Chapter 3

Materials and Methods

3.1 Introduction

This chapter provides a brief outline of the methods applied in chapter 4 to 10. For more detail on the methods the reader is referred to the relevant chapter.

3.2 Vegetation mapping of the Hantam-Tanqua-Roggeveld subregion

Colour, texture and topography were used as a basis to visually stratify satellite images (Bands: 4,5,3 (R,G,B)) of the Hantam-Tanqua-Roggeveld subregion. A total of 390 sample plots were surveyed from August to October 2004 in the stratified homogeneous units close to any national or provincial road or farm track. Most of the surveys were conducted in a 10 m x 10 m plot but larger plots (20 m x 20 m) were used in more denuded areas (Rubin 1998). Geographic Positioning System (GPS) co-ordinates were taken at each site and each species present in a plot was noted and a cover-abundance value assigned according to the Braun-Blanquet cover-abundance scale (Werger 1974). Environmental characteristics such as altitude, topography, aspect, slope, position on the slope, soil type and colour, an estimation of rock cover, rock size and erosion were noted at each survey plot. Biotic effects for example, trampling, small mammal activity and invasion by alien plants, were also recorded.

Analysis of floristic data was undertaken using the TURBOVEG and MEGATAB computer packages (Hennekens & Schaminée 2001). The TURBOVEG software was used to capture the vegetation data and a Two Way Indicator Species Analysis (TWINSPAN) (Hill 1979) was run in MEGATAB. The resulting TWINSPAN on the entire data set of 390 relevés indicated the presence of two distinct floristic groups and enabled the data set to be split into two. A TWINSPAN was then run separately on each data set. The resulting tables were further refined to obtain clear species assemblages using Braun-Blanquet procedures.

The major vegetation units distinguished were termed associations following the definition by Nelder et al. (2005). Species presence and abundance, vegetation structure and spatial distribution of individuals in the dominant layer were used as a basis for the description of the vegetation units. The subassociations were described in terms of a list of species within the subdominant structural layer, together with its canopy cover.

Botanical survey data as well as supporting data such as satellite images, 1:250 000 topocadastral maps, land type maps (Agricultural Research Council 1986a, 1986b, 1995, 1999a, 1999b, 2002, 2003), geological maps (Council for Geoscience 1973, 1983, 1989, 1991, 1997, 2001) and electronic information supplied by the Council for Geoscience (2008) were used to map the vegetation associations and subassociations. Mosaics of specific vegetation types were mapped where two or more subassociations were present in a mapping unit but where it was not possible to map them separately as a result of a high spatial diversity.

Unidentified species were collected and herbarium specimens sent to the Compton Herbarium, Kirstenbosch, for identification. Specimen collection code (HR) and numbers were kept throughout the process since all species have not yet been positively identified, especially those within the Aizoaceae (Mesembryanthemaceae). Voucher specimens are housed at the H.G.W.J. Schweickerdt Herbarium (PRU), University of Pretoria. Nomenclature follows that of Germishuizen and Meyer (2003) and the South African National Biodiversity Institute's 'Plants of South Africa' electronic database (http://posa.sanbi.org).

3.3 Plant diversity studies

Within each of the eight vegetation associations described in the Hantam-Tanqua-Roggeveld subregion (Van der Merwe et al. 2008a, 2008b), Whittaker plots were surveyed. A total of 40 plots were surveyed using Whittaker's plant diversity plot technique (Shmida 1984). The ease with which the plot can be set up and sampled relative to other techniques such as the Modified Whittaker Nested Vegetation Sampling Technique of Stohlgren et al. (1995) and facilitation of comparisons with other diversity studies were the main reasons for using the Whittaker plot technique. Also, Wilson and Shmida (1984) concluded that the Whittaker method came close to fulfilling four criteria of 'good' performance of beta diversity measures.

The only modification to the methodology described by Shmida (1984) related to the field form and notations used on the field form. Each size quadrat was noted in a separate column on the field form with the vegetation of the two 5 m^2 quadrats noted in two separate columns and the 10 m x 10 m square separated into two 5 m x 10 m rectangles with the species noted apart from one another in two columns on the field form. The columns thus read: ten 1 m^2, two 5 m^2, two 50 m^2 and one 1000 m^2. Each species in a quadrat was noted within a column and a percentage cover value was assigned for each species in the 1000 m^2 quadrat. Thus, each column contained a list of all the species present in that quadrat enabling additional calculations for quadrats of a different size than actually measured. At each survey plot, various environmental data were collected, for example, altitude, aspect, slope, geology, various soil characteristics and biotic effects such a small mammal activity and trampling.

The total species number for seven plot sizes (1 m^2, 5 m^2, 10 m^2, 20 m^2, 50 m^2, 100 m^2 and 1000 m^2) were determined by using the mean of the ten 1 m^2 plots for the 1 m^2 plot, the mean of the two 5 m^2 plots for the 5 m^2 plot, mean of the total of ten 1 m^2 plots and the total of two 5

m^2 plots for the 10 m^2 plot, total of the ten 1 m^2 and the two 5 m^2 plots for a 20 m^2 plot, mean of the two 50 m^2 plots for a 50 m^2 plot, the total of the two 50 m^2 plots for a 100 m^2 plot and the total for the 1000 m^2 plot.

Throughout the chapters in this thesis comparisons are made with respect to the vegetation associations as described in Van der Merwe et al. (2008a, 2008b). For convenience, the three Mountain Renosterveld associations are grouped together and called Mountain Renosterveld vegetation, the Escarpment Karoo, Hantam Karoo and Roggeveld Karoo are collectively referred to as the Winter Rainfall Karoo vegetation and the Tanqua and Loeriesfontein Karoo together with the Central Tanqua Grassy Plains are collectively termed the Tanqua Karoo vegetation.

The STATISTICA computer package (StaSoft, Inc. Version 7 and Version 8, 2300 East 14th Street, Tulsa, OK 74104) were used to determine species-area equations, r-values and p-values (significance). ANOVAs were conducted to compare slopes of species-area curves between the three vegetation groups for each of the three functions as well as to determine the significant difference in diversity parameters between the vegetation associations or between different plot sizes. All ANOVAs were preceded by a test for normality. Life form data was compared at species and cover levels across the broad vegetation groups and plant associations using an analysis of variance was performed using the GLM (General Linear Model) Procedure in SAS (SAS® Version 8.2 running on an IBM z9 mainframe computer under z/VM 5.3.0 at the University of Pretoria). Since assumption that the variances among treatment levels were constant was violated, the data were transformed. A power transformation test indicated that the appropriate transformation would be of the form: $\log_{10}$ (life form + 1). The transformed life form values were then used in the statistical analysis. Statistical analyses of the data to investigate a degree of succulence were conducted using the STATISTICA computer package (StaSoft, Inc. Version 8, 2300 East 14th Street, Tulsa, OK 74104) (ANOVA's – Kruskal-Wallis test) since the data were not normally distributed.

Differences in the slope and intercept values of the species-area curves were analysed by an Analysis of Covariance (Quinn & Keough 2002) with GraphPad Prism 4.03 for Windows (GraphPad software, San Diego, California, USA, www.graphpad.com). The SYN-TAX computer program (Podani 2001) was used to ordinate the total number of species for all seven plot sizes for the 40 survey plots using Principal Co-ordinate Analysis (PCoA).

3.3.1 Species-area relationships

Type II species-area curves (Scheiner 2003, 2004) for each of the 40 Whittaker plots were constructed using the seven different plot sizes. Three different functions were used to construct these species-area curves namely: 1) the untransformed linear function between species richness (S) and area (A): S = zA + c where c and z are constants for the slope and y-intercept respectively; and 2) the power function, typically expressed as the log transformation: log S = log c + z log A, and 3) the exponential function, expressed as a semilog function: S = z log A + c (Veech 2000). A fourth function, the logistic function, was not used in the study since the whole community was not sampled. If sampling covers the whole of a community, the logistic is expected to be the best model to describe the species-area relationship (He & Legendre 1996).

The species-area curves produced using all three functions were calculated for each sample plot and mean values derived for each subassociation using the function which produced the best fit to the data. Additionally, species-area curves along a transect of ten survey plots running from west to east through the study area was compiled to illustrate the changes in species-area relationships along such an environmental gradient. The transect begins in the Tanqua Karoo and stretches eastwards across the Roggeveld escarpment onto the Roggeveld plateau and crosses five of the eight plant associations.

3.3.2 Diversity parameters

The PC-ORD computer program (PC-ORD Version 4 for Windows, MjM Software design) was used to calculate species richness (S), Shannon's index of diversity (H'), Simpson's index of diversity (D) and a measure of evenness (E) for each 1000 m² (0.1 ha) plot sampled. PC-ORD calculates these four diversity measures as follows:

S = richness = number of non-zero elements in a row.

H' = Shannon diversity

$$H' = -\sum_{i}^{S} p_i \log p_i$$

Where p_i = importance probability in column *i*.

E = Evenness (equitability) = H' / ln (richness)

D = Simpson's index of diversity for an infinite population. This is the complement of Simpson's original index and represents the likelihood that two randomly chosen individuals will be different species.

$$D = 1 - \sum_{i}^{S} p_i{}_{i}^{2}$$

Mean values for each of these parameters were calculated for each association as well as for the three vegetation groups, i.e. Mountain Renosterveld, Winter Rainfall Karoo and Tanqua Karoo.

3.3.3 Life form spectra

The species noted in the 1000 m^2 Whittaker plots were classified into broad life form categories following Raunkiaer's (1934) classification as modified by Mueller-Dombois and Ellenberg (1974) (Appendix 1). Relative life form contribution at both a species and vegetation cover level, was calculated for each plot using Raunkiaer's classic forms. Comparisons of each life form were made across the eight plant associations as well as for the three broad vegetation groups (Mountain Renosterveld, Winter Rainfall Karoo and Tanqua Karoo) found in the region. An analysis of variance was performed using the GLM (General Linear Model) Procedure in SAS (SAS® Version 8.2 running on an IBM z9 mainframe computer under z/VM 5.3.0 at the University of Pretoria). The assumption that the variances among treatment levels were constant was violated and thus the data were transformed. A power transformation test indicated that the appropriate transformation would be of the form: $\log_{10}$ (life form + 1). The transformed life form values were then used in the statistical analysis. The complete SAS outputs are included in Appendix 2 for the association level output and Appendix 3 for the vegetation group level output.

A measure of the succulence in the vegetation was determined by calculating the percentage contribution of succulent species to the total species as well as the percentage contribution by succulents in terms of vegetation cover. Statistical analyses of these data were conducted using the STATISTICA computer package (StaSoft, Inc. Version 8, 2300 East 14th Street, Tulsa, OK 74104) (ANOVA's – Kruskal-Wallis test) since the data were not normally distributed.

3.4 Life form and species diversity on abandoned croplands in the Roggeveld

Whittaker's plant diversity plot technique (Shmida 1984) was used to sample eight abandoned croplands of various ages (3-, 4-, 8-, 10- 15- and 20-years old) and an undisturbed plot of natural vegetation close to the 20-year old abandoned cropland. All surveys were conducted in one season in the same vegetation type and on the same geological substrate, on one farm in the Roggeveld. The same modification from Shmida's (1984) methodology was used for the field form and notations on the field form as described in section 3.3 of this chapter were applied.

Raunkiaer's life form categories (1934) as modified by Mueller-Dombois and Ellenberg (1974) were used to classify the species encountered in the surveys into broad life from categories

(Appendix 1). The relative contribution of each life form, in terms of species as well as vegetation cover, to the 1000 m² (0.1 ha) sample plot were calculated.

Species number totals for seven plot sizes (1 m², 5 m², 10 m², 20 m², 50 m², 100 m² and 1000 m²) were determined and used to construct Type II species-area curves (Scheiner 2003, 2004) for each of the nine plots sampled using the exponential function, since this function produced the best results across the study area (Chapter 6). The exponential function is expressed as a semilog function: $S = z \log A + c$ (Veech 2000).

The PC-ORD computer program (PC-ORD Version 4 for Windows, MjM Software design) was used to calculate species richness (S), Shannon's index of diversity (H'), Simpsons index of diversity (D) and a measure of evenness (E) for each 1000 m² (0.1 ha) plot sampled as set out in section 3.3.2. The Shannon index was also used to calculate a life form diversity index using frequency of life forms instead of species.

Life form distributions were compared using the Chi-square test in the STATISTICA computer package (StaSoft, Inc. Version 7, 2300 East 14th Street, Tulsa, OK 74104). The SYN-TAX computer program (Podani 2001) was used to ordinate the floristic data for all nine plots surveyed using Principal Co-ordinate Analysis (PCoA). Principal Co-ordinates Analysis is a more general form of Principal Component Analysis (PCA) that can give a marked improvement over PCA by allowing the use of a wide array of distance measures (McCune & Grace 2002).

An Analysis of Covariance (Quinn & Keough 2002) in GraphPad Prism 4.03 for Windows (GraphPad software, San Diego, California, USA, www.graphpad.com) was used to analyse differences between slope values and intercepts of the exponential function curves between the abandoned croplands of different ages.

3.5 Vegetation trends following fire in the Roggeveld

On 26 January 1999 more than 10 000 ha burnt in a lightning induced fire in the Roggeveld. The local farmers requested that the, then, Northern Cape Nature Conservation Service conduct surveys to track vegetation changes following the fire. Since the department was under serious financial strain at the time, a small project was initiated in October 1999. Five monitoring sites were selected and surveyed yearly in order to monitor trends in species composition and vegetation cover.

A point or plotless method was used to acquire ten years of data on vegetation changes that followed the fire. Due to the steep slopes and rock-strewn areas, the descending point method (Roux 1963, Novellie & Strydom 1987) was deemed the most appropriate method to track post-fire vegetation trends at the five sites.

The post-fire transects were permanently marked with iron poles ('droppers') indicating the position of the beginning and end points of a 50 m rope which was marked at 1 m intervals. Four lines, 1 m apart and parallel to one another were surveyed in order to limit the chance of surveying transitional areas. A total of 200 points were surveyed per locality. Monitoring was conducted yearly in the last week of September or the first week of October from 1999 to 2008.

The number of strikes per species were expressed as a percentage of the 200 points surveyed and these totals added to determine the percentage vegetation cover since the number of strikes on a species was calculated as a percentage of the total number of point observations made and were not expressed as a percentage of only the strikes (Du Toit 1998a). The sum of the individual plant species percentages obtained rarely totals one hundred because the number of strikes observed are fewer than the total number of point observations made (Du Toit 1998b).

Additionally, the species were classified among the classic life forms as defined by Raunkiaer (1934) and modified by Mueller-Dombois and Ellenberg (1974) (Appendix 1). The post-fire vegetation was investigated in terms of (a) total vegetation cover, (b) total species richness, (c) Shannon-Wiener index of diversity, (d) vegetation cover per life form, (e) species richness per life form, and (f) changes in species composition over the 10 year period.

Shannon's index of diversity (H') was calculated for each sampled plot using the PC-ORD computer program (PC-ORD Version 4 for Windows, MjM Software design) which calculates this diversity measure as follows:

H' = Shannon diversity

$$H' = -\sum_{i}^{s} p_i \log p_i$$

Where p_i = importance probability in column *i*.

The species compositional data for each of the five post-fire monitoring plots were ordinated using Principal Co-ordinate Analysis (PCoA) in the SYN-TAX computer program (Podani 2001) in an attempt to visualise vegetation recovery over time.

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Chapter 4

Vegetation of the Hantam-Tanqua-Roggeveld subregion, South Africa. Part 1. Fynbos Biome related vegetation

(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.)

Vegetation of the Hantam-Tanqua-Roggeveld subregion, South Africa. Part 1: Fynbos Biome related vegetation

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ABSTRACT

The Succulent Karoo Hotspot stretches along the western side of the Republic of South Africa and Namibia. A lack of botanical information on the Hantam-Tanqua-Roggeveld area of the Succulent Karoo Hotspot was identified during the SKEP (Succulent Karoo Ecosystem Plan) process. A grant from CEPF (Critical Ecosystem Partnership Fund) funded a study to produce a vegetation map of the area to serve as baseline for ecosystem management.

Vegetation surveys were conducted over an area of more than three million hectares from August to October 2004. Two major floristic units were identified, namely the Fynbos Biome related (Mountain Renosterveld) and Succulent Karoo Biome related units. An analysis of the floristic data of the predominantly Mountain Renosterveld vegetation unit is presented in this paper. Three associations were identified, which were subdivided into nine subassociations, one of which contains four variants. The vegetation units are described in terms of their species composition and their relationships with the physical environment. A vegetation map is provided depicting the geographical distribution of the different vegetation types. The main threat to the vegetation of the region identified by the farming community was a lack of infrastructure.

Keywords: Mountain Renosterveld, phytosociology, Succulent Karoo, vegetation classification, vegetation map

The Succulent Karoo, which stretches along the western side of South Africa and Namibia, is recognised by the IUCN as one of the global hotspots of biodiversity (Myers *et al*. 2000, CEPF 2003) and one of only two hotspots that are entirely arid (Conservation International – website).

In 2002 the Succulent Karoo Ecosystem Plan (SKEP) was launched to identify and generate consensus for a 20-year conservation and sustainable land-use strategy for the Succulent Karoo Hotspot. SKEP aims to meet the quantitative targets for the conservation of vegetation and globally threatened and endemic species at particular sites, as well as critical ecological and evolutionary processes that must be conserved to ensure the persistence of these species (Conservation International – website).

For management purposes, the SKEP initiative subdivided the Succulent Karoo into four subregions, of which the Hantam-Tanqua-Roggeveld constituted one. In common with the rest of the Succulent Karoo, the vegetation of the Hantam-Tanqua-Roggeveld subregion includes a wide range of succulents, geophytes and annuals. After good rains, the spectacular autumn and spring displays of wild flowers in parts of the region attract large numbers of tourists. Unlike many parts of Namaqualand, such brilliant shows of annuals and geophytes are not only a feature of fallow fields, but also occur in the undisturbed natural vegetation in the Hantam and Roggeveld (Van Wyk & Smith 2001).

The identification, description and classification of vegetation units across the landscape comprise the critical first steps in building a framework for ecosystem management planning. Information on the spatial, temporal and ecological properties of the vegetation units can lead to the improved understanding, protection and management of natural resources. Progression of the SKEP initiative soon showed the paucity of data available on the biodiversity of the Hantam-Tanqua-Roggeveld subregion, which was key to future planning, conservation and development. The Critical Ecosystem Partnership Fund (CEPF), which is a joint initiative of Conservation International, the Global Environmental Facility, the Government of Japan, the MacArthur Foundation and the World Bank, therefore granted funding for botanical studies in the subregion.

The first step of the botanical study was to undertake a systematic broad-scale vegetation survey of the entire subregion of approximately three million hectares, which could be used as the basis for further detailed botanical investigations. The survey revealed two distinct vegetation groups, i.e. the Fynbos Biome related Mountain Renosterveld vegetation group and the Succulent Karoo Biome related vegetation group. The aim of the present article is to report on the Mountain Renosterveld vegetation, depicting its component vegetation units on a map. A second article (Van der Merwe *et al*. in press) will report on the latter vegetation group.

STUDY AREA

The Hantam-Tanqua-Roggeveld subregion (Fig. 1), as defined in the current study, lies in the predominantly winter rainfall region of the Northern and Western Cape Provinces of South Africa, and covers an area of approximately three million hectares. In the west it stretches from east of the Cederberg Mountains in the southwestern corner, northwards along the Bokkeveld Mountains to just north of Loeriesfontein. The eastern border includes the Roggeveld and Nuweveld Mountain Ranges to just southwest of Fraserburg, while the southern limit includes the Tanqua and Ceres Karoo to where the Swartrug Mountains and the Bontberg Mountains meet north of Ceres.

The Mountain Renosterveld discussed in the current article is found on the Roggeveld, Nuweveld, Komsberg, Klein Roggeveld, Koedoesberg and Hantam Mountains. In general, this is the higher-lying part of the larger subregion that is actually situated in the Fynbos Biome (Rutherford & Westfall 1986). This area includes Acocks's (1988) Mountain Renosterveld (Veld Type 43), which is equivalent to the Escarpment Mountain Renosterveld (Unit 60) of Low and Rebelo (1998). According to Mucina *et al*. (2005), six vegetation types are represented in the area, namely the Nieuwoudtville Shale Renosterveld (FRs 2); the Roggeveld Shale Renosterveld (FRs 3); the Central Mountain Shale Renosterveld (FRs 5); the Nieuwoudtville Roggeveld Dolerite Renosterveld (FRd 1); the Hantam Plateau Dolerite Renosterveld (FRd 2); and the Roggeveld Karoo (SKt 3).

The earliest references to the botanical wealth of the Hantam-Roggeveld date from the early 1900s. Diels (1909 in Van Wyk & Smith 2001) mentioned the high levels of endemism in the Hantam-Roggeveld and provided a useful floristic analysis of the region. He concurred with Marloth (1908) that the region is floristically more closely related to the Succulent Karoo and the Great Karoo than to the Cape Floristic Region, although Cape floristic elements are clearly present, especially on the Hantamsberg (Van Wyk & Smith 2001). The Roggeveld was also one of the three centres of endemism that Hilton-Taylor (1994) identified within the Western Cape Domain, the other two centres being the Western Mountain Karoo and Tanqua Karoo, which also fall within the Hantam-Tanqua-Roggeveld subregion. Van Wyk and Smith (2001) combined the Hantam-Roggeveld into one of their 13 principal centres of plant endemism in southern Africa and stressed the unique botanical importance of this area.

The rainfall ranges from 132–467 mm per year (Weather Bureau 1998), which, although falling mainly in winter, includes a few summer thunderstorms. In 2004 the rainfall season was poor and the usual winter snowfalls on the high-lying areas were limited to the light snow that fell on one occasion, compared

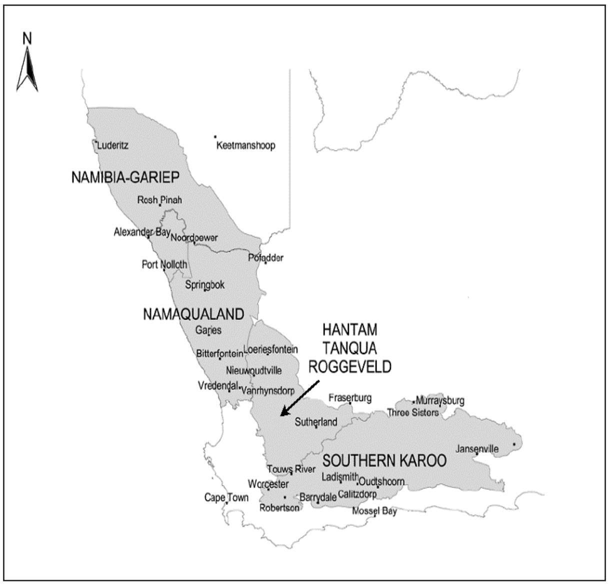

FIGURE 1
Subregions in the SKEP planning domain (CEPF 2003).

with the mean of six snow days recorded over a 24-year period by the Weather Bureau (1998). At Sutherland the mean maximum for the warmest month, January, is 27.1°C, while, the extreme maximum recorded was 35.5°C in January 1980 (Weather Bureau 1998). The mean minimum for the coldest month, July, is –2.4°C, while the extreme minimum, -13.6°C, was recorded in July 1970 and August 1978 (Weather Bureau 1998).

Rocks of the Ecca Group cover most of this area with Dwyka (consisting of tillite, sandstone, mudstone and shale) cropping out in the west and the Beaufort Group in the east (Council for Geoscience 1973, 1983, 1989, 1991, 1997, 2001). The Ecca Group includes sediments of the Koedoesberg Formation (consisting of sandstone and shale) and the Tierberg Formation (consisting of shale) (Council for Geoscience 1973, 1983, 1989, 1991, 1997, 2001). Mudstones of the Beaufort Group are found on the eastern side of the study area (Council for Geoscience 1973, 1983, 1989, 1991, 1997, 2001). Igneous intrusions of dolerite occur throughout the region, being easily recognisable as very hard, dark grey to nearly black rocks (Van Wyk & Smith 2001). The soils of the Roggeveld consist primarily of clays and silts derived from the Karoo sequence shales (Low & Rebelo 1998) and are found on the slopes and foothills of the Great Escarpment along the various mountain ranges.

METHODS AND MATERIALS

Satellite images (Bands: 4, 5 and 3 (R,G,B)) of the study area were visually stratified into relatively homogeneous units on the basis of colour, texture and topography. This stratification was used to select the sites at which sample plots were surveyed from August until October 2004. At each site GPS (Global Positioning System) coordinates were taken and each species present in the plot was noted and assigned a cover-abundance value according to the Braun Blanquet cover-abundance scale (Werger 1974). Various environmental characteristics, such as altitude, topography, aspect, slope, an estimation of rock cover, the size of the rocks, soil type and colour, and the degree of erosion were noted at each sampling point. Biotic effects, such as trampling, small mammal activity, or invasion by alien plants, were also recorded.

A total of 390 sample plots covering the entire Hantam-Tanqua-Roggeveld subregion were surveyed in 2004. An analysis of the floristic data was undertaken using the TURBOVEG and MEGATAB computer package (Hennekens & Schaminée 2001). Vegetation data were captured with the TURBOVEG software and the data were classified with the aid of MEGATAB.

As a first step to the classification of the floristic data, a Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979) was run in MEGATAB. The result of the TWINSPAN on the entire data set confirmed the presence of two distinct floristic groups, which enabled the data set to be split into two. A TWINSPAN was then run separately on each data set, with the resulting tables being further refined to obtain clear species assemblages. The first phytosociological table, which characterises the vegetation of the predominately Mountain Renosterveld as defined by Acocks (1988), is discussed in the current article.

The major vegetation units distinguished in the Mountain Renosterveld were termed associations following the use as defined by Nelder *et al*. (2005). Associations are produced on the basis of the presence and abundance of species, vegetation structure and the spatial distribution of individuals in the dominant layer. Subassociations are generally distinguished on the basis of elements in the subdominant layers. The subassociations are described in terms of a list of species featuring each structural layer, together with its canopy cover.

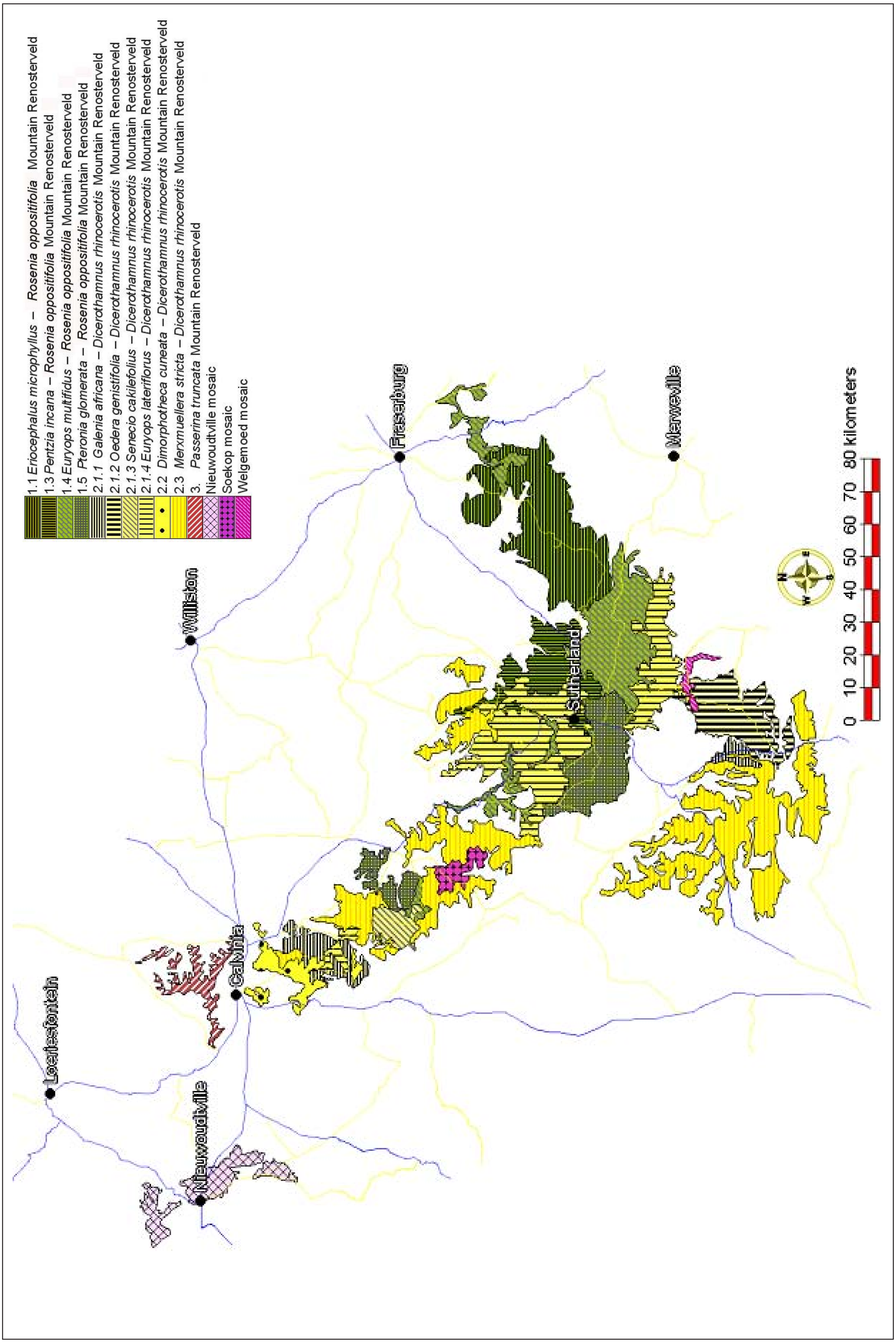

FIGURE 2*
Vegetation map of the Mountain Renosterveld vegetation of the Hantam-Tanqua-Roggeveld subregion. *Enlarged figure is available online.

TABLE 1
Phytosociological table of the predominantly Mountain Renosterveld vegetation of the Hantam-Tanqua-Roggeveld subregion

RELEVÉ NUMBER	1.1	1.2	1.3	1.4	1.5	2.1.1	2.1.2	2.1.3	2.1.4	2.2	2.3	3
	313 314 315 321 332 310 311 312 316 317 320	145 269 341 292 307	144 284 138 283 271 275 343 150 305 306	274 309 330 333 323 324 329 282	272 335 291 325 326 336 342 273 285 288 195 72 99 146	31 196 153 132 198 25 34 130 233	344 345 131	82 34 339 363 365 75 289	252 281 286 337 280 338 29 152 22 287	85 81 83 147 149 364 24 100 148 155 182	193 361 362 367 334 279 348 346 154 194 192 340 366 101 190	368 370 369 371
SPECIES GROUP A												
Eriocephalus microphyllus	1.aa....1.a	.....	....++..+.	..+.....	....	+......+.	.++	....	....	....	.........++....	....
Pentzia (HRp317) sp.	.++..+++.+.	.....	....	....	....	....	...	....	....	....	....	....
Euryops imbricatus	11..1......	....+	....	....	....	....	...	....	....	....	....	....
Diospyros austro-africana	r..+.......	.....	....	....	....	....	...	....	....	....+......	....	...+
SPECIES GROUP B												
Antimima cf. granitica (HR248)	....	++...	....	....	....	....	...	....	....	....	......r....+...	....
Pelargonium sp.	....	+..+.	....	....	....	....	...	....	....	.........r.	....	....
Senecio erosus	....	...++	....	....	....	....	...	....	......+...	....	...........+...	....
Lotononis sp.	....	.++..	....	....	....	.+.......	...	....	.........+	..........+	....	....
Asparagus asparagoides	....	+....	....+.....	....	....	....	...	....	....	....	....	....
SPECIES GROUP C												
Salvia disermas	....	.....	+.+.......	....	....	....	...	....	....	....	....	....
Chrysanthemoides incana	....	.....	.+.1......	....	....	....	...	....	....	....	....	....
Aptosimum indivisum	....	.....	+.........	....	..........+...	....	...	....	....	....	....	....
Stipagrostis namaquensis	....	.....	..a.......	....	....	....	...	....	....	....	....	....
Braunsia sp.	....	.....	.a........	....	....	....	...	....	....	....	....	....
SPECIES GROUP D												
Pentzia incana	....	.+...	.++.++.+++	....	....	.....+...	...	....	....	....	.........+.+...	....
Mesembryanthemum guerichianum	....	.....	+........+	....	....	....	...	....	....	....	....	....
Androcymbium volutare	....	.....	+.....+...	....	....	....	...	....	....	....	....	....
SPECIES GROUP E												
Euryops multifidus	....++.....	.....	.+........	.+1+++..	....	....	...	....	....	....	....	....
Phyllobolus tenuiflorus	....	+..+.	.........+	+.++..+.	....+.........	....	...	....	....	....	....	....
SPECIES GROUP F												
Rosenia oppositifolia	..++1++b...	++a1.	.+..++111.	+++++a.3	.a3..a+33..1..	....	...	......+	...+......	......+....	...+...........	....
Pteronia glomerata	...+++.+++.	+++.+	.+..++.+++	..+.++..	+1a+.+...+++++	....+....	...	.....+.	+..+......	.......+...	+...+++........	....
Lycium spp.	.+++.+++.++	+..++	+.++..+..+	....+r..	..+........+..	....	...	....	....	....	...........++..	....
Karroochloa schismoides	...+++.....	.....	+.+.....++	+.1+....	.+.+++.+++....	....	...	....	....	.........++	.........+.....	....
Eriocephalus decussatus	......b....	.....	..++.+....	++......	..........+..+	.1.......	...	....	....	....	....	....
Pentzia cf. sphaerocephala	....	+..+.	.....+....	...+....	....	....	...	....	....	....	....	....
Ruschia cradockensis	....	.1...	....	...1....	......1.......	.....+...	...	....	....	....	....	....
SPECIES GROUP G												
Galenia africana	....	.....	.......+..	....	....	.r.r.+r++	...	....	......+...	+......+..+	+........+...r.	....
Medicago sp.	....	.....	....	....	....	..+...a++	...	......+	....	........+..	....	....
SPECIES GROUP H												
Oedera genistifolia	....	.....	....	....	....	..1.1..++	.1+	....	....	..........+	.......++......	....
Ursinia pilifera	....	.....	....	....	....	...++....	++r	....	....	....	....	....
Ruschia intricata	.....1.....	.....	....	....	............+.	.a.+.....	+.+	....	....	....	......+....+...	....
Ursinia calenduliflora	....	.....	....	....	....	+.....1..	.++	....	....	++.........	....	....
SPECIES GROUP I												
Plantago cafra	....	.....	....	....	....	....	...	++...+.	....	....	....	.+..
Poa bulbosa	....	+....	....+.....	....	....	....	..+	++....+	..+.......	+..........	....	....
Galenia sarcophylla	....	.....	....	....	............+.	....	...	++.....	....	..+........	....	....
Cromidon varicalyx	....	.....	....	....	.....+.......+	....	...	..+.+..	....	....	....	....
Eriocephalus paniculatus	....	.....	....	....	....	....	...	++.....	....	..+........	...+...........	....
Lotononis hirsuta	....	.....	....	....	....	....	...	...++..	........+.	....	....	....
SPECIES GROUP J												
Leysera gnaphalodes	....	.....	....	....	....	....	.r+	....+..	....	...+.......	....	.+..
Selago sp.	....	.....	.........+	....	.......+++....	....	++.	......+	....	....	....	....

Table 1 (cont...)

RELEVÉ NUMBER	1.1	1.2	1.3	1.4	1.5	2.1.1	2.1.2	2.1.3	2.1.4	2.2	2.3	3
	313 314 315 321 332 310 311 312 316 317 320	145 269 341 292 307	144 284 138 283 271 275 343 150 305 306	274 309 330 333 323 324 329 282	272 335 291 325 326 336 342 273 285 288 195 72 99 146	31 196 153 132 198 25 34 130 233	344 345 131	82 34 339 363 365 75 289	252 281 286 337 280 338 29 152 22 287	85 81 83 147 149 364 24 100 148 155 182	193 361 362 367 334 279 348 346 154 194 192 340 366 101 190	368 370 369 371
Tribolium hispidum	. . . .	. . . . .	. . . .	. . . .	. . . . + .	. . . .	+ . .	+ . . . . + .	. . . .	. . . . . + ...	. . . .	. . . .
Albuca sp.	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	+ . .	. . . + . . .	. . . .	. . . .	. . . .	. . . .
Ehrharta calycina	. . . .	. + . . .	+	. . . .	. . . .	. . . .	+ . .	. . + . + . .	. . . .	. . . .	. . . .	. . . .
SPECIES GROUP K												
Cotula nudicaulis	. . . .	. . . . .	. . . .	. . . .	. . . .	. + + ... + .	. . +	. + . . + . .	+ . + . + ...	. . . .	. . . .	. + . .
Polycarena aurea	. . . .	. + . . .	. . . .	. . . .	. . . . + ...	. + + . + ...	+ + .	. . . . + . +	. . + ...	. . . . . + ...	. . . .	. . . .
Nemesia spp.	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . . . + . . .	. . .	. . . + . . .	. + ...	. + ... r .	. . . .	. . . .
Pharnaceum aurantium	. . . .	. . . . .	. . . .	. . . .	. . . .	+	. + .	. . . . . . +	. . . + ...	. . + ...	. . . . . + ...	. . . .
Berkheya sp.	. . . .	. . . + .	. . . + ...	. . . .	. . . . + + ... +	. . . . + ...	. . +	. . . + + . +	. + + + ...	. . . . + . . . r . .	. . . . + ...	. . . .
SPECIES GROUP L												
Erodium cicutarium	. . . .	+	. + . + ...	+ . . + ...	. . . 1 3 . . . . + + . . .	. . . . . + + . .	. . +	+ + + + + + .	. . + . + . + + + .	. . . . . . + ...	. . . .	. + + .
Bromus pectinatus	. . . .	+ . + . .	. . . . + . . + . .	. . . .	+ . + + . . . + ...	+ + + . . + . + +	. . .	. . . . + . .	+ . . . . . + . + .	. . . .	. . . .	. . . .
Senecio cakilefolius	. . . .	. . . . +	+	. . . .	+ . + + . + . + . . . + . +	. + + . + ...	+ + +	+ . . + + + +	. + . . + ...	. . . . + ...	. . . .	. + + .
Felicia australis	. . . .	. . + . .	. + . + ... +	. . . .	+ . . . + + + ...	. . + ... +	. + +	. . + . + . .	+ . + . . + ...	. . . .	. . . .	. + . .
Heliophila spp.	. . . .	. . + . +	. . . .	. . . . . . + .	. . . . . . + . + ...	. . . .	. . .	. . . + + . .	. + . + . + . + . .	. . . . . + ...	. . . .	. + + .
Arctotheca calendula	. . . .	. . . . .	+ . . + ...	+ . . . . . . +	. . . . + . . + . .	. . . . + .	. . .	. . . . . + .	. . . . r . . + + .	. . . .	. . . .	. . . .
Helichrysum lucilioides	. . . . + ...	. + . . +	. . . .	. . . . + . . .	. . . . +	. . . .	. . .	. . . + . . .	. . . + ...	. . . .	. . . .	. . + .
Eriocephalus pauperrimus	. . . .	. . . a 1	. . . .	. . . .	. . + ... b . .	. . . .	. . .	. . . . . 1 .	. . . + ...	. . . .	. . . .	. . . .
Leysera tenella	. . . .	. . . . .	+	+ . . + . . . +	. . . . + .	1	. + .	. . . .	. . . .	. . . .	. . . .	. . . .
Gazania rigida	. . . . + ...	. . . . .	. . . . . . + . + .	+	. . . .	. + ...	. . .	. . . .	. . + + ...	. . . . +	. . . . + ...	. . + .
Adenogramma glomerata	. . . .	. . . . .	. . . . +	. . . .	. + ...	. + ...	. . .	. . . .	. . . . . + . + . .	. . . .	. . . .	. + . .
SPECIES GROUP M												
Hermannia cuneifolia	. . . .	. . . . .	. . r . . . . + . .	. . . .	. . . .	. + ...	. . .	. . . + . . .	. . . . r .	+ . . . + + . r . . .	. . . .	. . . .
Dorotheanthus sp.	. . . .	. . . . .	+ . . . . . . + . .	. . . .	. . . .	+ . . . + ...	. . .	. . . .	. . . . . . + . . .	+ + . . + . + ...	. . . . + ...	. . . .
Helichrysum hamulosum	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . + + + . . r . .	. . . .	. . . .
Oedera sedifolia	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	+ + 1	. . . .	. . . .
Tripteris aghillana	. . . .	. . . . +	. . . + ...	. . . .	. . . .	. . . r	. . .	. . . .	. . . .	. . . + ... + . +	. . . . + . . .	. . . .
Ursinia nana	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . . + ...	. . .	+ . . . . + .	. . . .	. + ... + . + .	. . . .	. . . .
Cyperaceae sp.	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . + . . + ...	. . . .	+ . . .
Tetragonia microptera	. . . .	. . . . .	. . . .	. . . .	. . . .	+ . . . . + . . .	. . .	. . . .	. . . .	+ . . . . . + ...	. . . .	. . . .
Tylecodon wallichii	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	+ . . . . + .	. . . .	. . . .
Dorotheanthus maughanii	. . . .	. . . . .	. . . .	. . . .	. . . .	. + ...	. . .	. . . .	. . . .	. . . . + +	. . . .	. . . .
Scleranthus annuus	. . . .	. . . . .	. . . .	. . . .	. . . . + + ...	. . . .	. . .	. . . . + . +	. . . . +	. + . + . + ...	. . . .	. . + .
Pelargonium grossularioides	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . . + . .	. . . .	. . . . . + . . r . .	. . . .	. . + .
Festuca scabra	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . . + . .	. . . .	. . . r . . . . r . .	. + ...	. . + .
SPECIES GROUP N												
Felicia filifolia	. . . . . . r . . a .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . +	. . . .	. . . .	. . . + + . 1 r . . +	+ + + + + . . + ...	. . . .
Polygala scabra	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . . + ...	. . r	. . . + . . .	. . . .	+ . . . . r .	. + + ...	. . . .
Ehrharta melicoides	. . . + r	+	. . . .	. . . .	. . . .	. . . .	. . .	. . . . . . +	. . . .	. . . . . + . . r . .	. + + . + + . + . . . + . . .	. . + .
SPECIES GROUP O												
Pteronia glauca	. . . .	. . . . .	. . . .	. . . .	. . . .	. . r . . . . 1 .	. + .	. . . .	. . . .	. . . . 1 .	. . . . . . + . + + . + b . .	. . . .
Helichrysum asperum	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . . + . .	. . . .	. . . . + . + ...	. . . .
Androcymbium sp.	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . .	. . . . + . + . . .	. . . +
Stachys rugosa	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . .	. . . + ... + ...	. . . .
Leipoldtia (HRp347) sp.	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . .	. . . . . . 1	. . . .
SPECIES GROUP P												
Passerina truncata	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . .	. . . .	b + + +
Cliffortia arborea	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . .	. . . .	. . . +
Agathosma sp.	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . .	. . . .	. . . .	. . . .	. . . +
Othonna auriculifolia	. . . .	. . . . +	. . . .	. . . .	. . . .	. + . r	. . .	. . . . . + .	. . . .	. . . .	. . . .	. + r .
Hesperantha sp.	. . . .	. + . . .	. . . .	. . . .	. . . .	. . . . + .	. . +	. . . .	. . . .	. . . .	. . . .	. . . .

Table 1 (cont...)

RELEVÉ NUMBER	1.1	1.2	1.3	1.4	1.5	2.1.1	2.1.2	2.1.3	2.1.4	2.2.	2.3	3
	3 3 3 3 3 3 3 3 3 3 3	1 2 3 2 3	1 2 1 2 2 2 3 1 3 3	2 3 3 3 3 3 3 2	2 3 2 3 3 3 3 2 2 2 1 _ _ 1	_ 1 1 1 1 _ _ 1 2	3 3 1	_ _ 3 3 3 _ 2	2 2 2 3 2 3 _ 1 _ 2	_ _ _ 1 1 3 _ 1 1 1 1	1 3 3 3 3 2 3 3 1 1 1 3 3 1 1	3 3 3 3
	1 1 1 2 3 1 1 1 1 1 2	4 6 4 9 0	4 8 3 8 7 7 4 5 0 0	7 0 3 3 2 2 2 8	7 3 9 2 2 3 4 7 8 8 9 7 9 4	3 9 5 3 9 2 3 3 3	4 4 3	8 3 3 6 6 7 8	5 8 8 3 8 3 2 5 2 8	8 8 8 4 4 6 2 0 4 5 8	9 6 6 6 3 7 4 4 5 9 9 4 6 0 9	6 7 6 7
	3 4 5 1 2 0 1 2 6 7 0	5 9 1 2 7	4 4 8 3 1 5 3 0 5 6	4 9 0 3 3 4 9 2	2 5 1 5 6 6 2 3 5 8 5 2 9 6	1 6 3 2 8 5 4 0 3	4 5 1	2 4 9 3 5 5 9	2 1 6 7 0 8 9 2 2 7	5 1 3 7 9 4 4 0 8 5 2	3 1 2 7 4 9 8 6 4 4 2 0 6 1 0	8 0 9 1
SPECIES GROUP Q												
Dicerothamnus rhinocerotis	+ 3 . . . . . . r + .	. . . . .	. . . .	a	. . . . r . . + + . r . . .	1 . a + 1 . 4 a +	a . a	+ 1 + + . . a	r a 1 a + . 4 4 . +	. b 1 + + a . 1 a . 1	b b 1 a 1 3 1 a . . b . . 4 .	b + 3 .
Merxmuellera stricta	. . . .	. . . . .	. . . .	. . . . +	 3	. . . . + ...	1 1 +	+ 3 . a . . .	. + . . 3 . + . . a	1 + + + + + . + a . .	r 1 3 + . + . . a b . 4 + . a	+ . + .
Geophytic spp.	. . . + ...	+ . + + +	. . . + ...	. . . . . + . .	. . . . . + + . + + + + + 1	+ . . + . + + . +	. + +	+ + . + + + +	. . + + . + + . + .	. + . + . + + . + . .	. . + ... + + + . + . . +	+ + + .
Oxalis spp.	. . . .	. . . . .	. . . . + . .	. . . .	. . . . + + + + +	+ + + + + + . + +	. + +	+ + + + + + +	+ . . . . + + . + +	+ + + + + . + + . + .	. . + . + . . . + + + . . + .	. . + .
Dimorphotheca cuneata	. . . .	+	. . . . + ...	. . . .	. . . . . + . + + + . + . +	. . . . + ...	. . .	+ + . . + . a	1 + + + . + . . . 1	1 + + + r . . . + + .	. . + ...	+ + . .
Heliophila crithmifolia	. . . .	. . . . .	. . + ...	. . . .	+ . . . . . . + . + . + + .	. . + ...	. . .	. + ...	+ . + ...	+ + . + . . . + . . .	. . . .	. . . .
Zaluzianskya benthamiana	. . . .	. . . . .	+	. . . .	. . . . + .	. + ...	. . .	+ . + . + . +	. . . .	+ + . + . + ...	. . . .	. . . .
Gnidia scabra	. . . .	. . . . .	. . . .	. . . .	. . . .	. . . .	. . .	. . . . a . .	. + . + ...	. + . + ...	. + ...	. . . .
SPECIES GROUP R												
Chrysocoma ciliata	+ . + . + + + + + + +	. . . + .	1 + + . . + + . + +	+ a + + . . . a	. + + ... + . + + + + .	. . + . . + . + .	. . .	. . . + + . +	a . . . + ... +	+ . + + + + . r + . .	1 . + + + . r . 1 . 1 . + r .	. . r .
Asparagus capensis	+ . . . . + + . . + .	. + + + .	. . . . . . + . . .	. . . .	. . . . . . + + . . + . + +	+ . . . . . . r +	. . +	. . . + + . .	+ . + . + . . . r .	r . . . . . . r . . .	. . + . . + r . + . . + r . .	. . . .
Moraea spp.	. . . . + .	1 + . + .	+ + + + + + . + . .	+ + ... +	+ . + ... + + . + . + +	. + ... + + .	. + r	. . + + + + +	. . . . + . . . + +	. . . . + . .	. . + ... + . + + . + . .	+ . + .
Euryops lateriflorus	. . a 1 . . + . + . .	. . . . .	. 1 . + a	. . . .	. . . . . a + 1 1	. . . .	+ + .	1 . . . . . +	+ 1 a + 1 1	. + + 1 1 . . 1 . 1 .	. . . 1 + + . + 1 . . + + 1 1	. . . .
Eriocephalus ericoides	. r . . + 1 . b . . .	1 a 1 . .	+ . . . . . a . . 1	. . . + a b . .	. + . . . + ...	. . . .	. . .	. . a . + . .	. . . .	. + ... + . + 1	. . . . + . 1 . . . . + . . .	+ + . .
Helichrysum obtusum	. . . .	. . . . .	+ + ...	+ . r + ...	. . . . + +	. + ...	. . .	. . . .	. . . .	. . . .	. . . . + ...	. + . .

* Non-diagnostic species are excluded
* HR collection code and numbers are included for future reference, if necessary
* Specimens inadequate for identification yet different from species that could be identified are indicated with a plot number (p…)
* sp. = one species in a taxonomic group
* spp. = more than one species in a taxonomic group. These species, even although they are grouped together, are included in the table since they occur in different species groups. However, they are not used in the descriptions in the text.

Using the distribution of the sample plots, supported by 1:250 000 topocadastral maps, land type maps (Agricultural Research Council 1986a, 1986b, 1995, 1999a, 1999b, 2002, 2003), geology maps (Council for Geoscience 1973, 1983, 1989, 1991, 1997, 2001) and satellite images, the stratified units were assigned to a vegetation unit in the floristic classification. Where two or more subassociations were present in a mapping unit, but it was not possible to map them separately as a result of high spatial diversity, they were mapped as mosaics of specific vegetation types.

Species that were unidentifiable during the field surveys were collected and the herbarium specimens sent to the Compton Herbarium, Kirstenbosch, for identification. The collection code (HR) and numbers of the specimens were kept throughout the process as not all the species, especially within the Mesembryanthemaceae, have yet been positively identified. All voucher specimens are lodged at the Schweickerdt Herbarium (PRU), University of Pretoria, Pretoria. Nomenclature follows that of Germishuizen and Meyer (2003).

RESULTS

The floristic data analysis resulted in two phytosociological tables. The first table (Table 1) contains the predominantly Mountain Renosterveld veld type, as defined by Acocks (1988), or the Escarpment Mountain Renosterveld vegetation type, as defined by Low and Rebelo (1998), and is described in this article. Three associations were identified, which were subdivided into nine subassociations, one of which contains four variants, as set out in the following scheme:

1. *Rosenia oppositifolia* Mountain Renosterveld
   - 1.1 *Eriocephalus microphyllus* – *Rosenia oppositifolia* Mountain Renosterveld
   - 1.2 *Antimima cf. granitica* (HR248) – *Rosenia oppositifolia* Mountain Renosterveld
   - 1.3 *Pentzia incana* – *Rosenia oppositifolia* Mountain Renosterveld
   - 1.4 *Euryops multifidus* – *Rosenia oppositifolia* Mountain Renosterveld
   - 1.5 *Pteronia glomerata* – *Rosenia oppositifolia* Mountain Renosterveld
2. *Dicerothamnus rhinocerotis* Mountain Renosterveld
   - 2.1 *Erodium cicutarium* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
     - 2.1.1 *Galenia africana* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
     - 2.1.2 *Oedera genistifolia* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
     - 2.1.3 *Senecio cakilefolius* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
     - 2.1.4 *Euryops lateriflorus* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
   - 2.2 *Dimorphotheca cuneata* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
   - 2.3 *Merxmuellera stricta* – *Dicerothamnus rhinocerotis* Mountain Renosterveld
3. *Passerina truncata* Mountain Renosterveld

With the exception of unit 1.2, all vegetation units could be mapped (Fig. 2). Three additional mosaics were also mapped:

- the Nieuwoudtville mosaic, consisting of vegetation units 2.1.1, 2.1.4, 2.2 and 5.1 (Van der Merwe *et al.* in press);
- the Soekop mosaic, consisting of units 2.1.3 and 2.2; and the
- Welgemoed mosaic, consisting of units 1.2, 1.3 and 1.5.

A large number of different land types are found in the study area and therefore only the predominant types are listed for each vegetation unit (Agricultural Research Council 1986a, 1986b, 1995, 1999a, 1999b, 2002, 2003). Table 2 summarises the most important features of the various land type symbols that have been used in the text.

Description of plant communities (Table 1, Fig. 2)

The 2004 winter season was extremely dry, resulting in annuals and geophytes being poorly represented in the survey. The following description will therefore focus on the perennial plant species with permanent above-ground organs.

1. Rosenia oppositifolia *Mountain Renosterveld*

This plant association is located at the southern end of the Roggeveld and Nuweveld Mountains as well as in the vicinity of the farms Onderplaas and Droëkloof further north and occurs predominantly on Land Types Fc and Da. Mudstones of the Beaufort Group as well as dolerites are found underlying this association. The association is generally found on level terrain, gentle or moderate sloping ridges with a low rock cover from 0 to 10% or a high rock cover of 70 to 90%. Brown or light brown sandy soils are prevalent in this high-lying plant association. Although a high shrub cover is present, the grass and annual component only sometimes feature, usually with less than 5% cover.

The vegetation of this association is characterised by species group F with a high cover of *Rosenia oppositifolia* and includes species such as *Pteronia glomerata* and *Karroochloa schismoides*. Common species include *Chrysocoma ciliata, Euryops lateriflorus* and *Eriocephalus ericoides* (species group R). This association has been subdivided into five subassociations.

1.1 Eriocephalus microphyllus – Rosenia oppositifolia *Mountain Renosterveld*

This unit is found in the region of the Nuweveld Mountains and covers an area of 106 454 ha (13.2% of the total area covered by Mountain Renosterveld vegetation). Geologically, this subassociation is found on mudstones of the Beaufort Group and predominantly on Land Type Fc, indicating that there is lime present in the entire landscape. This high-lying vegetation occurs at an altitude of > 1400 m above sea level on ridges with level terraces to gentle slopes. The rock cover varies from zero to > 85%, and is usually comprised of stones (> 50–200 mm) and boulders (> 200 mm).

Shrub cover is generally high (mean cover 66%) and is characterised by species such as *Rosenia oppositifolia* and *Pteronia glomerata* (species group F) as well as the diagnostic species *Eriocephalus microphyllus, Pentzia* sp. (HRp317) and *Euryops imbricatus* (species group A). Other shrubs also present include *Chrysocoma ciliata, Euryops lateriflorus* and *Eriocephalus ericoides* of species group R. Grasses are either absent or their cover is limited to less than 5%, while annuals are seldom present. This phenomenon could, however, be a result of the drought conditions experienced during the time in which the surveys were conducted.

1.2 Antimima *cf.* granitica *(HR248)* – Rosenia oppositifolia *Mountain Renosterveld*

Dolerite-derived B horizon soils on Land Types Da and Fc characterise this subassociation that is scattered throughout the Roggeveld Mountains and has not been mapped as a separate unit. The altitude generally ranges from 1200 to 1350 m above sea level. The high-lying ridges with level terrain to moderate slopes on brown to red brown sandy soils are usually covered with stones (> 50–200 mm in size). Shrub cover in this unit is high (with a mean value of 72%), while the herbaceous component is generally < 5%. Almost no grasses contribute to the herbaceous cover.

The shrub layer is characterised by species such as *Rosenia oppositifolia, Pteronia glomerata* (species group F), *Eriocephalus pauperrimus* (species group L) as well as *Asparagus capensis* and *Eriocephalus ericoides* (species group R). Diagnostic perennial species include *Antimima* cf. *granitica* (HR248) and *Pelargonium* sp. (species group B).

TABLE 2
Land type symbols and their meaning within the text (Du Plessis 1987)

LAND TYPE	MEANING OF SYMBOL
D	Prismacutanic and/or pedocutanic diagnostic horizons dominate. After subtracting exposed rock, stones or boulders, more than half of the remaining land must consist of duplex soils.
Da	Refers to land where duplex soils with red B horizons comprise more than half of the area covered by duplex soils.
Db	Refers to land where duplex soils with non-red B horizons comprise more than half of the area covered by duplex soils.
F	Glenrosa and/or Mispah forms (though other soils may occur). The group accommodates pedologically young landscapes that are not predominantly rock, alluvial or aeolian and in which the dominant soil-forming processes have been rock weathering, the formation of orthic topsoil horizons and clay illuviation.
Fa	Refers to land in which lime is rare or absent from the entire landscape.
Fb	Indicates land where lime occurs regularly (though possibly in small quantities) in one or more valley bottom soils.
Fc	Refers to land where lime is generally present throughout the entire landscape.
I	Miscellaneous land classes.
Ia	Refers to land types with a soil pattern difficult to accommodate elsewhere, at least 60% of which comprises pedologically youthful, deep (more than 1 m to underlying rock) unconsolidated deposits.
Ib	Indicates land types with exposed rock (country rock, stones or boulders) covering 60–80% of the area.

1.3 Pentzia incana – Rosenia oppositifolia *Mountain Renosterveld*

Subassociation 1.3 is located around Sutherland and east of Sutherland on mudstones of the Beaufort Group. It also occurs further south in combination with subassociations 1.2 and 1.5 in the vicinity of the farm Welgemoed, at the foot of the Komsberg Mountains. This subassociation, excluding the mosaic unit, covers an area of 44 499 ha (5.5% of the total area covered by Mountain Renosterveld vegetation). Land types include Fc and Da and altitude ranges from approximately 1300–1500 m above sea level. The high-lying ridges on level terrain to moderate slopes are usually covered with brown or light brown sandy soils.

The high shrub cover is attributed to species such as *Pentzia incana* (species group D), *Rosenia oppositifolia* and *Pteronia glomerata* (species group F) as well as *Chrysocoma ciliata* and *Euryops lateriflorus* (species group R). This subassociation shows local variations resulting from a low constancy of such species as *Stipagrostis namaquensis, Braunsia* sp. and *Chrysanthemoides incana* (species group C). When the perennial shrub cover is high, species in group C do not occur, however, when the shrub cover is lower, species in group C can dominate. Generally, the cover of the grass and non-grassy herbaceous layer is limited, except in the case of the grass species *Stipagrostis namaquensis* that occurred in a single relevé sampled in a drainage line.

1.4 Euryops multifidus – Rosenia oppositifolia *Mountain Renosterveld*

Located just north of the Komsberg, subassociation 1.4 is found predominantly on mudstones of the Beaufort Group and covers an area of 106 189 ha (13.1% of the total area covered by Mountain Renosterveld vegetation). Land types present include Fc and Da, with, occasionally, deep deposits of the Ia land type. This subassociation is found at an altitude of between 1400–1500 m above sea level. The level to gently sloped ridges and light brown soils in this subassociation support a high shrub canopy cover of between 60 and 90%.

The diagnostic species *Euryops multifidus* and *Phyllobolus tenuiflorus* (species group E), together with *Rosenia oppositifolia* (species group F), *Chrysocoma ciliata* and *Eriocephalus ericoides* (species group R) characterise this subassociation. The cover of the herbaceous component (including grasses) is usually limited to < 5%, which could be the result of the drought conditions in the year of survey.

1.5 Pteronia glomerata – Rosenia oppositifolia *Mountain Renosterveld*

Geologically, this subassociation occurs predominantly on mudstones of the Beaufort Group and is similar to subassociations 1.3 and 1.4. It is found on Land Types Fc, Da and Db on the southwestern extreme of the Roggeveld Mountains. It also occurs in a mosaic with subassociations 1.2 and 1.3 in the vicinity of the farm Welgemoed at the foot of the Komsberg Mountains. This subassociation covers an area of 69 233 ha (8.6% of the total area of the Mountain Renosterveld vegetation), excluding the mosaic unit. This high-lying (1200–1600m above sea level) subassociation is found on level terrain and gentle slopes on a range of different rock sizes, varying from gravel (< 10 mm) to boulders (> 200 mm). The soil colour also varies substantially from light brown to brown to red brown.

Shrub cover is generally high (> 60%) and the grassy component has a higher presence and cover compared with the previous subassociations. Likewise, annual species are present in all relevés, with their cover generally being higher than in the previous subassociations. This was probably the case due to the local rain showers received in the area during the year of survey.

No diagnostic species group separates this subassociation. The most prominent species present include *Rosenia oppositifolia, Pteronia glomerata* (species group F), *Erodium cicutarium* (species group L) and *Euryops lateriflorus* (species group R). The grass component is represented by *Karroochloa schismoides* (species group F) and *Bromus pectinatus* (species group L) with, in one relevé, a high cover of *Merxmuellera stricta* (species group Q). *Erodium cicutarium* and *Felicia australis* (species group L) as well as *Heliophila crithmifolia* (species group Q) represent some of the annual species.

2. Dicerothamnus rhinocerotis *Mountain Renosterveld*

This plant association is located in the Roggeveld, Klein Roggeveld, Koedoesberg and Komsberg Mountains and has been further subdivided into three subassociations. Generally it can be found on the mudstones of the Beaufort Group or the shales of the Ecca Group on Land Types Da, Fb, Fc, Ib and Fa. The level terrain and gentle slopes of subassociations 2.1 and 2.2 as well as the gentle to moderate slopes of subassociation 2.3 are usually comprised of light brown or brown sandy soils. The shrub cover is high (50–95%) and a grass and annual component are generally present throughout the association. The very high cover of *Dicerothamnus rhinocerotis, Merxmuellera stricta* and *Dimorphotheca cuneata* (species group Q) distinguishes this association from the *Rosenia oppositifolia* Mountain Renosterveld (association 1).

2.1 Erodium cicutarium – Dicerothamnus rhinocerotis *Mountain Renosterveld*

Subassociation 2.1 generally occurs on mudstones of the Beaufort Group in the Roggeveld, Klein Roggeveld and Komsberg Mountains on Land Types Da, Fb, Fc and Ib, and excluding mosaic units, covers an area of 213 410 ha (26.4% of the total area of Mountain Renosterveld vegetation). The altitude varies from 600 to about 1600 m above sea level and the landscape is gently undulating. Soils are light brown sandy soils with a varying rock cover consisting predominantly of boulders (> 200 mm). The shrub cover is generally high (50–95%), with grass and other herbaceous species consistently occurring across all the surveyed sites.

Prominent perennial species in this subassociation include *Dicerothamnus rhinocerotis, Merxmuellera stricta* (species group Q) as well as *Euryops lateriflorus* (species group R). Common annual species occurring in the unit include *Erodium cicutarium, Bromus pectinatus, Senecio cakilefolius* and *Felicia australis* (species group L). This subassociation has been subdivided into four variants.

2.1.1 Galenia africana – Dicerothamnus rhinocerotis *Mountain Renosterveld*

This variant is floristically very diverse and occurs on the mudstones of the Beaufort Group and the shales of the Ecca Group. It is located in the region of the farms M'Vera and Vondelingsfontein at the northern extreme of the Roggeveld Mountains and Kareebos and Rooiwal west of the Klein Roggeveld Mountains. It also forms a mosaic in combination with variant 2.1.4, subassociation 2.2, and subassociation 5.1 (Van der Merwe *et al*. in press) in the Nieuwoudtville area. Excluding mosaics, this variant covers an area of 25 369 ha (3.1% of the total area of the Mountain Renosterveld vegetation). Various land types are present, predominantly of the Da and Fb types. The altitude is notably lower than for the other vegetation units, and varies from 600 to 1300 m above sea level. This variant occurs on undulating terrain. The light brown to brown coloured sandy soils are usually not covered by much rock, however, boulders (> 200 mm) do occur locally.

A high shrub cover results primarily from the presence of *Dicerothamnus rhinocerotis* (species group Q) as well as the diagnostic species *Galenia africana* (species group G). Various annual species, such as *Cotula nudicaulis* and *Polycarena aurea* (species group K) and *Erodium cicutarium, Senecio cakilefolius, Felicia australis* and *Leysera tenella* (species group L), are present. The annual grass *Bromus pectinatus* (species group L) contributes to the low cover of the grass component in the variant. The absence of species group J in this variant differentiates it from variant 2.1.2. The presence of *Galenia africana* and various annuals indicates the increased disturbance that has taken place in this variant in the past.

2.1.2. Oedera genistifolia – Dicerothamnus rhinocerotis *Mountain Renosterveld*

Variant 2.1.2 occurs on the mudstones of the Beaufort Group in the Klein Roggeveld Mountains, and covers an area of 46 797 ha (5.8% of the total area of the Mountain Renosterveld vegetation). It is found at an altitude between 1000 and 1300 m above sea level on level terrain to gentle slopes. The light brown sandy soils of this variant are covered with gravel (< 10 mm), small stones (> 10–50 mm) and boulders (> 200 mm), which are typical of Land Type Ib.

The high shrub cover (more than 70%) is primarily a result of the presence of *Dicerothamnus rhinocerotis* (species group Q) as well as *Oedera genistifolia* (species group H) and *Euryops lateriflorus* (species group R). *Merxmuellera stricta* (species group Q), a perennial grass, dominates the grass component of this variant. Annual species are consistently present, however, their cover is low due to the drought conditions in the year in which the surveys were conducted.

The presence of species groups G and J distinguishes variant 2.1.1 from variant 2.1.2, whereas the absence of species group I distinguishes variant 2.1.2 from variant 2.1.3.

2.1.3 Senecio cakilefolius – Dicerothamnus rhinocerotis *Mountain Renosterveld*

This variant, excluding mosaics, covers an area of 13 654 ha (1.7% of the total area covered by Mountain Renosterveld vegetation) and is found on mudstones of the Beaufort Group and shales of the Ecca Group in the region of the farms Botuin, Blomfontein and De Hoop in the Roggeveld Mountains, predominantly on Land Types Da and Fc. In combination with subassociation 2.2 in the region of the farm Soekop, it is found in a mosaic vegetation unit. It occurs at altitudes higher than 1200 m above sea level on level terrain to gently sloping landscapes with light brown to brown coloured soils. Rocks are mostly absent, although boulders do occasionally occur.

Shrub cover varies considerably, with the main contributors being *Dicerothamnus rhinocerotis* and *Dimorphotheca cuneata* (species group Q) as well as *Chrysocoma ciliata, Asparagus capensis, Euryops lateriflorus* and *Eriocephalus ericoides* (species group R). The grass component varies considerably depending on the presence or absence of the perennial grass *Merxmuellera stricta* (species group Q). The most prominent annual species include *Cromidon varicalyx* and *Plantago cafra* (species group I), *Cotula nudicaulis* and *Polycarena aurea* (species group K) as well as *Erodium cicutarium* and *Senecio cakilefolius* (species group L). The cover of this component is highly variable, depending on the amount of rainfall received locally during the season.

Variant 2.1.3 has a close affinity with variant 2.1.2 due to their sharing species group J, however, they differ as a result of the presence of species group I that is confined to variant 2.1.3.

2.1.4 Euryops lateriflorus – Dicerothamnus rhinocerotis *Mountain Renosterveld*

Variant 2.1.4 occurs on Land Types Da and Fc in the Komsberg Mountains and southwest of the Basterberg Mountains and covers an area of 127 590 ha (15.8% of the total Mountain Renosterveld vegetation), excluding the mosaic vegetation unit. The mosaic is found in combination with variant 2.1.1, subassociation 2.2, and subassociation 5.1 in the Nieuwoudtville area (Van der Merwe *et al*. in press). This variant is generally found at high altitudes on level terrain to gentle slopes. The light brown soils are derived from mudstones of the Beaufort Group. Rocks are generally absent, although boulders (> 200 mm) may occur locally.

The high shrub cover is due primarily to *Dicerothamnus rhinocerotis* and *Dimorphotheca cuneata* (species group Q) as well as *Chrysocoma ciliata, Asparagus capensis* and *Euryops lateriflorus* (species group R). The grass cover is generally low, except where *Merxmuellera stricta* (species group Q) dominates. The cover of the annual component is generally low.

Two forms of variant 2.1.4 occur as a result of the presence or absence of species group K, which mainly consists of annual species. Such species might have occurred throughout the region in a normal rainfall year.

2.2 Dimorphotheca cuneata – Dicerothamnus rhinocerotis *Mountain Renosterveld*

This high-lying subassociation can be found in the Keiskie Mountains, at the northern extreme of the Roggeveld Mountains, and excluding mosaics, covers an area of 20 196 ha (2.5% of the total area covered by Mountain Renosterveld vegetation). It also occurs in combination with variant 2.1.3 in the region of the farm Soekop and additionally, it forms a mosaic in the Nieuwoudtville area in combination with variants 2.1.1 and 2.1.4 and subassociation 5.1 (Van der Merwe *et al*. in press). The land types present include Da, Fa and Fc and the altitude varies from 700–1400 m above sea level. The undulating terrain is usually covered by a high percentage of boulders (>200 mm). The light brown to brown coloured sandy soils are derived from Ecca shales.

The shrub cover varies greatly (20–80%), whereas the cover of both the grass and annual species remains low. Diagnostic species include *Hermannia cuneifolia, Helichrysum hamulosum* and *Oedera sedifolia* (species group M). *Felicia filifolia, Polygala scabra* and *Ehrharta melicoides* (species group N) are common to both subassociation 2.2 and 2.3, although subassociation 2.3 lacks species group M. The dominant species is *Dicerothamnus rhinocerotis* and other prominent species include *Merxmuellera stricta, Dimorphotheca cuneata* (species group Q) and *Chrysocoma ciliata, Euryops lateriflorus* and *Eriocephalus ericoides* (species group R).

2.3 Merxmuellera stricta – Dicerothamnus rhinocerotis *Mountain Renosterveld*

This subassociation is located in the region of the farms Piet se Nuplaas, Droëberg, Nuwepos, Soekop and Vaalhoek in the Roggeveld Mountains and includes the higher-lying vegetation of the Koedoesberg and Basterberg Mountains. It covers an area of 230 838 ha (28.5% of the total Mountain Renosterveld vegetation). Geologically, it occurs on the mudstones of the Beaufort Group, the shales of the Ecca Group and even, occasionally, on dolerites occurring within the mudstones and shales. Land types include Fc, Da and occasionally Ib at an altitude of 900 to 1600 m above sea level. The high-lying gentle to moderately steep slopes are usually covered with stones (> 50–200 mm) or boulders (> 200 mm). The soils are generally brown sandy soils. Shrub and grass cover vary considerably, whereas the annual component is either absent or covers less than 1% of the area.

Three variations are distinguished in this subassociation. The first variation is differentiated by the presence of species group N, which is shared with subassociation 2.2. The second variation is characterised by the perennial shrub *Pteronia glauca* (species group O), whereas the third variation does not include species group N or O. In all of these variations *Dicerothamnus rhinocerotis, Merxmuellera stricta* (species group Q) and *Chrysocoma ciliata* (species group R) dominate with a very high cover (60–95%). Other species present include *Asparagus capensis, Euryops lateriflorus* and *Eriocephalus ericoides* (species group R).

3. Passerina truncata *Mountain Renosterveld*

The third plant association, which is found exclusively on dolerites on Land Type Ia, occurs at high altitudes (approximately 1500 m above sea level and higher) on the Hantam Mountain as well as at various locations scattered throughout high-lying areas in the Roggeveld Mountains. It covers an approximate area of 17 982 ha (2.2% of the total area of the Mountain Renosterveld vegetation). The high-lying terraces and plateaux consist of red brown sandy clay soils, with the rock cover varying from 20– 80%. The shrub cover is very high, except where a high cover of exposed rocks occurs. Compared to the high shrub cover, the cover of the grass and annual species is generally very low.

This association is differentiated by species group P, which includes diagnostic species such as *Passerina truncata* and *Othonna auriculifolia*. Other common species present include *Dicerothamnus rhinocerotis, Merxmuellera stricta* and *Dimorphotheca cuneata* (species group Q) and *Eriocephalus ericoides* (species group R).

DISCUSSION

According to Rutherford and Westfall (1986), Low and Rebelo (1998) and Mucina *et al*. (2005) the vegetation of the subregion, as discussed in the present article, is situated predominantly in the Fynbos Biome. However, Diels (1909 in Van Wyk & Smith 2001) concurred with Marloth (1908) that the region is floristically more closely related to the Succulent Karoo than to the Cape Floristic Region. This area was also included in the SKEP initiative and not in the CAPE (Cape Action Plan for the Environment) initiative.

The clear split between Table 1 and the table presented on the Succulent Karoo related vegetation (Van der Merwe *et al*. in press) reveals that most of the species in species group F (Table 1) are found in the general species group in the upper portion of the Succulent Karoo table, whereas most of the species in species group Q (Table 1) are not found in the Succulent Karoo table. Such a finding indicates association 1's affinity with the Succulent Karoo Biome vegetation of the Escarpment Karoo, Roggeveld Karoo and Hantam Karoo, as described in Van der Merwe *et al*. (in press). The true Renosterveld of associations 2 and 3, as defined by species group Q (Table 1), is, however, lacking from the Succulent Karoo table and belongs to the Fynbos Biome related vegetation. This Mountain Renosterveld is probably distinct from other Renosterveld vegetation types in any case and could be studied in the future.

Grazing and cropping are the main land-uses in the Mountain Renosterveld. Sustainable land management tries to minimise the risk of veld degradation or species extinction by managing populations of plants and animals within an area to ensure that they can continue to reproduce and function normally, even after stressful conditions such as drought (Esler *et al*. 2006). Although damage can happen 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.

Inadequate farming practices, resulting from a severe lack of infrastructure, especially fencing, pose a serious threat to the vegetation. Farms in the region yield a low income as a result of the harsh environmental conditions and the unpalatable grazing caused by the dominance of *Dicerothamnus rhinocerotis*. Because of the low monetary value of the land and the high cost of infrastructure it is not financially viable for a farmer to invest too much in infrastructure, as the ability to recover such costs is limited. Although the farmers are generally willing to implement improved veld management and infrastructure development, their financial means hinder their doing so.

According to Low and Rebelo (1996) the degree of transformation in the Escarpment Mountain Renosterveld, which closely corresponds to the Mountain Renosterveld as described in the current article, is unknown. However, many large tracts of land cultivated in the past are still cultivated due to the higher rainfall in the region compared with that experienced in the surrounding areas of the Hantam and Tanqua Karoo.

Invasive species in the vegetation type described are predominantly annuals that were brought into the region with fodder from other parts of the world, and of which many have been naturalised over the centuries. The isolated individuals of *Prosopis* species present are usually limited to highly disturbed areas alongside water points and feeding areas. The unpalatable renosterbos, *Dicerothamnus rhinocerotis*, which dominates large sections of the Mountain Renosterveld is considered an encroacher by most farmers with its dominance being blamed on centuries of incorrect management practices in the region. Also, overgrazing is thought to have substantially reduced the grassy component in the vegetation.

The protected area network for the Mountain Renosterveld is severely under-represented. Two local municipal nature reserves, namely the Nieuwoudtville Wildflower Reserve (115 ha) and the Akkerendam Nature Reserve (230 ha), fall within the region. A natural heritage site at Banksgate, near Sutherland, protects the rare sterboom, *Cliffortia arborea*. The Tanqua National Park has substantially expanded during the last 3–5 years, with the latest land acquisitions including a section of Mountain Renosterveld vegetation.

In conclusion, the aims of the project described in this article were to classify and describe the various vegetation units present in the Mountain Renosterveld part of the Hantam-Tanqua-Roggeveld subregion in terms of their species composition, environmental parameters and relationships to one another as well as to map their geographical distribution. Such an inventory of vegetation types should aid future planning, resource management and biodiversity conservation, which should encourage sustainable land use practices, reducing the negative impact on the environment.

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