954. Vegetation science concepts. I. Initial floristic composition – a factor in old-field vegetation development. Vegetatio 4, 412-418.

ESLER , K.J., JONES, F.E., BURKE, A., SAMWAYS, M., BARNARD, P., GILBERT, F. AND WISSEL C. 2002. Guidelines for sustainable rangeland management: recommendations on ecological restoration of rangelands in the semi-arid Nama Karoo Biome. Magenta media, Cape Town.

ESLER, K.J., MILTON, S.J. AND DEAN, W.R.J. 2006. Karoo veld Ecology and Management. Briza publications, Pretoria.

GUO, Q. 2001. Early post-fire succession in California chaparral: changes in diversity, density, cover and biomass. Ecological research 16, 471-485.

JÜRGENS, N. 1997. Floristic biodiversity and history of African arid regions. Biodiversity and Conservation 6, 495-514.

KEELEY, S.C., KEELEY, J.E., HUTCHINSON, S.M. AND JOHNSON, A.W. 1981. Post-fire succession of herbaceous flora in southern California chaparral. Ecology 62, 1608-1621.

KONGOR, R.Y., 2009. Plant response to habitat fragmentation: clues from species and functional diversity in three Cape lowland vegetation types of South Africa. PhD thesis, University of Stellenbosch, Stellenbosch.

KÖRNER, C. 2000. Why are there global gradients in species richness? Mountains might hold the answer. Trends in Ecology and Evolution 15, 513-514.

KRUG, C.B. AND KRUG, R.M. 2007. Restoration of old fields in Renosterveld: a case study in a Mediterranean-type shrubland of South Africa. In: V.A. Cramer and R.J. Hobbs (Eds). Old fields. Dynamics and restoration of abandoned farmland, pp. 265-285. Island Press, Washington.

LOW, A.B. AND REBELO A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

MAGURRAN, A.E. 1988. Ecological diversity and its measurement. University Press, Cambridge.

MARLOTH, R. 1908. Das Kapland, insonderheit das Reich der Kapflora, das Waldgebiet und die Karoo, pflanzengeografisch dargestellt. Wiss. Ergebn. Deutsch. Tiefsee-Exped. 'Waldivia', 1898 – 1899. 2, T. 3, Fischer, Jena.

MIDGLEY, G.F., HANNAH, L., ROBERTS, R., MacDONALD, D.J. AND ALLSOPP, J. 2000. Have pleistocene climatic cycles influenced species richness patterns in the greater Cape Mediterranean Region? Journal of Mediterranean Ecology 2, 137-144.

MIDOKO-IPONGA, D., KRUG, C.B. AND MILTON, S.J. 2005. Competition and herbivory influence growth and survival of shrubs on old fields: implications for restoration of renosterveld shrubland. Journal of Vegetation Science 16, 685-692.

MILLENNIUM ECOSYSTEM ASSESSMENT 2005. Ecosystems and human well-being: Desertification Synthesis, Washington DC.

MOUILLOT, D. AND LEPRÊTRE, A. 1999. A comparison of species diversity estimators. Research on Population Ecology 41, 203-215.

MUCINA, L., JÜRGENS, N., LE ROUX, A., RUTHERFORD, M.C., SCHMIEDEL, U., ESLER, K.J., POWRIE, L.W., DESMET, P.G. AND MILTON, S.J. 2006. Succulent Karoo Biome. In: L. Mucina and M.C. Rutherford (Eds). The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, pp. 220-299. South African National Biodiversity Institute, Pretoria.

MUCINA, L., RUTHERFORD, M.C. AND POWRIE, L.W. (Eds) 2005. Vegetation map of South Africa, Lesotho and Swaziland, 1 : 1 000 000 scale sheet maps. South African National Biodiversity Institute, Pretoria.

POTTS, S.G., VULLIAMY, B., DAFNI, A., NE'EMAN, G., O'TOOLE, C., ROBERTS, S. AND WILLMER, P. 2003. Response of plant-pollinator communities to fire: changes in diversity, abundance and floral reward structure. OIKOS 101, 103-112.

PROCHEŞ, Ş., COWLING, R.M. AND MUCINA, L. 2003. Species-area curves based on relevé data for the Cape Floristic Region. South African Journal of Science 99, 74-476.

REBELO, A.G., BOUCHER, C., HELME, N., MUCINA, L. AND RUTHERFORD, M.C. 2006. Fynbos Biome. In: L. Mucina and M.C. Rutherford (Eds). The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, pp. 52-219. South African National Biodiversity Institute, Pretoria.

RICHARDSON, D.M., COWLING, R.M., BOND, W.J., STOCK, W.D. AND DAVIS, G.W. 1995. Links between biodiversity and ecosystem function in the Cape Floristic Region. In: G.W. Davis and D.M. Richardson (Eds). Mediterranean-type ecosystems: The function of biodiversity, pp. 285-333. Springer-Verlag, Berlin, Heidelberg.

RUTHERFORD, M.C., MUCINA, L. AND POWRIE, L.W. 2006. Biomes and bioregions of southern Africa. In: L. Mucina and M.C. Rutherford (Eds). The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, pp. 30-51. South African National Biodiversity Institute, Pretoria.

RUTHERFORD, M.C. AND WESTFALL., R.H. 1994. Biomes of Southern Africa. An objective characterisation. Memoirs of the Botanical Survey of South Africa 63, 1-94.

SCHULZE, R.E. 1997. South African Atlas of Agrohydrology and – Climatology. Water Research Commission, Pretoria, Report TT82/96.

SCHWILK, D.W., KEELEY, J.E. AND BOND, W.J. 1997. The intermediate disturbance hypothesis does not explain fire and diversity pattern in fynbos. Plant Ecology 132, 77-84.

STEYN, H.M., VAN ROOYEN, N. AND VAN ROOYEN, M.W. 1996. The prediction of phenological stages in four Namaqualand ephemeral species using thermal unit indices. Israel Journal of Plant Sciences 44, 147-160.

VAN DER MERWE, H., VAN ROOYEN, M.W. AND VAN ROOYEN, N. 2008a. Vegetation of the Hantam-Tanqua-Roggeveld subregion, South Africa. Part 1. Fynbos Biome related vegetation. Koedoe 50, 61-71.

VAN DER MERWE, H., VAN ROOYEN, M.W. AND VAN ROOYEN, N. 2008b. Vegetation of the Hantam-Tanqua-Roggeveld subregion, South Africa. Part 2. Succulent Karoo Biome related vegetation. Koedoe 50, 160-183.

VAN WYK, A.E. AND SMITH, G.F. (Eds) 2001. Regions of Floristic Endemism in Southern Africa: A review with emphasis on succulents, pp. 1-199. Umdaus Press, Pretoria.

WEIMARCK, H. 1941. Phytogeographical groups, centres and intervals within the Cape flora. Lunds Universitets Årsskrif Avd. 2. 37, 1-143.

ZIMMERMANN, H.G. 1991. Biological control of mesquite, *Prosopis* spp. (Fabaceae), in South Africa. Agriculture, Ecosystems and Environment 37, 175-186.

Chapter 12

Summary

Located within the Succulent Karoo and Fynbos Biomes, the Hantam-Tanqua-Roggeveld lies within the Northern and Western Cape Provinces of the Republic of South Africa. The aim of this study was to gain information on the floristics, diversity and dynamics of the vegetation to improve our understanding, conservation and management of this unique, botanically unexplored, arid area.

After undertaking a phytosociological study, which identified eight associations and 25 subassociations 40 Whittaker plots were surveyed across the eight associations to collect diversity data. Comparisons of the slopes of the species-area curves showed that the slopes of the Tanqua Karoo associations were significantly shallower than those of the other associations.

Species richness values for the Mountain Renosterveld were highest, Winter Rainfall Karoo values intermediate and Tanqua Karoo values lowest. The evenness, Shannon and Simpson indices did not differ significantly between the Mountain Renosterveld and Winter Rainfall Karoo, however, these values were significantly higher than for the Tanqua Karoo. An ordination of species richness data confirmed a clear Tanqua Karoo cluster, but the Mountain Renosterveld could only be partially separated from the Winter Rainfall Karoo.

Chamaephyte, cryptophyte and therophyte species dominated the study area. Comparisons of life form spectra among associations showed clear differences in the percentage contribution of life forms at a species and vegetation cover level. The percentage contribution of succulent species was low in Mountain Renosterveld, intermediate in Winter Rainfall Karoo and highest in the Tanqua Karoo. Results confirmed the Tanqua Karoo and Winter Rainfall Karoo inclusion into the Succulent Karoo Biome and the strong karooid affinities of the Mountain Renosterveld.

Various species and life form diversity parameters were studied on abandoned croplands of different ages and in the natural vegetation of the Roggeveld (Mountain Renosterveld vegetation). Therophyte and chamaephyte species at a species level were most abundant. Although therophytes dominated early successional croplands they were quickly replaced by chamaephytes which made an overwhelming contribution to vegetation cover. Species-area curves using the exponential function differed significantly for all the abandoned croplands and the natural vegetation. Species richness increased with an increase in age of the abandoned croplands but evenness, Shannon and Simpson indices did not show a similar increase. It was found that after 33-years, an abandoned cropland should be as species rich

as the natural vegetation, however, a Principal Co-ordinate Analysis indicated that floristically these abandoned croplands were still extremely different from the natural vegetation. The rate of recovery varied among life forms and geophytes (cryptophytes) still remain greatly under represented after 20 years of abandonment.

A ten year post-fire study in the Roggeveld indicated that the vegetation cover began to establish within nine months following fire. Generally, species richness and Shannon index values reached a maximum within three years after the fire and then declined in the subsequent years. A Principal Co-ordinate Analysis of species compositional data clearly separated the first two years from the following years. This study seems to lend support for the ‘initial floristic composition’ model of Egler (1954).