



Landscape unit concept enabling management of a large conservation area: A case study of Tankwa Karoo National Park, South Africa



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ABSTRACT

Effective management of conservation areas is critical to ensure the adequate protection of the natural resources. The landscape unit concept can be used as a tool in conservation management as a spatial planning unit. Landscape units are areas with a specific set of biotic and abiotic characteristics that can be classified, mapped and described. These units then form the basis on which a conservation area can be planned and managed.

A vegetation map was compiled for Tankwa Karoo National Park (TKNP), when it was originally proclaimed as 27,064 ha. The park has subsequently expanded to more than 145,000 ha and is still growing. A need has been identified by park management as well as scientists working in the park for an effective framework for managing the park, and for conducting scientific research. The latest vegetation map of South Africa is at too coarse a scale for park planning. The purpose of the current study was to classify, map and describe the current extent of the TKNP to fulfill this need.

Two primary zones were identified for the park: the Tanqua Plains Zone and the Roggeveld Mountain Zone. These two zones were further subdivided into landscape units using land type units and a combination of field work and satellite imagery. Furthermore, the landscape units were related to habitats and/or vegetation types as identified during previous studies in the area. Environmental parameters for each landscape unit were summarised in order to provide additional information for consideration in management and research decisions. Thirteen landscape units were identified in the current TKNP and are mapped and described.

Delineation of the TKNP into landscape units will aid in the effective conservation management of this large national park as well as facilitate scientific research and monitoring.

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1. Introduction

Tankwa Karoo National Park (TKNP) was proclaimed in 1986 at a size of 27,064 ha (Rubin, 1998), but has since expanded rapidly to more than 145,000 ha (Park Management Plan, 2014). The TKNP mission statement is to 'endeavour towards the conservation of the TKNP through the integrated, effective and adaptive management of ecological systems, cultural heritage, and responsible tourism. As a regional partner, parks develop and maintain community participation and empowerment' (Park Management Plan, 2014). Five objectives are listed in order to attain the above-mentioned mission. One of

these objectives is 'effective park management: to manage processes and resources adequately to enable the TKNP to achieve all its objectives' (Park Management Plan, 2014).

A sound understanding of the larger ecosystem functioning of the TKNP will contribute considerably to the effective management of its resources and processes. One of the tools that can be used to assist in effective management is a landscape unit classification. The necessity of an ecological landscape unit classification for protected area management, the description thereof and mapping of an area has already been established (Bredenkamp and Theron, 1978; Van Rooyen et al., 2008; Chytrý et al., 2011; De Ca'ceres and Wiser, 2012; Jürgens et al., 2012; Luther-Mosebach et al., 2012). Although developed at a fine scale, a landscape unit can be used at different scales and by different users, for example: (a) to inform conservation and management authorities by contributing important baseline information for regional assessments, conservation planning processes (Jürgens et al., 2012) and decision making (Chytrý et al., 2011); (b) for defining vegetation or

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ecosystem type and a framework for understanding differences among them (Chytrý et al., 2011); and (c) to provide valuable information for farmers and other land users (Luther-Mosebach et al., 2012). For the park management plan document, as well as for the day-to-day management of the national park, there is a need for an ecologically sound classification in the absence of a more comprehensive phytosociological analysis (Brown et al., 2013). The identification and description of landscape units within the conservation area will assist in addressing this demand.

Previous landscape scale studies in the TKNP focused on the physical environment and major plant communities in the then proclaimed area of the TKNP. There are two vegetation studies, the detailed vegetation classification of Rubin (1998) for the initial Park, and a more recent unpublished study by Kraaij and Bezuidenhout (2005) on a larger section of the park which identified broad vegetation units based on land types and soils. Additionally, in 2008, a vegetation map of the Hantam, Tanqua and Roggeveld areas was compiled at a much larger scale in which vegetation units were classified, described and mapped (Van der Merwe et al., 2008a, 2008b). Information gained from the Rubin (1998) study has been used to guide park management and research. Rubin (1998) highlights, for example, endemic species and succulent species of conservation significance important for conservation protection efforts, degraded areas and areas susceptible to erosion important to monitoring and rehabilitation exercises by management whereas, the threat of *Prosopis* spreading within the park is listed as a serious concern and has led to the initiation of eradication efforts. The issues raised in her study have been used by park management and researchers to guide their decisions and actions. However, the more than 5-fold expansion of the park has left significant gaps making park management and monitoring in this expanded area difficult.

None of the studies previously conducted cover the entire area of the expanded TKNP, and each only provides information at a specific scale. The detailed map of Rubin (1998) only covers the original 27,064 ha of the TKNP whereas the South African national vegetation map (Mucina and Rutherford, 2006) and the regional map (Van der Merwe et al., 2008a, 2008b) have limited fine scale detail.

The units identified in the current study were termed “landscape units”, adapted from the definition of Gertenbach (1983) where “A landscape is an area with a specific geomorphology, macroclimate, soil and vegetation pattern, and associated fauna”. However, our landscape unit is a smaller scale entity than that of the Kruger National Park defined landscape (Gertenbach, 1983). Our landscape unit also has a distinctive geomorphology, soil, plant species composition and vegetation structure associated with it, but additionally, it incorporates land types (Land Type Survey Staff, 2010, 2012) and refinements thereof for increased detail (*sensu* Bezuidenhout, 1993). The insights gained from the previous botanical studies (Rubin, 1998; Kraaij and Bezuidenhout, 2005; Van der Merwe et al., 2008a, 2008b) were used to produce a fine scale composite map of the larger area. Such a description and map can aid in conservation and management activities, such as the selection of sites for vegetation monitoring (Van Rooyen et al., 2008) and serve as a basis to determine wildlife-habitat relationships (Ferreira et al., 2013), as well as provide a detailed map for the park management plan, and for the day-to-day management of the national park. Tourist management can also be informed by landscape level findings (Van Rooyen et al., 2008).

The main aim of this study was to classify, map and describe the landscape units of the TKNP, which can be used as the basis for park planning, management, and research.

2. Study area

2.1. Location and size

The TKNP straddles the Northern and Western Cape provinces in the northern section of the Tanqua Karoo basin, ascending the Roggeveld

Escarpment into the Roggeveld Mountains (Fig. 1). The park currently covers 148,568 ha, 138,570 ha of which have been declared (Park Management Plan, 2014).

2.2. Geology

Geologically, the study area is dominated by the Dwyka and Ecca Groups (Rubidge and Hancox, 1999). Tillite, diamictite and subsidiary shale of the Dwyka Group are present, with shale and siltstone of the Tierberg, Prince Albert and Whitehill Formations representing the Ecca Group. Mudstone, siltstone and sandstone of the Beaufort Group as well as alluvium and colluvium are found in places. Igneous rock intrusions of dolerite occur throughout the area, and are easily recognisable as very hard dark grey to nearly black rocks (Van Wyk and Smith, 2001).

2.3. Physiography, soil, land types and vegetation

From west to east, the physiography of the study area varies from flat to gently undulating plains, with a large flat-topped inselberg (Elandsberg) and smaller inselbergs, to the slopes of the Roggeveld Escarpment and sections of the undulating Roggeveld Plateau (Fig. 2). The Tankwa and Renoster Rivers traverse the park, eventually flowing into the Atlantic Ocean. Altitude varies from about 300 m above sea level (asl) on the plains in the west to 1200 m asl in the Roggeveld Mountains in the east.

Tanqua Karoo soils are shallow and rocky (lithosols), often including a desert pavement and deep unconsolidated deposits in the alluvial parts (Francis et al., 2007). The mountains of the Great Escarpment are covered by shallow stony (lithosol) soils and duplex soils are found in the occasional lowlands (Francis et al., 2007).

An array of land types (Land Type Survey Staff, 2010, 2012) are found in the study area, including Da, Fc, Ia and Ib. Land Type Da refers to land where duplex soils with red B horizons comprise more than half of the area covered by the duplex soils. The Fc land type refers to land where lime is generally present throughout the entire landscape. Land Type 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. The Land Type Ib indicates land types with exposed rock, stones or boulder outcrops covering 60–80% of the area (Land Type Survey Staff, 2010, 2012).

The TKNP is situated mostly within the Succulent Karoo Biome, but includes portions of the Fynbos Biome at higher elevations (Rutherford and Westfall, 1986; Mucina and Rutherford, 2006; Van der Merwe et al., 2008a, 2008b). In the Succulent Karoo Biome, succulents and non-succulent chamaephytes, geophytes and therophytes are unusually common relative to trees and grasses (Milton et al., 1997). The Succulent Karoo has a remarkable dominance and unique diversity of short to medium-lived leaf-succulent shrubs as well as high numbers of geophytic flora (Esler et al., 1999a; Jürgens et al., 1999). Indeed, the high diversity of dwarf leaf-succulent shrubs is the biome's most distinctive character (Mucina et al., 2006) with most of the species concentrated in two families (Mesembryanthemaceae and Aizoaceae). A feature of the Succulent Karoo Biome are the spring floral displays of winter-growing annuals (Milton et al., 1997), that are seasonally relatively predictable and often extravagant (Cowling et al., 1999; Van Rooyen, 1999).

While fynbos is the predominant vegetation type in the Fynbos Biome (Cowling et al., 1997), the biome actually comprises three quite different, naturally fragmented vegetation types (fynbos, renosterveld and strandveld), (Mucina and Rutherford, 2006). These vegetation types occur in the winter and aseasonal rainfall areas, and are mostly dominated by small-leaved, evergreen shrubs. The regeneration of many species, particularly within fynbos and renosterveld vegetation types are strongly dependent on fire

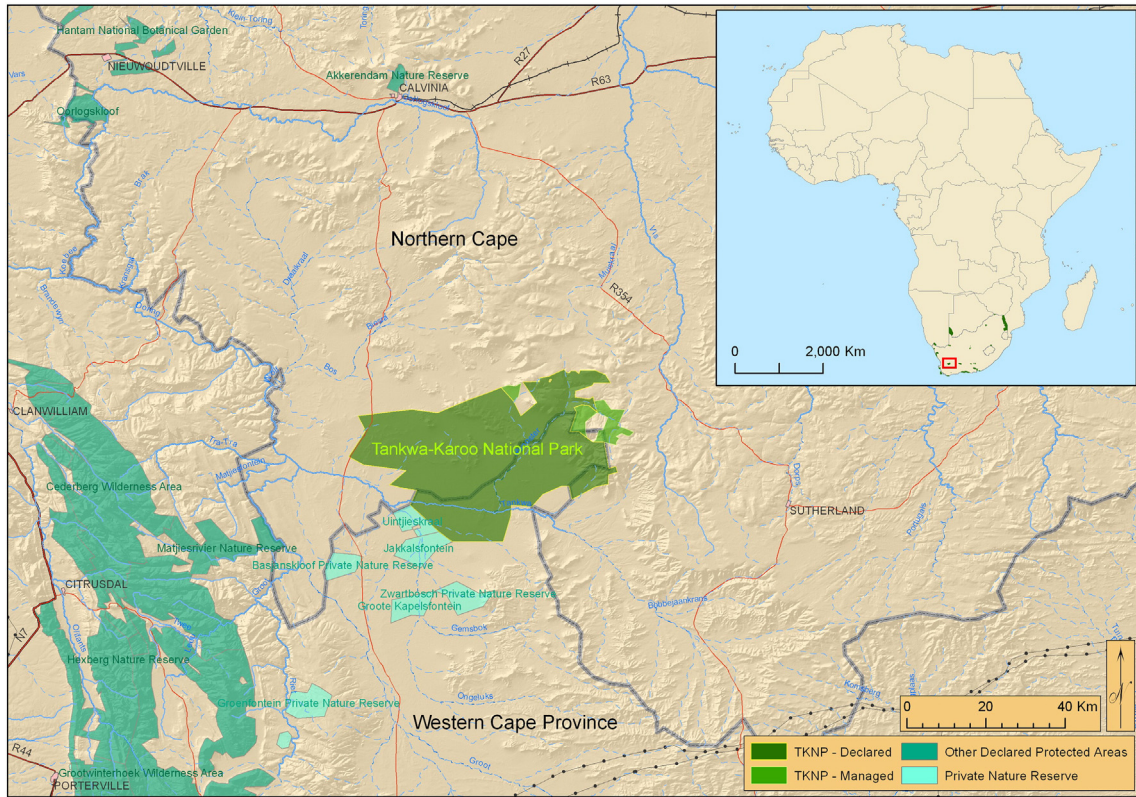


Fig. 1. Location of the Tankwa Karoo National Park.

(Rebello et al., 2006). Renosterveld is found in the TKNP on the Roggeveld Escarpment and is an evergreen, fire-prone vegetation dominated by small-leaved, asteraceous shrubs (especially *Dicerthamnus*

rhinocerotis, *renosterbos*), and has an understory of Poaceae and geophytes (Moll et al., 1984; Cowling et al., 1997). Geophytes are as prevalent in the Fynbos Biome as they are in the Succulent Karoo Biome in

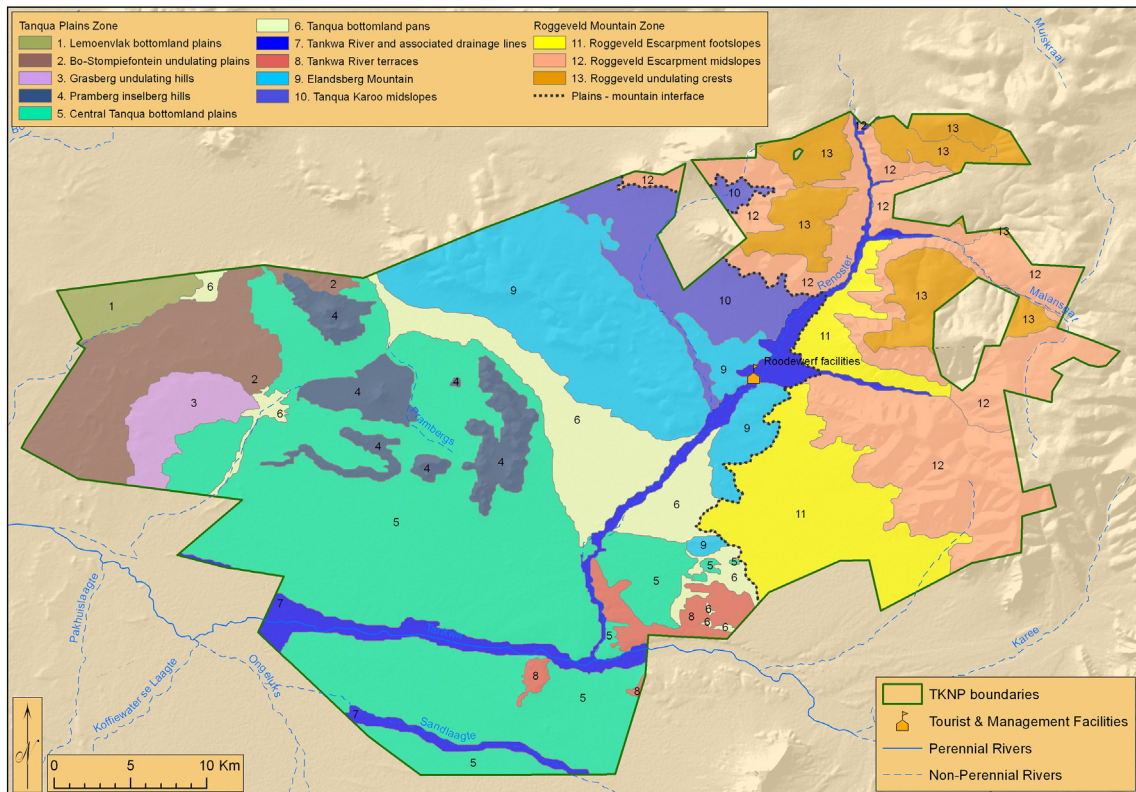


Fig. 2. Landscape units identified for the Tankwa Karoo National Park.

terms of abundance and diversity (Snijman and Perry, 1987; Esler et al., 1999b; Mucina et al., 2006).

2.4. Climate

Climate data are sourced from the closest two towns with regular weather recordings, Calvinia and Sutherland (Fig. 1). Calvinia is located at the base of the Hantamsberg with an elevation of 990 m asl, while Sutherland is higher, located on the Roggeveld Plateau at ca. 1465 m asl. Additionally, rainfall and temperature data have been collected for approximately 7 years at the TKNP office, situated at Roodewerf (± 495 m asl), (Fig. 2). The different characteristics of the two physiographic areas of the TKNP, the Tanqua Karoo Basin and the Roggeveld Escarpment and Mountains, have a strong influence on the climate.

Rainfall across the region ranges from 50 to 300 mm a year, with a mean of 228 mm per year measured at Calvinia, and 266 mm per year measured at Sutherland (Weather Bureau, 1998). Maximum mean annual rainfall of 472 mm for Calvinia and 467 mm for Sutherland were recorded in 1976 (Weather Bureau, 1998). The majority of the rainfall events occur in winter; however, a few summer thunderstorms do contribute to the total annual rainfall. The mean annual precipitation for the Tanqua Karoo Plains ranges from <100 mm to 200 mm, with an annual average of 167 mm measured at Roodewerf (1 April 2006 to 30 September 2013, unpl. park data). The higher Roggeveld Mountains receive between 200 mm and 400 mm annually (Schulze, 1997). Snowfalls usually occur on the high-lying areas and over a 20-year period a mean of one snow day per year was recorded for Calvinia. Over a 24-year period, a mean of six snow days per year was recorded for Sutherland (Weather Bureau, 1998).

In Calvinia, temperatures in January and February reach a mean daily maximum of 30.8 °C; January is also the warmest month in Sutherland with a mean daily maximum of 27.1 °C (Weather Bureau, 1998). At Roodewerf, a mean annual maximum temperature of 38.35 °C for January was recorded over a 7 year period (unpl. park data). The coldest months are June and July, with a mean daily minimum of 4.4 °C in Calvinia and -1.2 °C in Sutherland (Weather Bureau, 1998). Over a 7 year period, a mean minimum of 6.12 °C was recorded for the month of June at Roodewerf (unpl. park data).

3. Materials and methods

The TKNP study area was initially divided into two primary zones on the basis of physiography, i.e. the Tanqua Plains Zone and the Roggeveld Mountain Zone. Potential landscape units were identified using labelled wireframe land type units (Land Type Survey Staff, 2010, 2012) plotted on SPOT5 imagery (years 2006, 2011) in GIS (ESRI 2013) and printed at A0. The hardcopy map was then interrogated and refinements were made to derive finer scale landscape units based on the terrain units (Bezuidenhout, 1993), identifying local physiographic features (e.g. flats, plains, talus slopes, scarps, crests) from the satellite image of the study area (Land Type Survey Staff, 2010, 2012).

In order to verify the validity of the refined landscape units, these units were related to habitat or vegetation types identified during previous studies in the area (Rubin, 1998; Kraaij and Bezuidenhout, 2005; Van der Merwe et al., 2008a, 2008b). The studies by Rubin (1998) and Van der Merwe et al. (2008a, 2008b) classified the vegetation following Braun Blanquet procedures (Wenger, 1974). These surveys noted each species present in a plot of 10 m \times 10 m (20 m \times 20 m in denuded areas) and a cover abundance value was assigned to each species according to the Braun Blanquet cover abundance scale (Rubin, 1998; Van der Merwe et al., 2008a, 2008b). Standard Braun Blanquet procedures were used to produce the resulting phytosociological table(s) which were then interpreted using additional information including environmental parameters such as land types and soils (Land Type Survey Staff, 2010, 2012). Ninety-three of the 98 survey plots of

the Rubin (1998) study and 19 plots of the Van der Merwe et al. (2008a, 2008b) study are located within the current extent of the TKNP.

Environmental parameters for each landscape unit were sourced. We used SRTM90 (Jarvis et al., 2008) elevation data for calculating the average elevation of each land use unit. Topographic heterogeneity was calculated as standard deviation of elevation in a 3 \times 3 square roving window block on SRTM90 data (Jarvis et al., 2008). We sourced most climatic data from the South African atlas of agrohydrology and climatology (Schulze, 1997). The above-mentioned parameters are useful to managers and scientists working in the park as they provide background information on the environment. The altitudinal differences between landscape units such as Landscape unit 11 and Landscape unit 13, inform management plans and decisions as altitude may limit certain actions, for example, travelling from the bottom of the Roggeveld Escarpment to the top will have time implications. Whereas, knowledge of the similarities and differences between landscape units aids in the interpretation of findings by scientists in the field.

The finer landscape units were then digitised to a shapefile. Finally, these refined mapped landscape units were verified by visiting the park. Each of the landscape units were inspected to confirm boundaries and vegetation associations.

4. Results and discussion

Two primary physiographic zones were identified, one for the plains landscape units (Tanqua Plains Zone) and one for the escarpment and plateau landscape units (Roggeveld Mountain Zone), (Fig. 2). Thirteen landscape units were identified for the Tankwa Karoo National Park (Table 1, Fig. 2) across the primary two zones; ten in the Tanqua Plains Zone and three in the Roggeveld Mountain Zone. The most recent South African national vegetation map (Mucina and Rutherford, 2006) identifies four vegetation units for the delineated Roggeveld Mountain Zone and only two for the Tanqua Plains Zone, one of which is shared with the Roggeveld Mountain Zone.

The landscape units identified in this study rely on various environmental parameters such as land types, terrain units, soil form and depth, clay content and geology (Table 1).

Two published vegetation studies were particularly relevant to the description of the suggested landscape units. These are the more detailed study by Rubin (1998) of the originally proclaimed Tankwa Karoo National Park, and the much broader regional study by Van der Merwe et al. (2008a, 2008b) in which the vegetation of the entire Hantam, Tanqua and Roggeveld areas were mapped. The use of information found in these studies, such as species presence and composition, vegetation structure, threat of exotic species, environmental parameters including erosion, erosion potential, steepness of terrain, were all used to inform a description for the newly delineated landscape units (Table 2). More detail regarding the species mentioned in this text can be obtained in Bester et al. (2012) and Steyn et al. (2013).

Additional characteristic environmental parameters for each landscape unit were sought and these data were summarised (Table 3) providing information to the managers and scientists working in the park in order to guide their decisions, as ecological processes within each of these different landscape units are strongly driven by rainfall and temperature. The environmental parameters per landscape unit indicate trends, such as, the increase in altitude, mean annual precipitation (MAP), frost duration, positive chill units and topographic heterogeneity from Landscape unit 1 in the Tanqua Karoo to Landscape unit 13 in the Roggeveld Mountains (Table 3). Conversely, minimum and maximum temperatures, coefficient of variation of MAP, annual potential evapotranspiration and heat units decrease from Landscape unit 1 to 13 (Table 3).

Table 1
Summary of soil parameters relating to each zone and landscape unit.

Landscape unit	Size of landscape unit	Land type	Terrain unit	Dominant soil form	Other soil forms	Soil depth (mm)	Clay content (%)	Geology
<i>Tanqua Plains Zone (105,373.0 ha)</i>								
1. Lemoenvlak bottomland plains	1907.6 ha	Fc 807	1	Mispah	Hutton	50-150	6-15	Tillite, diamicite & subsidiary shale of the Dwyka Group
2. Bo-Stompiefontein undulating plains	8714.7 ha	Fc 809, Fc 806 occurs at times	1 & 3	Mispah	Hutton/Glenrosa	50-150	6-15	Tillite, diamicite & subsidiary shale of the Dwyka Group with some dolerite intrusions
2a. Bo-Stompiefontein undulating plains drainage lines (not mapped but important in this landscape unit)		Fc 809	4(1) & 5	Hutton	Mispah/Oakleaf	200-500	15-20	Shale & siltstone of the Prince Albert & Whitehill Formations; Ecça Group
3. Grasberg undulating hills	2919.3 ha	Fc 804	3	Rock	Mispah/Glenrosa	50-150	6-20	Shale & siltstone of the Prince Albert & Whitehill Formations; Ecça Group with dolerite
4. Pramberg inselberg hills	6076.3 ha	Fc 804, Fc 803 could occur at times	3	Rock	Mispah/Glenrosa	5--150	6-20	Dolerite with shale & siltstone of the Tierberg Formation; Ecça Group
5. Central Tanqua bottomland plains	45,020.3 ha	Fc 287	4(1)	Mispah	Glenrosa/Oakleaf	50-150	6-15	Shale & siltstone of the Tierberg, Prince Albert & Whitehill Formations; Ecça Group with dolerite intrusions
6. Tanqua bottomland pans	9869.4 ha	la 56	4(1)	Oakleaf	Hutton	300->1200	10-30	Shale & siltstone of the Ecça Group, Karoo Sequence with alluvium & some dolerite intrusions
7. Tankwa River and associated drainage lines	6337.7 ha	la 57 & la 208	5	Oakleaf	Dundee/Clovelly	600->1200	10-35	Quaternary to recent alluvium derived from mudstone, siltstone, sandstone & shale of the Beaufort and Ecça Groups; Karoo Sequence & also dolerite
8. Tankwa River terraces	2261.1 ha	Fc 288	3	Glenrosa	Rock/Mispah	50-120	6-15	Dolerite with shale & siltstone of the Tierberg Formation; Ecça Group
9. Elandsberg Mountain	16,267.8 ha	Fc 286	1(2) & 3	Mispah	Rock/Glenrosa	100-150	6-15	Dolerite with shale and siltstone of the Tierberg Formation, Ecça Group
10. Tanqua Karoo midslopes	5998.8 ha	la 55	4(1)	Oakleaf	Hutton	300- > 1200	10-30	Shale & siltstone of the Tierberg Formation; Ecça Group & dolerite with alluvium & colluvium
<i>Roggeveld Mountain Zone (41,339.5 ha)</i>								
11. Roggeveld Escarpment footslopes	11,813.4 ha	la 55, Fc 289 occurs at times	4	Oakleaf	Hutton/Rock/Glenrosa	300- > 1200	10-30	Shale & siltstone of the Tierberg Formation; Ecça Group & dolerite with alluvium & colluvium
12. Roggeveld Escarpment midslopes	21,182.7 ha	lb 231	3	Rock	Mispah/Glenrosa	50-100	6-15	Mudstone, siltstone & sandstone of the Beaufort Group with shale, siltstone & sandstone of the Ecça Group; Karoo Sequence as well as dolerite
13. Roggeveld undulating crests	8343.4 ha	Da 70	1(2)	Swartland	Glenrosa/Mispah	100-150	6-15	Mainly mudstone, siltstone & sandstone of the Beaufort Group with sandstone, siltstone & shale of the Ecça Group; Karoo Sequence & dolerite intrusions

Terrain units: 1 – crest; 1(2) – escarpment; 3 – midslope; 4 – valley bottomland (Tanqua plains); 4(1) – floodplain (Tanqua Plains), footslope (Roggeveld Mountain); 5 – river or drainage line.

5. Description of the landscapes of the TKNP (Table 1, Fig. 2)

The landscape units presented here generally include a number of Rubin's (1998) more finely partitioned units, but usually more than one of our landscape units fit within the coarser units of Van der Merwe et al. (2008a, 2008b). We briefly list these vegetation unit affiliations in Table 2. Soil parameters (Table 1) and various modelled environmental parameters (Table 3) for each landscape unit are included and are relevant as they do have management implications. Tables 1, 2 and 3 should be consulted for more detail on each of the landscape units.

5.1. Tanqua Plains Zone

The Tanqua Plains Zone includes landscape units 1–10.

1. Lemoenvlak bottomland plains

The Lemoenvlak bottomland plains landscape unit is found in the north western corner of the TKNP on Land Type Fc 807 (Fig. 2, Table 1). This

low-lying area (300–400 m asl) has gently sloping ridges and plains. The topography of the Dwyka tillite, diamicite and subsidiary shale is fairly even and gradually slopes upwards to the south-east. Rock or soil forms that were recorded included Mispah, Hutton and rocky outcrops (Land Type Survey Staff, 2010, 2012), (Table 1). Rock cover varies considerably, from no rocks, to 50–99% rock cover, comprising small stones (>10 – 50 mm). The sharply undulating black desert pavement has large areas denuded of vegetation, with vegetation restricted to localised areas, covered in a monoculture of annual mesembs, resembling green lawns in spring during good rainfall years (Rubin, 1998).

Shrub cover is low, and grass cover is low or absent, while annual cover ranges from very low to isolated dense patches with 50–80% cover. The dominant plant species of this landscape are the perennials such as *Ruschia robusta*, *Augea capensis* and the annual *Euryops annuus*. Other plant species include *Cheiridopsis acuminata*, *Mesembryanthemum nodiflorum*, *M. stenandrum* and *Hereroa fimbriata*. Annual plant species such as *Osteospermum pinnatum*, *Heliophila digitata*, *Nemesia ligula* and *Hebenstretia parviflora* are also found in this landscape.

Table 2

Vegetation units identified in previous vegetation studies and their presence in each newly described and mapped landscape unit.

Landscape unit	Rubin's (1998) vegetation description (community and/or subcommunity)	Van der Merwe's et al. (2008a, 2008b) vegetation description (association and/or subassociation)
<i>Tanqua Plains Zone</i>		
1. Lemoenvlak bottomland plains	Community 5.3 (i), which also includes the more evenly sloped Dwyka tillites	Subassociation 7.1
2. Bo-Stompiefontein undulating plains	Communities 4.1, 4.3, 5.2, 5.3 (ii), 5.3 (iii) and 5.3 (iv). The components of Community 5.3 occur on: (ii) the larger red Dwyka shale hills; (iii) the suddenly contrasting undulating black desert paving areas with the landscape carved by many dry drainage lines; and (iv) a narrow gently sloped homogeneous area paved with red-black sandstone stones	Association 8
3. Grasberg undulating hills	Communities 2, 3 and 4.1	Tanqua pan mosaic consisting of Subassociation 7.2 on shales and alluvial deposits and, Association 10 on brackish soils
4. Pramberg inselberg hills	Communities 1.1, 1.2 and 1.3	Tanqua pan mosaic consisting of Subassociation 7.2 on shales and alluvial deposits and, Association 10 on brackish soils
5. Central Tanqua bottomland plains	Communities 3, 4.2, 4.3, 5.4 and 6	Association 8 including two variations
6. Tanqua bottomland pans	Community 8	Subassociation 7.2
7. Tankwa River and associated drainage lines	Community 4.1 on the more silty drainage lines and flood plains	Van der Merwe et al. (2008b) lists species common to the drainage lines, but did not assign the area to a specific unit
8. Tankwa River terraces	Not covered by Rubin (1998), as this area was not yet included in the park	Sections of Landscape unit 8 to the north of the Tankwa River within Subassociation 7.1 and the sections to the south of the Tankwa River within Association 8
9. Elandsberg Mountain	Not covered by Rubin (1998), as this area was not yet included in the park	Subassociation 7.1
10. Tanqua Karoo midslopes	Not covered by Rubin (1998), as this area was not yet included in the park	Subassociation 7.1
<i>Roggeveld Mountain Zone</i>		
11. Roggeveld Escarpment footslopes	Not covered by Rubin (1998), as this area was not yet included in the park	Subassociation 4.1
12. Roggeveld Escarpment midslopes	Not covered by Rubin (1998), as this area was not yet included in the park	Subassociation 4.1
13. Roggeveld undulating crests	Not covered by Rubin (1998), as this area was not yet included in the park	Subassociation 2.3 and the Soekop mosaic consisting of Subassociations 2.1.3 and 2.2

2. Bo-Stompiesfontein undulating plains

This landscape unit is found in the vicinity of Bo-Stompiesfontein in the north-west of the TKNP, on Land Type Fc 809 (Fig. 2, Table 1). The area is low-lying (300–400 m asl) and the topography is predominantly flat to slightly undulating (Rubin, 1998). Landscape unit 2 is comprised of tillite, diamictite and subsidiary shale of the Dwyka group with some dolerite intrusions (Table 1). Shale and siltstone of the Prince Albert and Whitehill Formations of the Ecca group are found along the drainage lines in this unit (Land Type Survey Staff, 2010, 2012), (Table 1). The sandy plains and ridges generally have no rock cover, except for high rock cover in localised patches where the surface cover comprises a thin layer of grey-black to shiny-black desert paving gravel. This unit contains large denuded areas that may be particularly sensitive to physical disturbance.

Vegetation cover is low (Rubin, 1998; Van der Merwe et al., 2008b) with a shrub cover of <20%, and grass cover ranges from 10–90%. Annuals are generally absent or have a low cover of <5%. Common species include *Augea capensis*, *Aridaria noctiflora*, *Galenia fruticosa*, *Lycium cinereum*, *Malephora luteola*, *Ruschia robusta*, *R. spinosa*, *Salsola aphylla*, *Stipagrostis obtusa*, *Tripteris oppositifolia* and *Zygophyllum microcarpum*. Plant communities found on sandy soils include the grasses *Stipagrostis obtusa* and *Stipagrostis ciliata*. The other noteworthy grass species is the unpalatable *Cladoraphis spinosa* which is present at times and also closely associated with sandy patches.

3. Grasberg undulating hills

Landscape unit 3 is situated in the north-west of the park in the vicinity of Grasberg Hill at 300–400 m asl (Fig. 2). This area includes dolerite plateaus with slightly undulating topography and low shale mounds protruding through the dolerite, limestone outcrops and Ecca shales (Rubin, 1998). Land type Fc 804 is indicated for the area (Table 1). The soil-rock complex is dominated by rock, with Glenrosa and Mispah soil forms (Land Type Survey Staff, 2010, 2012). Limestone outcrops are found in localised areas below the dolerite plateaus (Rubin, 1998). Brackish alluvial soils are also found in this unit, with vegetation differing according to the salinity of these soils.

Shrub cover is intermediate to high (30–60%), whereas the grass component is absent, and annual cover is very low. Species common to this landscape unit are *Aridaria noctiflora*, *Berkheya spinosa*, *Gnidia polycephala*, *Malephora crassa*, *Pteronia glabrata*, *P. luciloides*, *P. pallens*, *P. villosa*, *Ruschia intricata*, *R. wittebergensis*, *Salsola aphylla* and *Zygophyllum microcarpum*. Additionally, *Atriplex lindleyi*, *Lycium cinereum*, *Malephora luteola*, *Ruschia cradockensis*, *Salsola aphylla*, *S. tuberculata* and *Tripteris oppositifolia* are found on floodplains and in silty drainage lines.

4. Pramberg inselberg hills

This landscape unit is found in the valley bottomlands of TKNP as prominent inselberg hills. These hills with flat hilltops and rocky steep slopes are higher than the surrounding plains and are classified as Land type Fc 804 (Fig. 2, Table 1). Land type Fc 804 is described as dolerite with shale and siltstone of the Tierberg, Prince Albert and Whitehill formations belonging to the Ecca group (Table 1). Rock characterises this landscape, with Mispah and Glenrosa soil forms present. These inselberg hills are scattered throughout the western section of the TKNP at approximately 500–700 m asl. This landscape unit is found on all of the prominent hills such as Pramberg, Leeuberg, Potkleiberg and Bloukop-Platkop. On the slopes, the most dominant soil forms are Mispah and Glenrosa, whereas the crests of these hills generally constitute the Mispah soil form (Land Type Survey Staff, 2010, 2012), (Table 1). The steep, rocky slopes are sensitive to erosion, with several gullies visible (Rubin, 1998).

The vegetation structure of this landscape has been described as succulent dwarf shrubland (Rubin, 1998). Shrub cover ranges between 30 and 60%, annual cover is very low, whereas, the grass component is absent. Shrub cover is higher in the more sandy convex areas, with species such as *Berkheya spinosa*, *Pteronia pallens*, *P. viscosa* and *Tripteris sinuata* present. In the more rocky areas species such as *Euphorbia hamata*, *E. decussata*, *Ruschia spinosa* and *Zygophyllum microcarpum* occur (Rubin, 1998). Prominent species that can be found in this landscape unit are *Euphorbia hamata* and *Felicia lasiocarpa* (Rubin, 1998). Other species include *Euphorbia decussata*, *Pteronia pallens*, *P. viscosa*, *Pentzia incana*, *Drosanthemum hispidum*, *Dipcadi brevifolium*, *Pelargonium*

Table 3

A summary of environmental parameters for each landscape unit.

Landscape unit	Altitude	Minimum temperature	Maximum temperature	Mean annual precipitation (MAP)	Coefficient of variation of MAP	Annual potential evapo-transpiration	Frost duration	Positive chill units (May – September)	Heat units (April – September)	Heat units (October – March)	Topographic heterogeneity
<i>Tanqua Plains Zone</i>											
1. Lemoenvlak bottomland plains	382.48 (±14.78)	4.00 (±0.00)	33.67 (±0.47)	141.16 (±25.36)	38.5 (±0.50)	1665.17 (±6.59)	60.00 (±0.58)	454.01 (±13.64)	836.50 (±10.89)	2300.00 (±16.13)	1.72 (±0.71)
2. Bo-Stompiefontein undulating plains	378.49 (±25.40)	3.97 (±0.18)	33.61 (±0.49)	141.80 (±30.52)	38.65 (±0.74)	1664.94 (±8.28)	61.48 (±2.67)	459.74 (±21.91)	831.26 (±18.26)	2303.10 (±16.75)	2.28 (±1.78)
3. Grasberg undulating hills	384.51 (±26.90)	4.00 (±0.00)	33.27 (±0.45)	145.72 (±30.52)	38.64 (±0.64)	1661.18 (±10.63)	62.82 (±1.70)	475.95 (±27.46)	817.73 (±22.00)	2293.18 (±30.37)	2.31 (±1.51)
4. Pramberg inselberg hills	474.67 (±64.07)	3.19 (±0.39)	33.24 (±0.43)	174.38 (±36.66)	37.90 (±0.87)	1656.61 (±16.92)	71.05 (±4.38)	551.33 (±54.48)	743.42 (±51.99)	2263.14 (±50.98)	7.61 (±7.41)
5. Central Tanqua bottomland plains	397.56 (±37.54)	3.53 (±0.50)	33.67 (±0.47)	132.36 (±26.94)	38.91 (±0.66)	1676.16 (±7.83)	69.55 (±4.06)	490.31 (±32.47)	793.94 (±30.59)	2335.18 (±25.31)	1.77 (±1.07)
6. Tanqua bottomland pans	408.13 (±20.22)	3.19 (±0.39)	34.00 (±0.00)	116.00 (±29.45)	39.25 (±0.79)	1692.84 (±5.19)	72.69 (±4.10)	488.67 (±24.17)	794.28 (±26.25)	2358.75 (±9.36)	1.07 (±0.52)
7. Tankwa River and associated drainage lines	433.23 (±112.44)	3.22 (±0.42)	33.37 (±0.47)	126.83 (±41.63)	38.94 (±0.85)	1683.28 (±8.84)	73.33 (±4.62)	502.56 (±38.64)	779.22 (±34.82)	2338.44 (±35.76)	2.20 (±4.76)
8. Tankwa River terraces	421.01 (±12.40)	3.38 (±0.48)	33.88 (±0.33)	149.75 (±26.51)	38.38 (±0.70)	1683.00 (±7.14)	72.50 (±1.94)	496.21 (±22.86)	784.63 (±20.01)	2353.75 (±14.18)	2.35 (±2.48)
9. Elandsberg Mountain	522.40 (±80.07)	3.13 (±0.33)	33.27 (±0.59)	162.38 (±47.97)	38.25 (±1.10)	1665.96 (±26.66)	74.60 (±4.00)	554.83 (±71.75)	738.00 (±61.55)	2266.98 (±81.32)	5.70 (±6.56)
10. Tanqua Karoo midslopes	584.02 (±63.95)	3.00 (±0.00)	32.95 (±0.22)	186.15 (±41.64)	37.65 (±0.96)	1658.60 (±13.14)	81.25 (±4.17)	594.35 (±49.09)	700.90 (±40.00)	2236.00 (±42.71)	2.89 (±2.85)
<i>Roggeveld Mountain Zone</i>											
11. Roggeveld Escarpment footslopes	538.12 (±90.10)	2.95 (±0.22)	33.46 (±0.55)	188.02 (±40.68)	37.64 (±1.01)	1673.02 (±18.33)	79.78 (±5.90)	562.35 (±71.55)	726.73 (±59.16)	2291.56 (±58.79)	3.63 (±4.21)
12. Roggeveld Escarpment midslopes	1055.66 (±266.01)	1.71 (±0.87)	31.19 (±1.13)	287.90 (±80.50)	35.34 (±1.90)	1590.87 (±54.97)	112.44 (±18.00)	1122.76 (±306.91)	406.13 (±142.79)	1900.75 (±191.20)	24.64 (±14.26)
13. Roggeveld undulating crests	1251.97 (±93.80)	1.08 (±0.28)	30.13 (±0.33)	331.17 (±65.87)	34.38 (±1.49)	1563.00 (±42.81)	125.33 (±9.53)	1381.88 (±93.45)	289.21 (±36.21)	1735.25 (±62.16)	10.04 (±9.52)

magenteum and *Microloma saggitatum*. This Pramberg inselberg hills landscape unit was considered the most taxon diverse in the park (subsequent eastward expansion) with relatively high numbers of perennial and succulent species (Rubin, 1998).

5. Central Tanqua bottomland plains

The Central Tanqua bottomland plains unit currently covers the largest area of the park, and is found at between 300 and 400 m asl on Land Type Fc 287 (Fig. 2, Table 1). The topography varies from flat to slightly concave plains and consists of shale and siltstone of the Tierberg, Prince Albert and Whitehill Formations of the Ecca Group, with dolerite intrusions. Soil forms include the dominant Mispah form as well as Glenrosa and Oakleaf forms (Land Type Survey Staff, 2010, 2012), (Table 1). The sandy plains and isolated ridges generally have no rock cover, or have high cover in localised ridge patches, with a 60 to 90% cover of gravel and small stones. The sandy soils vary in colour from light brown to brown to red brown.

Vegetation canopy cover is low and the soil surface is generally flat and covered with shale, gravel and/or sand. Shrub cover is less than 20%, and grass cover ranges from 10 to 90%. Annuals are generally absent or have less than 5% cover. The sandy landscape is dominated by *Augea capensis*, *Stipagrostis obtusa*, *S. brevifolia* and *S. ciliata*, while the annuals are represented by *Euryops annuus* and *Ursinia nana*. Other species generally found were *Aridaria noctiflora*, *Augea capensis*, *Berkheya spinosa*, *Galenia africana*, *Gnida polycephala*, *Lycium cinereum*, *Malephora luteola*, *Pteronia glabrata*, *P. lucilioides*, *Salsola aphylla*, *Ruschia spinosa*, *R. wittenbergensis*, *Tripteris sinuata* and *Zygophyllum microcarpum*. Species of the Kimberlite hills which occur in this vegetation unit (Community 6 of Rubin, 1998), are greatly different from the species present in the rest of the plant communities, and include *Brownanthus ciliatus*, *Enneapogon scaber* and *Galenia crystallina* (Rubin, 1998). Cooler southern slopes are more vegetated, and species such as *Atriplex lindleyi*, *Tripteris sinuata* and *Stipagrostis obtusa* are present there.

6. Tanqua bottomland pans

This landscape unit is generally found in the central area of the TKNP at about 400 m asl on Land Type Ia 56 (Van der Merwe et al., 2008b), (Fig. 2). Shale and siltstone of the Ecca Group, Karoo sequence, with alluvium and some dolerite intrusions were noted. The dominant Oakleaf soil form occurs on the pan floors, whereas the Hutton soil form is occasionally present (Land Type Survey Staff, 2010, 2012), (Table 1). The soils are high in silt, often with more silt than clay (Rubin, 1998). The flat, alluvial floors are generally denuded of vegetation during the dry season, but after good rain, these floors are rapidly covered by succulent forbs.

Plant species such as *Aridaria noctiflora*, *Cephalophyllum* sp., *Malephora crassa*, *Pteronia glabrata*, *P. pallens*, *P. villosa*, *Ruschia intricata*, and *Tripteris sinuata* are common (Van der Merwe et al., 2008b). Wind driven sand, exposed due to vegetation degradation, frequently accumulates producing elevated shrub clumps (mostly *Salsola tuberculata* bushes) with the spiny grass species *Cladoraphis spinosa* present around the sandy edges of the alluvial floors (Rubin, 1998).

7. Tankwa River and associated drainage lines

The Tankwa and Renoster Rivers are the major drainage lines traversing the TKNP and are mapped within Landscape unit 7, whereas additional smaller drainage lines are found scattered throughout the park (Fig. 2). Altitude ranges from about 300 m asl in the Tanqua Karoo basin to approximately 1200 m asl in the Roggeveld Mountains. The lower elevation areas of the Tankwa River and associated drainage lines landscape unit is found on Land Types Ia 57 and Ia 208 (Table 1). The higher elevation areas which include the upper reaches of the Renoster River in the Roggeveld Mountains occur on Land Type Da 70, surrounded by the Roggeveld undulating crests landscape unit (Landscape unit 13). Quaternary to recent alluvium derived from mudstone, siltstone, sandstone and

shale of the Beaufort and Ecca Groups from the Karoo Sequence, as well as dolerite intrusions are found in this landscape unit. The dominant soil form is Oakleaf, while Dundee and Clovelly are also present in the landscape (Land Type Survey Staff, 2010, 2012).

Vegetation along the drainage lines varies from well-established tree and shrub communities on the banks and surrounding floodplains (55% cover), to generally more sparsely vegetated drainage lines where water drains faster due to a slight gradient (2–5% cover), (Rubin, 1998). *Vachellia karroo* trees are well-established along the larger, more perennial drainage systems. The more silty drainage lines and flood plains include species such as *Aridaria noctiflora*, *Augea capensis*, *Lycium cinereum*, *Malephora luteola*, *Salsola aphylla*, *Tripteris oppositifolia* and *Zygophyllum microcarpum*. *Aridaria noctiflora*, *Atriplex lindleyi*, *Galenia africana*, *Ruschia cradockensis*, *Salsola aphylla* and *S. tuberculata* are also occasionally present. There are numerous derelict flood-irrigated agricultural lands which exploited the more water favourable conditions along the drainage system (Van der Merwe et al., 2008b). Other forms of transformation evident include the presence of the invasive alien *Prosopis* species, and the naturalised *Atriplex lindleyi* (Van der Merwe et al., 2008b).

8. Tankwa River terraces

Landscape unit 8 is found in the central southern area of the park on Land Type Fc 288 at an elevation of between 300 and 400 m asl (Fig. 2, Table 1). These gently sloping ridges and plains comprise dolerite, and shale and siltstone (Tierberg Formation) of the Ecca Group (Table 1). The Glenrosa soil form is dominant, with rock and the Mispah soil form present in places (Land Type Survey Staff, 2010, 2012), (Table 1). Rock cover varies from absent to 50%, to as high as 99%, comprising small stones (>10–50 mm), (Van der Merwe et al., 2008b).

Grass component cover is absent or low while annual cover is usually very low. In places, isolated patches of annuals are dense (50–80%). Generally the shrub cover is low. Species common north of the Tankwa River include *Aridaria noctiflora*, *Augea capensis*, *Pteronia pallens* and *Ruschia robusta*, while species abundant to the south are *Stipagrostis obtusa*, *S. ciliata* and *S. brevifolia* and, occasionally, *Cladoraphis spinosa*.

9. Elandsberg Mountain

This landscape unit is found in the region of the Elandsberg, 500–700 m asl on Land Type Fc 286 (Fig. 2, Table 1), at the foot of the Roggeveld Escarpment. The unit is underlain by dolerite, and shale and siltstone of the Tierberg Formation belonging to the Ecca group (Table 1). The dominant soil form is Mispah while, rock and the Glenrosa soil form is present in places (Land Type Survey Staff, 2010, 2012), (Table 1). Small stones cover the unit (50–99%), or are absent on the soil surface.

Shrub cover is usually low but can be as high as 75%. Annual cover varies from very low (the norm) to dense patches with a 50–80% cover. Grass cover is absent or very low. Perennial species such as *Aridaria noctiflora*, *Augea capensis*, *Pteronia pallens* and *Ruschia robusta* are found in this landscape unit. The variable annual composition and cover is represented by species such as *Euryops annuus*, *Gazania lichtensteinii* and *Felicia australis*.

10. Tanqua Karoo midslopes

The Tanqua Karoo midslopes landscape unit is found to the east of the Elandsberg at the valley bottomlands of the Roggeveld Mountains, at approximately 600–700 m asl, on Land Type Ia 55 (Fig. 2, Table 1). This landscape unit occurs on the upper slopes of the Ecca plains and has a uniform topography with a gradual slope, and regular erosion rills fanning out in a southerly and south-westerly direction. Shale and siltstone of the Tierberg Formation (Ecca Group), and dolerite with alluvium and colluvium are found in this landscape unit (Table 1). The Oakleaf and Hutton soil forms are present (Land Type Survey Staff, 2010, 2012), (Table 1).

Van der Merwe et al. (2008b) did not distinguish between landscape units 9 and 10, however, the unpublished data by Kraaij and Bezuidenhout (2005) highlight the finer scale differences between these units. This data suggests that the most dominant species is *Ruschia spinosa* and to a lesser degree *R. robusta*, with *Euphorbia restituta* notable but scattered. *Tripteris sinuata*, *Stipagrostis obtusa* and *Galenia africana* indicate the plains character of this landscape unit, with *Galenia africana* particularly abundant in the erosion rills. The annuals *Euryops annuus*, *Gazania lichtensteinii*, and to a lesser extent *Ursinia* and *Arctotis* species are common. Other prominent species found include *Aridaria noctiflora*, *Augea capensis* and *Pteronia pallens*.

5.2. Roggeveld Mountain Zone

The Roggeveld Mountain Zone includes landscape units 11–13.

11. Roggeveld Escarpment footslopes

This landscape is located on the west facing slopes of the Roggeveld Mountains on Land Type Ia 55 (Fig. 2, Table 1) at approximately 600–800 m asl. These footslopes are gentle to moderately steep slopes. Doleritic rock cover is generally high (>90%) with colluvium found overlying the Ecca shale's and siltstones of the Tierberg Formation (Table 1). The following soil forms are found in the Roggeveld Escarpment footslopes landscape unit: Oakleaf, Hutton, Glenrosa and rock (Land Type Survey Staff, 2010, 2012), (Table 1).

Grasses are generally absent and annuals can be found at a low cover. Shrub cover is high (50–60%), and dominated by *Pteronia glauca*, at an especially high cover. Other species found in this landscape unit include *Euphorbia decussata*, *Galenia africana*, *Montina caryophyllacea*, *Pteronia glauca*, *P. incana*, *Tripteris sinuata* and *Tylecodon wallichii*.

12. Roggeveld Escarpment midslopes

Landscape unit 12 is found on the midslopes of the Great Escarpment at about 900–1100 m asl, on Land Type Ib 231 (Fig. 2, Table 1). These west facing slopes of the Roggeveld Mountains are generally moderate to steep, and usually have a high rock cover of stones (sized >50–200 mm) and boulders (>200 mm). This landscape unit comprises the mudstone, siltstone and sandstone of the Beaufort group together, with shale, siltstone and sandstone of the Ecca group (Table 1). Occasionally dolerites intrusions are found. Rock dominates the soil–rock complex, with Mispah and Glenrosa forms also present in this landscape unit (Land Type Survey Staff, 2010, 2012), (Table 1).

There is a considerable variation in grass and shrub cover. The annual component is absent or covers <1% of the area. *Dicerotheramnus rhinocerotis*, *Merxmullera stricta* and *Chrysocoma ciliata* are dominant at very high cover (60–95%). In places, *Pteronia glauca* is also dominant. Other species present include *Asparagus capensis*, *Eriocephalus ericoides*, *Euphorbia decussata*, *Euryops lateriflorus*, *Galenia africana*, *Montina caryophyllacea*, *Pteronia glauca*, *P. incana*, *Tripteris sinuata* and *Tylecodon wallichii*.

13. Roggeveld undulating escarpment

Landscape unit 13 is found on the plateau region of the Roggeveld Mountains at an elevation of about 1000–1200 m asl, on Land Type Da 70 (Fig. 2, Table 1). These areas generally comprise gentle to moderately steep slopes. Mainly mudstone, siltstone and sandstone of the Beaufort Group together with sandstone, siltstone and shale of the Ecca Group, are found in this unit. Dolerite intrusions are scattered throughout the landscape (Table 1). The Swartland soil form is dominant, with Glenrosa and Mispah soil forms occasionally present (Land Type Survey Staff, 2010, 2012), (Table 1). Rock cover varies on these light brown to brown, regularly sandy soils.

Shrub cover varies greatly (20–80%), whereas annual cover is generally low. Grass cover varies considerably, primarily as a result of the presence or absence of *Merxmullera stricta*. Common species include *Asparagus capensis*, *Chrysocoma ciliata*, *Dicerotheramnus rhinocerotis*, *Dimorphotheca cuneata*, *Ehrharta melicoides*, *Eriocephalus ericoides*, *Euryops lateriflorus*, *Felicia filifolius*, *Helichrysum hamulosum*, *Hermannia cuneifolia*, *Merxmullera stricta* and *Oedera sedifolia*.

6. Conclusion

The study has successfully produced a landscape unit map of the current extent of the TKNP, by integrating aspects from previous vegetation studies, and additional biotic and abiotic information, a description of each landscape unit was compiled. This description highlights aspects such as locality, land types and soils, and includes dominant and/or characteristic species that can be found in each unit.

The Tanqua Plains Zone and the Roggeveld Mountain Zone form the two primary physiographic zones of the TKNP, each being further divided into ten and three distinctive and ecologically meaningful landscape units respectively. Whereas the South African national vegetation map recognises four vegetation units in the Roggeveld Mountain Zone, only two are identified in the Tanqua Plains Zone. The landscape map presented here represents a considerable refinement of the Tanqua Plains area.

The finer scale landscape map and associated description as well as the summary of soil and environmental parameters is a useful tool that collates previous research and provides new information on the TKNP that can assist park management.

This tool can be applied with relative ease, is not extremely time consuming or expensive, and limits time as well as costs in the field especially considering the extent of large conservation areas. The resulting landscape unit classification, mapping and description can thus quickly assist park managers and scientists in, not only the compilation of park management plans, but also with the effective management of the conservation area from the early stages rather than waiting for personnel and funds to become available for a comprehensive vegetation classification exercise. Landscape units are larger than the fine scale vegetation mapping units and are thus easier to manage.

6.1. Management implications

The delineation of the TKNP into two physiographic zones, consisting of thirteen landscape units, that can be used to guide not only planning and management efforts across the park, but also ensure research and monitoring is spread throughout the park in the most cost-effective and time efficient manner. For example, the identification of sensitive landscapes such as the steep, rocky slopes of the Pramberg inselberg hills (Landscape unit 4) that are sensitive to erosion, and the identification and mapping of large denuded patches that are probably sensitive to physical disturbance (Landscape unit 2), can aid management, guide monitoring and, if necessary, rehabilitation efforts. Delimitation of the transformed landscapes, for instance Landscape unit 7 (Tankwa River and associated drainage lines), can help to quantify and direct rehabilitation and monitoring research to these areas. The monitoring of the spread of the invasive alien *Prosopis* can also be concentrated in Landscape unit 7 and eradication efforts directed there.

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