



# Phytosociology of the farm Haribes in the Nama-Karoo biome of southern Namibia

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## Note:

Nomenclature follows Craven (1999) and subsequent name changes used by the National Herbarium of Namibia (WIND).

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Limited historic vegetation data (prior to the 1980s) are available for Namibia. Finding such historic data at Haribes prompted a follow-up survey of the vegetation. We present a classification of the recent data in this paper as a first step towards comparing the two data sets. Six new associations (three with two subassociations each) are formally described. The landscape at Haribes is dominated by a pan with surrounding hummock dunes. The pan supports the *Lycio cinereum* – *Salsoletum*, whilst on the hummock dunes the *Salsole* – *Tetragonietum schenckii* can be found. The surrounding plains and escarpment can be divided into three landforms: the *torras* with the *Monsonio umbellatae* – *Boscietum foetidae*, the *ranteveld* with the *Acacio senegal* – *Catophractetum alexandri* (and two subassociations) and calcrete ridges with the *Zygophylo pubescentis* – *Leucosphaeretum bainesii*. Dry river beds on the farm support two subassociations of *Antheperho pubescentis* – *Ziziphodetum mucronatae*. The area covered by each dominant landform has been calculated after being mapped. The composition and diversity of the associations are briefly compared to other known vegetation descriptions within the Nama-Karoo. Since November 2011, Haribes has been used as a resettlement farm. This may result in the overutilisation of the limited grazing resources, to the extent that the present, fairly dense *Acacio senegal* – *Catophractetum alexandri* of the *ranteveld* is feared to become degraded to resemble the *Monsonio umbellatae* – *Boscietum foetidae* of the *torras*.

**Conservation implications:** This paper describes six plant associations of the Nama-Karoo biome in arid southern Namibia. The information presented forms a baseline description, which can be used for future monitoring of the vegetation under altered land use.

## Introduction

Vegetation in Namibia has been described only on a few attempts in the past (Burke & Strohbach 2000; Strohbach & Jürgens 2010). To date, the only concise vegetation map of Namibia was produced in the 1970s, based on field observations rather than actual surveys (Giess 1971, 1998), and depicts broad categories at biome rather than landscape level. Later attempts to map the vegetation of Namibia had to rely on partial, often incomplete, regional updates used in conjunction with the Giess vegetation map to fill in gaps (Mendelsohn *et al.* 2002). Grazing capacity maps dating from the 1970s (Departement Landbou Tegniese Dienste 1979) are used for land-use planning, including the ongoing Land Reform Programme of the Government of Namibia. However, these maps are regarded as outdated and in urgent need of revision (Espach 2006; Espach, Lubbe & Ganzin 2006; Lubbe 2005). Current efforts to upgrade the grazing capacity estimation with the aid of satellite images require extensive ground surveys, including surveys of the structure and composition of vegetation (Espach *et al.* 2006; Espach, Lubbe & Ganzin 2010). With this in mind, but also as basis for a biodiversity inventory, the Vegetation Survey of Namibia project was initiated (Strohbach 2001).

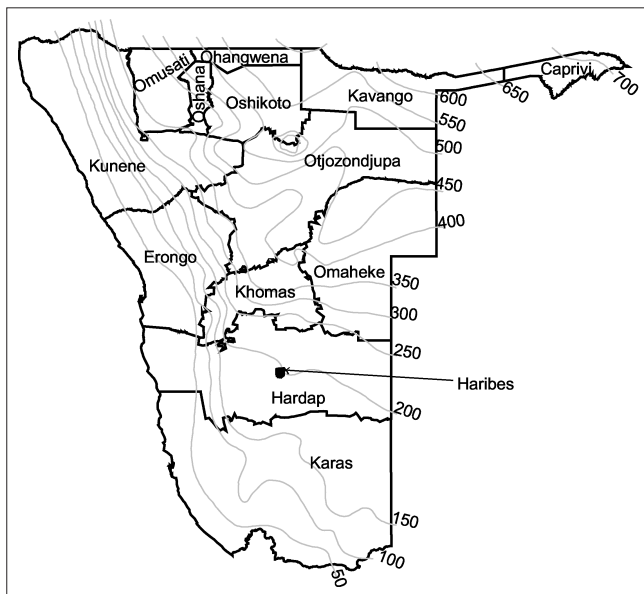
Prof. O.H. Volk was one of only a few vegetation scientists active in Namibia before the 1980s. During 1956, he conducted extensive vegetation surveys on selected farms in the former South West Africa. Unfortunately, only one of these data sets had been analysed and formally published (Volk & Leippert 1971); the others that could be retrieved were all in the form of raw data sets with brief comments on the vegetation, generally held in farm archives. Nonetheless, these data sets have proved to be of immense value in reconstructing vegetation changes over the past five decades of land use, especially with regard to the effects of land use and/or global climate change. One of these data sets, surveyed in April 1956, was from the farm Haribes.

This study was initiated to provide data on the current vegetation, for later comparison with Volk's historic data. The aim of this paper, however, is to classify and describe the present vegetation of the farm Haribes as an attempt towards filling the immense gap in vegetation data in Namibia (Strohbach & Jürgens 2010). In a subsequent paper, we intend to compare the present vegetation with that documented in 1956.

## Study area

Haribes, in the Mariental district of the Hardap region in southern Namibia (Figure 1), belonged to the Neue Haribes Company until 2010. In 1956 the farm covered 77 500 ha, but has been reduced to its present 50 100 ha through a process of selling off blocks of land. The present survey was conducted across blocks 019/1, 019/REM, 020, 672 and 673, which total 55 487 ha. Initially, Haribes was used for extensive commercial Karakul sheep farming. The most important land-use change took place in 1992, when all the sheep and goats were sold and replaced by cattle as the only domesticated commercial species. As a result of the selective utilisation of the grass layer, woody species, especially *Catophractes alexandri*, *Rhigozum trichotomum* and *Acacia nebrownii*, increased in abundance, resulting in a phenomenon commonly referred to as 'bush encroachment' (De Klerk 2004). A wide variety of game, often in large numbers, are found on the farm. Most numerous are springbok and oryx. There are also many bird species, including many ostriches. The farm was sold in May 2010 to the Government of Namibia as part of its land reform and resettlement scheme (Cloete 2010a; Pretorius 2010), with the first 13 families receiving their plots in November 2010 (Cloete 2010b; Kleinhans 2010).

Haribes is situated approximately 30 km west of Mariental and southwest of the Hardap Dam Nature Reserve within the Central Plateau 4-8 agro-ecological zone (De Pauw *et al.* 1998). This zone is described as a strongly dissected plain on Karoo rocks. The average rainfall is about 200 mm per year, with a coefficient of variation between 50% and 60% (Botha 1996). Temperatures rise to above 36 °C in summer, with minimum temperatures of between 2 °C and 4 °C in winter (Mendelsohn *et al.* 2002).



Source: Ministry of Agriculture, Water and Rural Development, 2001, *Namibian Agricultural Resources Information System (NARIS)*, Ministry of Agriculture, Water and Rural Development, Windhoek

**FIGURE 1:** Location of the farm Haribes in the Hardap region of southern Namibia. Also indicated on this map are the long-term average annual rainfall isohyets (in grey), with their values (in mm) indicated to the right.

The geomorphology can be described as a plateau broken up by many dry washes and some bigger ephemeral rivers that are responsible for the drainage of the area [a dissected plain according to the terminology of the Digital Soils and Terrain Database (SOTER) (FAO 1995; Oldeman & Van Engelen 1993]. The Riet River drains into a big pan surrounding the farmhouse complex. In and around the pan several well-developed dune hummocks have formed over time. The farm lies between 1120 m and 1320 m above sea level. The geological strata belong to the Fish River subgroup of the Nama sediments. The eastern part of the farm is situated on the Gross Aub Formation dominated by red shale and sandstone, whilst the larger, western part of the farm forms part of the older Nababis Formation with red sandstone and shales (Geological Survey 1980). The soils in the region (at a scale of 1:1 000 000) are classified as eutric leptosols, which means that the soils are fertile but generally very shallow (ICC, MAWRD & AECI 2000; Mendelsohn *et al.* 2002).

The farm falls within the Nama-Karoo biome (Irish 1994) and its vegetation is classified as Dwarf shrub savanna (Giess 1971, 1998). This can broadly be described as open, short-to-low shrublands dominated by *C. alexandri*, *R. trichotomum*, *Boscia foetida* and several dwarf shrubs. The grass layer, which includes species such as *Stipagrostis uniplumis*, *Eragrostis nindensis*, *Enneapogon cenchroides* and *Schmidtia kalahariensis*, is relatively sparse. Trees and larger shrubs, including species such as *A. nebrownii*, *Acacia karroo*, *Euclea pseudebenus* and *Ziziphus mucronata*, are largely confined to dry washes and rivers.

## Research method

A total of 177 plots were sampled between March and May 2005. Below average rain (*c.* 150 mm, D. Poggenpoel, pers. comm., May 2005) had fallen that season, with the first substantial rains falling only in March.

To compare the present composition with that documented by Volk in 1956, we made exhaustive attempts to relocate his original sampling sites according to route descriptions, odometer distance readings (in miles) and old farm maps. Although this information greatly eased the task of relocation, the exact position of those plots could not be determined. Additional vegetation types were sampled using a stratified sampling approach to achieve a good average for the main vegetation types. For the purpose of stratification, a satellite map of the farm (based on Landsat 7 ETM scene path 177 row 077, 26 March 2001) was used as base map. Relatively homogenous areas were delineated as derived from segmentations calculated by Definiens 5 (Definiens 2006). Occasional azonal vegetation types (especially small vleis and related features) were also sampled.

Surveying followed the Braun-Blanquet concept as applied during the Vegetation Survey of Namibia project (Strohbach 2001). For each 20 m × 50 m plot, all species were recorded, as well as their typical growth form and average height. Abundance was estimated according to the modified



Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). In addition, the position of the plot and environmental parameters such as altitude, aspect, slope, topography, stone cover, erosion and disturbances were noted. Owing to time constraints, no soil samples were taken. Instead, available soil data (ICC *et al.* 2000; Mendelsohn *et al.* 2002) were interpolated for the various vegetation associations described. Unknown plant species were collected and identified at the National Herbarium of Namibia. The relevé data were captured in the TurboVeg database (Hennekens & Schaminée 2001).

The data were classified with JUICE (Tichý 2002), using the Modified TWINSpan classification procedure (Roleček *et al.* 2009). The pseudospecies cut level was set to presence/absence, and total inertia was selected as heterogeneity measure. The classification process concluded after 14 divisions. At this stage, two communities (hummock dunes and the *ranteveld*) were already subdivided owing to high internal heterogeneity and had to be recombined manually (Figure 2). The classification result was ordered as a table using the phi coefficient fidelity measure (Chytrý *et al.* 2002) as sorting criterion.

The classification results were confirmed with an ordination using Detrended Correspondence Analysis (DCA) (Hill & Gauch 1980), prepared with PC-Ord 5 (McCune, Grace & Urban 2002). Two iterations were performed, with the first excluding only two wetland relevés (as outliers) whilst the second also excluded the pans and associated hummock dunes. Although DCA has been criticised in recent years for 'detrending' the arch effect, this very effect proved useful in illustrating the relationships between the various vegetation associations, as Reciprocal Averaging (RA) depicted only a severe arch effect. The DCA ordination diagram was also used to depict habitat relations, which could often only be overlaid as categorical data.

Mapping was performed using a Landsat 7 ETM satellite image (path 177, row 077; 26 March 2001). In addition, a digital terrain model derived from Shuttle Radar Topography Mission (SRTM) data (available from <http://srtm.csi.cgiar.org/>) (Jarvis *et al.* 2008) was used to elucidate the topography. The satellite image was clipped to an area slightly larger than the study area before further processing. This clip was imported into the Definiens software package (Definiens 2006) and segmented into relatively homogenous areas. The segments were classified using the classified sample sites as ground truth data. In a final step, the resulting shape file was clipped according to the farm boundaries and areas for each landscape calculated using the IDRISI Andes software package (Eastman 2006).

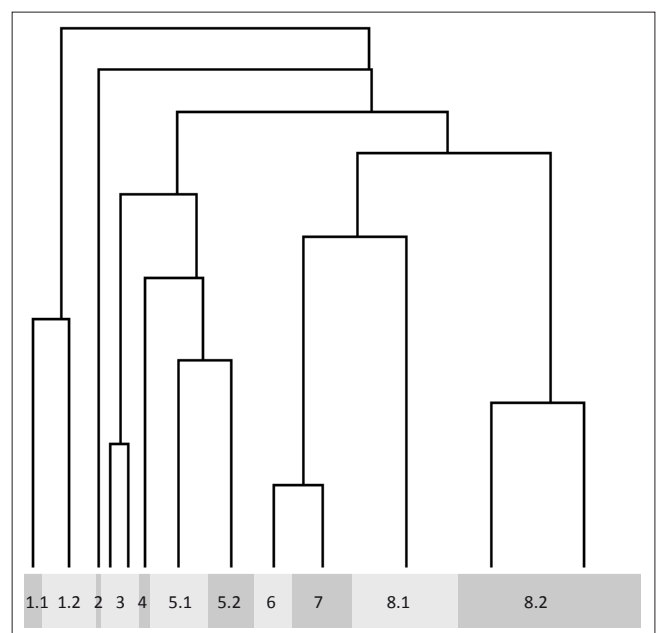
## Results

A total of 218 species, representing 42 families, were observed on the 177 relevés. Poaceae was the most abundant family, represented by the most species (54), followed by

the Fabaceae (27 species), Asteraceae (16 species) and the Aizoaceae (13 species).

The classification of these relevés revealed eight communities, of which three were divided into subcommunities. The phytosociological table is presented in an online appendix 1, whereas online appendix 2 is a synoptic table. Figure 2 depicts a dendrogram of the classification result. The ordination diagrams of the DCA are shown in Figure 3a (all data except for two outlier relevés) and Figure 3b (also excluding the relevés representing pans and associated hummock dunes). In Figure 3c, the lithology (i.e. the rock types which gave rise to the soils) has been imposed onto the DCA ordination diagram of Figure 3b to illustrate the habitat relationships between vegetation communities.

The pan and hummock dune communities form a well-defined continuum to the right of the ordination diagram in Figure 3a, indicating most likely a combined salinity and soil moisture gradient from the pan centre (community 1.2; upper right corner) to the surrounding hummock dunes (community 3; lower right corner). In contrast, the remaining communities (plains, *ranteveld* and rivers) are compressed on the left of the main axis. Splitting out the relevés representing the pan and hummock dune communities resulted in a continuum spread between the stony *ranteveld*, plain and *torra* communities as well as the rivers (Figure 3b). The limited habitat data available indicate that this is a gradient of increased stoniness towards the left of the main gradient (Figure 3c), representing the *ranteveld*. Together with the lithology (i.e. the rock type from which the substrate is derived), the stoniness forms the main ecological gradient in this environment.



The numbers at the bottom represent the community numbers, as used in the description of the vegetation types. Note that communities 3 (hummock dunes) and 8.2 (*ranteveld*) were divided owing to high internal heterogeneity and had to be recombined manually.

**FIGURE 2:** Dendrogram based on the Modified TWINSpan classification of the vegetation types in the study area.

## Description of the plant associations

We formally describe six of the observed communities as associations, three with subassociations, following the

International Code of Phytosociological Nomenclature (Weber, Moravec & Theurillat 2000). The two wetland communities, however, are described only informally, as the number of samples taken was too small for proper description.

### 1. *Lycio cinereum* – *Salsolietum* *ass. nov.*

The typicum for this association is relevé 2514, sampled at 24°35'36"S, 17°32'58"E on 09 March 2005 (Figure 4b). The association is represented by 21 relevés and characterised by the presence of *Salsola* spp. dwarf shrubs, which also dominate the vegetation. The structure is a short, open shrubland (*sensu* Edwards 1983), with an average shrub cover of 6%. Total vegetation cover barely reaches 10%. In total, 58 species have been observed on these pans, with an average species density of 12 per 1000 m<sup>2</sup>.

The *Lycio cinereum* – *Salsolietum* is typical of the large Haribes pan on the farm. The soils originate from weathered sandstones and some calcretes consisting of fine material which is very prone to capping and surface sealing (Figure 4c). The cation levels are probably elevated to form a halophytic environment, but not sufficiently so to render the pan a salt pan (M. Coetzee, pers.comm., March 2010).

Two subassociations can be distinguished, as described below.

#### 1.1 The *Zygophylo simplicis* – *Salsolietosum* *subass. nov.*

The typicum for this subassociation is relevé 2518, sampled at 24°37'53"S, 17°32'31"E on 09 March 2005 (Figure 4a). Only five relevés represent this subassociation. The occurrence of *Tetragonia schenkii*, *Trianthema* sp. and *Salsola* spp. is characteristic and *S. uniplumis* var. *uniplumis*, *S. kalahariensis*, *Boerhavia repens* and *A. nebrownii* also occur constantly.

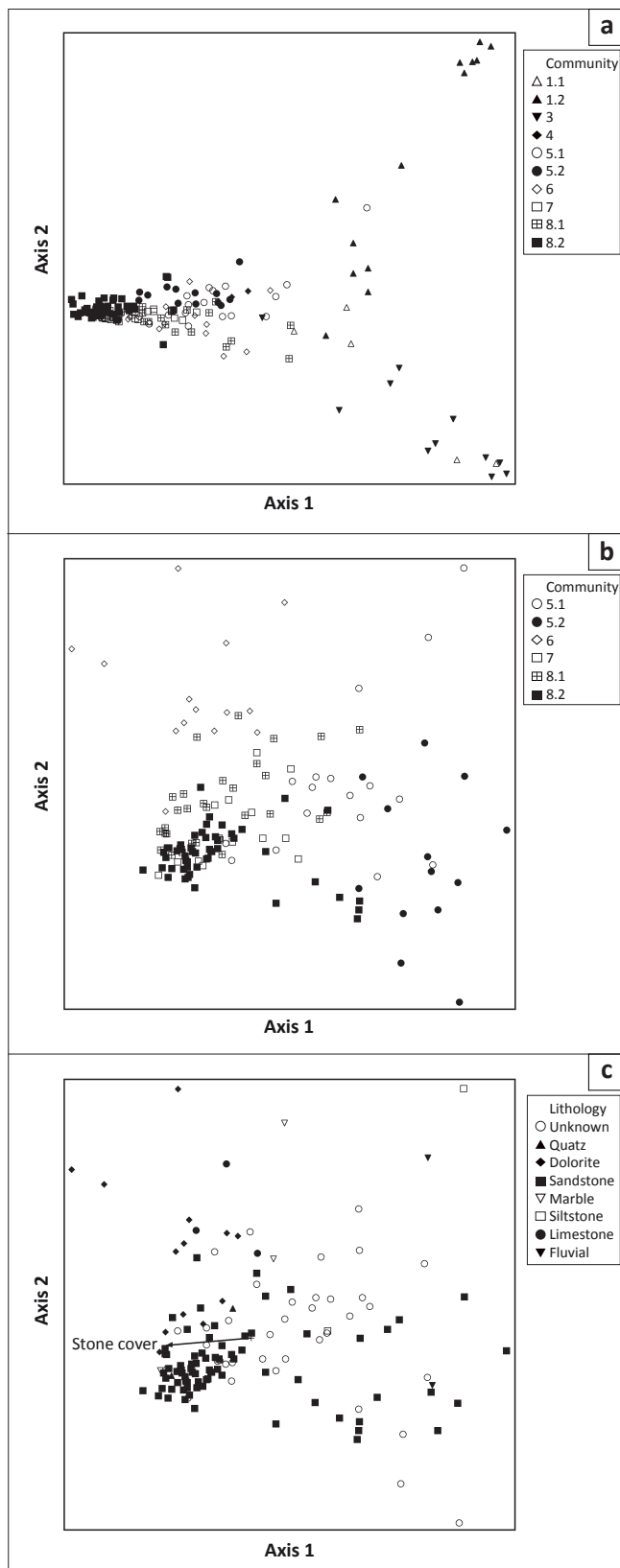
Along the outer parts of the pan and on the floodplains to the pan the vegetation is better developed, forming a tall, moderately closed shrubland (Figure 5). Few perennial herbaceous species occur here; this layer is dominated by ephemerals. The species density is on average 14 species per 1000 m<sup>2</sup> and in total 39 species have been observed here.

#### 1.2 The *Lycio cinereum* – *Salsolietosum* *subass. nov.*

This subassociation forms the typicum for the *Lycio cinereum* – *Salsolietum*. It is represented by 16 relevés and characterised by near-monospecific stands of *Salsola* shrubs. Other species that occur here are mostly of ephemeral nature. The shrubs are on average only 0.5 m – 1 m high and reach a cover of only about 6%, thus forming a short, open shrubland (Figure 5). On average, only five species occur per 1000 m<sup>2</sup>, with a total of 31 species being observed on these pans.

### 2. The *Eragrostis rotifer* – *Leptochloa fusca* community

This community was found once in relevé 2599 from a sample on a deeper vlei, which is regularly inundated. This



The codes used correspond to those used in the description of the vegetation types.

**FIGURE 3:** Detrended Correspondence Analysis ordination diagrams compiled from (a) all data, excluding two outlying wetland relevés and (b) data excluding wetland, hummock dune and pan relevés; (c) indicates the lithology of each plot, with a biplot indicating the stoniness of the substrate.





is indicated by the presence of the geophytic hydrophyte *Aponogeton* cf. *desertorum* and *Eragrostis rotifer*, also generally associated with water-logged soils (Figure 4d). These uncommon vleis form in relatively small depressions, mostly on top of the plateau area in pans that range from 20 m to 50 m in diameter. The pans are surrounded by sandstone stones varying in size between 5 cm and 80 cm. The reddish colour indicates that the soil is most probably relatively high in nutrient content (M. Coetzee, pers. comm., March 2010).

### 3. *Salsolo* – *Tetragonietum schenckii* ass. nov.

The typicum for this association is relevé 2501, sampled at 24°37'00"S, 17°31'01"E on 08 March 2005 (Figure 4e). Eleven relevés were classified within this association. The association is characterised by the presence of the endemic shrub *T. schenckii*. Constant species include *S. uniplumis* var. *uniplumis*, *Stipagrostis ciliata*, *Salsola* spp. and *R. trichotomum*. The association is dominated by *T. schenckii*. The typical structure is a tall, moderately closed shrubland (Figure 5), with the shrubs reaching a height of between 1 m and 1.5 m. On average 11 species are found per 1000 m<sup>2</sup>, with a total diversity of 56 species.

The *Salsolo* – *Tetragonietum schenckii* is found on hummock dunes probably originating from a deflation process during the formation of the Haribes pan, similar to that described for the Koës pan and other depressions in the Kalahari (Bullard & Nash 2000; Lancaster 1986; Shaw 1988; Shaw & Thomas 1997). The dunes vary in length, generally between 30 m and 50 m. The slopes of the dunes are often quite steep. The occurrence of *Salsola* spp. on these dunes indicate a high base status, which, in turn, supports the hypothesis that the dunes are the result of the deflation process of the pan.

### 4. The *Cullen obtusifolia* – *Leptochloa fusca* community

This community was identified in three relevés within the larger Haribes pan ecosystem. The presence of *Leptochloa fusca* and *Indigofera alternans* indicates water-logging at these vleis, whilst the absence of *E. rotifer* and *Aponogeton* sp. and the presence of the flat-growing therophytes *Cullen obtusifolia* and *Platycarpha carlinoides* indicate a drier environment than occurs in the deep vleis of the *E. rotifer* – *Leptochloa fusca* community. Typically for these vleis, *A. nebrownii* is dominant along the fringes (Figure 4f). These pans are small (50 m – 80 m in diameter) and very shallow. The high clay content of the soil allows the water to remain in the pan for approximately 2–3 weeks. In most cases, these pans are surrounded by reddish gravel, but no larger stones.

There are very few of these small pans that differ greatly from the big pans on the farm. Some are relatively small depressions, mostly on top of the plateau area, but there are also small pans below the plateau, especially near the old road along the tar road between Mariental and Maltahöhe. These depressions allow water to accumulate, resulting in microhabitats with a wetland character.

### 5. *Anthephoro pubescentis* – *Ziziphodetum mucronatae* ass. nov.

The typicum for this association is relevé 2649, sampled at 24°38'17"S, 17°28'12"E on 16 May 2005 (Figure 4h). A total of 30 relevés have been classified within this association. It is characterised by the diagnostic species *Z. mucronata*, *Ocimum americanum* var. *americanum*, *Aristida meridionalis*, *Grewia flava*, *Anthephoro pubescens*, *Monechma divaricatum* and *Melinis repens*. These are constantly associated with the species *S. uniplumis* var. *uniplumis*, *S. kalahariensis*, *Lycium cinereum*, *E. cenchroides*, *Gisekia africana*, *A. nebrownii*, *Eragrostis porosa*, *R. trichotomum* and *B. foetida*. The structure is a low open woodland (*sensu* Edwards 1983), dominated by trees between 4 m and 6 m high that attain a cover of about 2%. Shrubs attain a cover of between 5% and 10%, at a height of about 1 m to 2 m. A total of 130 species have been observed in this association.

The *Anthephoro pubescentis* – *Ziziphodetum mucronatae* represents the riverine woodlands (*sensu* Giess 1998). There are two types of drainage system on the farm, with dry washes, which contain water only for very short periods during rain storms, being most common. Geomorphologically they can be classified as very young river systems. In many cases the slope is relatively steep and the run-off very fast. They occur mostly on the plateau or at the edge of the plateau. Towards the centre of the farm, more mature rivers, like the Riet, Holz and Lewer, are responsible for drainage. There is a big dam near the farmhouse, where the water of these rivers is captured. These two different habitats support two different vegetation subassociations (5.1 and 5.2).

Although the vegetation of the riverbed and the riverbank differ, they were sampled as one for the purposes of this study and are thus included in the same plant association.

#### 5.1 *Ehretio albae* – *Ziziphodetosum mucronatae* subass. nov.

The typicum of this subassociation is relevé 2574, sampled at 24°32'34"S, 17°32'45"E on 11 May 2005 (Figure 4g). A total of 17 relevés belong to this subassociation. There are no diagnostic species for this association, but the following are constantly present: *S. uniplumis* var. *uniplumis*, *S. kalahariensis*, *L. cinereum*, *A. nebrownii*, *R. trichotomum*, *Limeum sulcatum*, *G. africana*, *B. foetida*, *E. cenchroides*, *G. flava*, *E. porosa* and *B. repens*. The structure is a low, open woodland (Figure 5), with the trees only 4 m – 5 m tall and shrubs reaching height of 1 m – 2 m. In this subassociation, 99 species have been recorded; on average 21 species occur per 1000 m<sup>2</sup>.

The *Ehretio albae* – *Ziziphodetosum mucronatae* occurs along the dry washes. Their slopes vary from steep to almost level (15°–20° and < 3°, respectively). Erosion is a common occurrence on the steeper slopes. Most of these dry washes start on top of the plateau and generally run eastward or southward to join the Riet, Holz and Lewer rivers. They are all typically ephemeral and are active only during and shortly after thunderstorms. Varied soil character is observed:



although most soils are very shallow, occasionally with big rocks, gravel and small stones also represent a common soil cover. At the base of the plateau some of the washes have deeper soils, which are also higher in nutrient content.

### 5.2 *Heteropogo contorti* – *Ziziphodetosum mucronatae* subass. nov.

This subassociation, with 13 relevés, is the typicum of the *Anthephoro pubescentis* – *Ziziphodetosum mucronatae* (Figure 4h). It is characterised by the presence of the diagnostic species *Heteropogon contortus*, *Cleome hirta*, *Kyphocarpa angustifolia* and *Senecio* sp. in addition to the diagnostic species defining the *Anthephoro pubescentis* – *Ziziphodetosum mucronatae*. These are also constantly accompanied by *Tephrosia dregeana*, *Otoptera burchellii*, *G. flava*, *Tribulus terrestris*, *Mollugo cerviana*, *Kohautia caespitosa* subsp. *brachyloba* and *Cenchrus ciliaris* (in addition to the constant species listed for the association). Owing to the higher moisture content in the soils, the trees grow up to 7 m tall, thus forming a short, open woodland with a tree cover of 2% (Figure 5). Species density is on average 28 species per 1000 m<sup>2</sup>, whilst a total of 109 species have been observed in this subassociation.

The *Heteropogo contorti* – *Ziziphodetosum mucronatae* occurs along the more mature rivers (Riet, Holz and Lewer). Their slopes are normally less than 3° and water remains standing in river pools for long periods. The soils in the riverbeds are normally rough gravels, which can be very stony with big rocks. The nutrient level in these gravels is low, but water content is usually relatively high. The soils of the river banks are sandy loams with a relatively high nutrient content, whilst the moisture content varies depending on the slope of the river.

### 6. *Zygophylo pubescentis* – *Leucosphaeretum bainesii* ass. nov.

The typicum for this association is relevé 2526, sampled at 24°32'34"S, 17°37'08"E on 10 March 2005 (Figure 4i). The association comprises 14 relevés and is characterised by the diagnostic species *Leucosphaera bainesii*, *Commiphora glandulosa*, *Zygophyllum pubescens*, *Stipagrostis obtusa* and *Eriocephalus pubescens*. These are constantly associated with *B. foetida*, *S. uniplumis* var. *uniplumis*, *R. trichotomum*, *C. alexandri*, *E. cenchroides*, *O. burchellii*, *Enneapogon desvauxii*, *Dicoma capensis* and *Tribulus* sp. The structure is a short, moderately closed shrubland (Figure 5), with shrubs standing approximately 0.5 m – 2 m tall and a canopy cover of about 10%, reaching up to 20%. Here, 65 species have been observed, with an average of 19 species per 1000 m<sup>2</sup>.

*Zygophylo pubescentis* – *Leucosphaeretum bainesii* is associated with shallow calcrete soils, either along the northern Haribes pan edge, as part of the flood plain system of larger rivers or on dolerite ridges. The soils are shallow (20 cm – 30 cm deep), whitish in colour and have a high clay content. The soils are expected to be alkaline with a pH of more than 7 (M. Coetzee, pers. comm., March 2010). Stone cover in the form of calcrete gravel and pebbles is often found mixed with medium to large dolerite blocks and can reach up to 80%.

Steep terraces, with slopes of between 5° and 10°, are formed along the pan edge.

### 7. *Monsonio umbellatae* – *Boscietum foetidae* ass. nov.

The typicum for this association is relevé 2632, sampled at 24°37'10"S, 17°37'03"E on 15 May 2005 (Figure 4j). This association was found on 17 plots in the study area. The occurrence of the low spreading forb *Monsonia umbellata* ('rabas') is characteristic of this association. In addition, the constant presence of *S. uniplumis* var. *uniplumis*, *R. trichotomum*, *C. alexandri*, *B. foetida*, *S. kalahariensis*, *Tribulus cristatus*, *Ptychotolobium biflorum* subsp. *biflorum*, *G. africana*, *E. desvauxii*, *D. capensis* and *T. dregeana* is typical for this association. The vegetation structure can be defined as a tall, open shrubland (Figure 5). The shrubs are between 0.5 m and 2 m high and represent less than 5% of the ground cover. Density is on average 17 species per 1000 m<sup>2</sup>, with a total of 67 species being observed in this association.

The *Monsonio umbellatae* – *Boscietum foetidae* typically occurs on the *torras* on the farm. *Torras* are defined as flat plains, with little or no internal relief, covered with reddish brown gravel on the surface (often more than 80%). The soils are loamy, with a crust, and with very low water infiltration capacity. This low water infiltration capacity results in patchy, near-banded vegetation, with run-off from the open patches feeding the vegetated patches (run-on). Similar vegetation patterns have been described as *brousse tigrée* in the Sahel (Boaler & Hodge 1962; Bromley *et al.* 1997; Couteron *et al.* 2000; Thiéry, D'Herbès & Valentin 1995) and banded *mulga* in arid Australia (Dunkerley 1997a, 1997b).

### 8. *Acacio senegal* – *Catophractetum alexandri* ass. nov.

The typicum for this association is relevé 2606, sampled at 24°32'31"S, 17°28'59"E on 13 May 2005 (Figure 4l). The association comprises 80 relevés. It is characterised by *Eragrostis nindensis* as characteristic species, with the following constant species: *S. uniplumis* var. *uniplumis*, *C. alexandri*, *B. foetida*, *L. cinereum*, *E. cenchroides*, *S. kalahariensis*, *Triraphis ramosissima*, *T. dregeana* and *Aristida adscensionis*. The structure is a typical tall, open shrubland, with shrubs of 1 m – 2 m in height, reaching a cover of about 5%. The total cover varies between 20% and 50%. Species density is on average 19 species per 1000 m<sup>2</sup>, whilst a total of 131 species have been recorded for this association. Two subassociations have been identified within this association.

#### 8.1 The *Schmidtio kalahariensis* – *Boscietosum foetidae* subass. nov.

The typicum of this subassociation is relevé 2546, sampled at 24°41'17"S, 17°34'54"E on 14 March 2005 (Figure 4k). This subassociation was represented by 28 relevés and is characterised by the following constant species: *S. uniplumis* var. *uniplumis*, *B. foetida*, *L. cinereum*, *R. trichotomum*, *C. alexandri*, *S. kalahariensis*, *E. cenchroides*, *Tribulus* sp., *D. capensis*, *A. nebrownii*, *T. dregeana* and *Aptosimum albomarginatum*. No characteristic species were identified. The structure is a tall, open shrubland (Figure 5), with a



shrub cover of less than 5%. Shrub height ranges between 0.5 m and 1.8 m. The species density is on average 18 species per 1000 m<sup>2</sup>, whilst a total of 87 species have been found in this subassociation.

The *Schmidtia kalahariensis* – *Boscietosum foetidae* occurs on flat plains and footslopes as well as on *ranteveld* proper and forms a transition between the *torras* and the *ranteveld*. These plains are underlain by sandstones of the Nababis formation. Fragments of these form the stone cover on the soil surface, ranging from gravel to medium-sized stones and covering up to 80% of the soil surface. The low vegetative cover indicates a tendency to degrade to a similar vegetation as the *Monsonio umbellatae* – *Boscietum foetidae* on the present *torras* (Figure 4j).

### 8.2 The *Acacio senegal* – *Catophractetosum alexandri* subass. nov.

This subassociation forms the typicum of the *Acacio senegal* – *Catophractetosum alexandri* (Figure 4l). A total of 52 relevés have been classified into this subassociation. It is characterised by *E. nindensis* as diagnostic species, with *S. uniplumis* var. *uniplumis*, *C. alexandri*, *B. foetida*, *L. cinereum*, *E. cenchroides*, *T. ramosissima*, *G. africana*, *S. kalahariensis*, *A. adscensionis*, *T. dregeana* and *Eragrostis porosa* as constant species. This subassociation forms a tall, open shrubland or occasionally a low bushveld (Figure 5), with shrubs of 0.5 m – 3 m tall. Occasional trees stand 4 m – 5 m tall. On average, 19 species have been found per 1000 m<sup>2</sup>, whilst the total species diversity is 105.

The *Acacio senegal* – *Catophractetosum alexandri* forms the *ranteveld* and occurs mainly in areas on top of the plateau. The plateau is dominated by very stony outcrops and small escarps (*rante*) of Nababis sandstone. The soils are leptosols, red in colour and very shallow, of moderately coarse to medium texture, with many coarse fragments and well drained. The surface layer is typically 10 cm – 20 cm thick. These soils have a moderate hydraulic conductivity and present a moderate infiltration rate with a low water holding capacity (ICC *et al.* 2000). The landscape is relatively flat on top of the plateau, but forms occasional low hills and an escarpment area to the west of the farm, with steep-sloped ravines in between.

### Vegetation mapping

It was not possible to map all vegetation types, for several reasons. Firstly, many units are just too small to map with the 30-m ground resolution of Landsat 7 ETM satellite images. This holds true for the two vle communities, *E. rotifer* – *L. fusca* and *C. obtusifolia* – *L. fusca*, as well as the *Zygophylo pubescentis* – *Leucosphaeretum bainesii*, which occurs on ridges with very limited spatial extent.

Differentiating between the *Monsonio umbellatae* – *Boscietum foetidae* and the *Schmidtia kalahariensis* – *Boscietosum foetidae* proved extremely difficult owing to their similar structures and especially similar low vegetative cover. For this reason, a landscape map was produced (Figure 6) to differentiate between plains and *torras*, and *ranteveld*. Table 1 lists the

mapped landscapes, their spatial extent and their included vegetation associations or subassociations.

## Discussion

Four distinct higher syntaxonomic groupings can be recognised, namely the saline pans and associated hummock dunes (as represented by the *Lycio cinereum* – *Salsolium* and the *Salsolo* – *Tetragonietum schenckii*), the wetlands (as represented by the two vle communities), the river systems (as represented by the *Antheophoro pubescentis* – *Ziziphodetum mucronatae*) and the surrounding plateaus (as represented by the *Zygophylo pubescentis* – *Leucosphaeretum bainesii*, the *Monsonio umbellatae* – *Boscietum foetidae* and the *Acacio senegal* – *Catophractetosum alexandri*). Unfortunately the data set is too limited to define and describe such higher syntaxonomic levels at this stage. Volk and Leippert (1971) refer to the class *Rhigozetea* as representing the larger dwarf shrub savanna of southern Namibia; this encompasses all those syntaxa containing *R. trichotomum* (i.e. specifically the latter grouping).

Giess (1998) superficially described the Dwarf shrub savanna, as follows:

Characteristic for the greatest part is *Rhigozum trichotomum* (...). *Parkinsonia africana*, *Acacia nebrownii*, *Boscia foetida* subsp. *foetida*, *B[oscia] abitrunca* var. *albitrunca* and *Catophractes alexandri* as well as Karoo bushes such as *Pentzia* spp., *Eriocephalus* spp., and others are typical for this vegetation type. (Giess 1998)

This description is illustrated with three plates. Yet the *Acacio senegal* – *Catophractetosum alexandri* has a too tall structure (2 m – 3 m) to be regarded as true dwarf shrub savanna. Within the broader Nama-Karoo (of which Giess' dwarf shrub savanna forms the northern extent), the *Acacio senegal* – *Catophractetosum alexandri* can structurally be compared to the *Acacia mellifera* open shrubland of the Blouputs karroid thornveld as described for the Augrabies Falls National Park (Bezuidenhout 1996; Mucina & Rutherford 2006). However, the shrub component here is dominated by *A. mellifera* subsp. *detinens*, a species rarely found in the *Acacio senegal* – *Catophractetosum alexandri*. In this respect, the *Acacio senegal* – *Catophractetosum alexandri* is to be regarded as a xeric outlier of the highland savanna (*sensu* Giess 1998). The rocky habitat with shallow soils, and often steep slopes, is similar in both vegetation types.

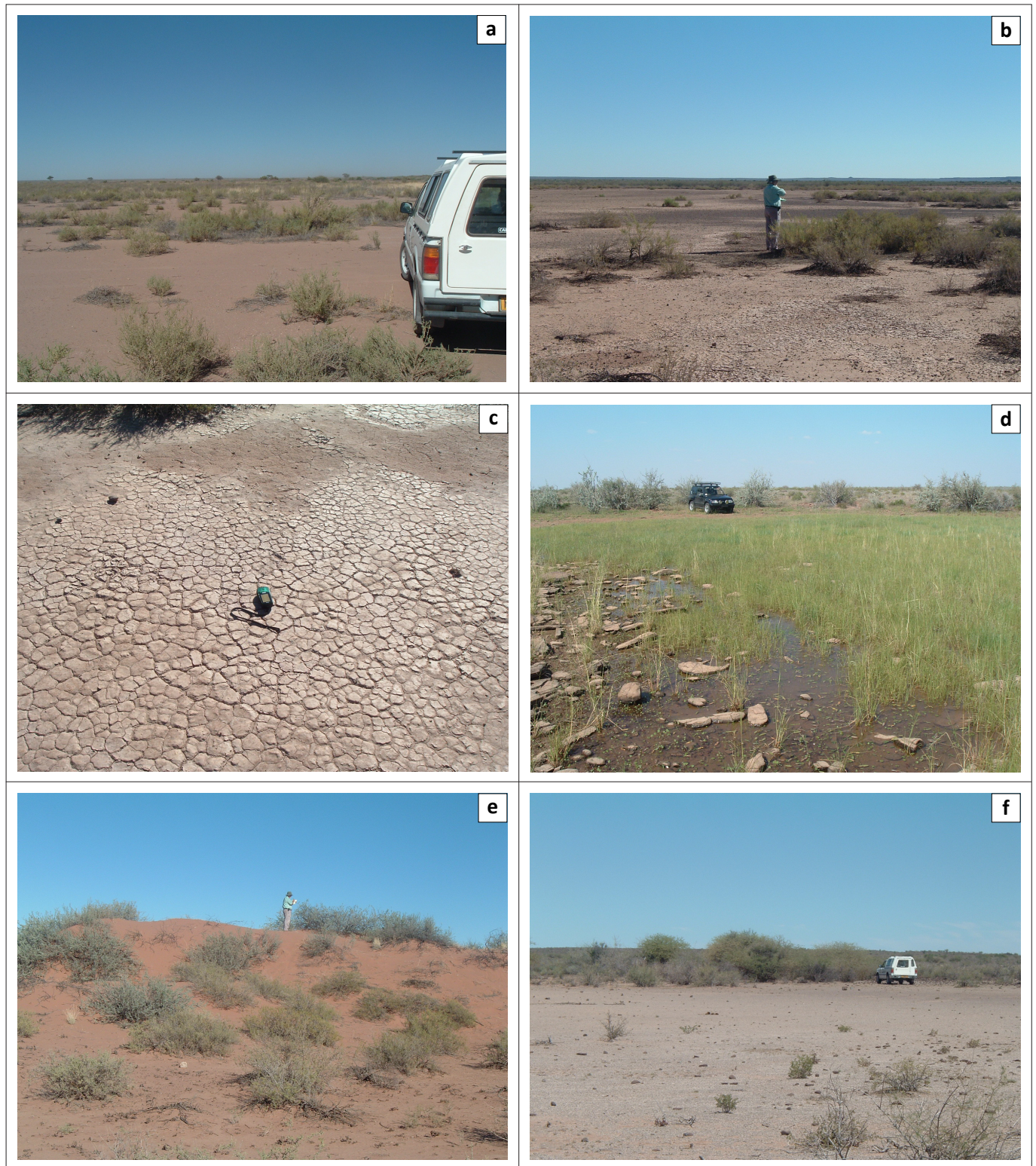
The *Salsolo* – *Tetragonietum schenckii* resembles the Saline desert and dwarf shrub savanna fringe (*sensu* Giess 1998) described for the Etosha pan. Here the structure of the hummock dune vegetation can specifically be compared to the Okondeka duneveld (Le Roux 1980). However, the composition varies widely, with *T. schenckii* not occurring in northern Namibia. For the *Lycio cinereum* – *Salsolium* no comparable vegetation type is known. It is likely that these, in a future synopsis of syntaxa, will form a class on their own.

The very close relationship between the *Monsonio umbellatae* – *Boscietum foetidae* and the two subassociations of the



*Acacio senegal* – *Catophractetum alexandri* is well illustrated in the ordination diagram in Figure 3b. This leads to the assumption that these three units form degradation stages of one another:

*Acacio senegal* – *Catophractetum alexandri* degrading to *Schmidtio kalahariensis* – *Boscietosum foetidae*, and in very extreme cases (possibly also owing to soil degradation

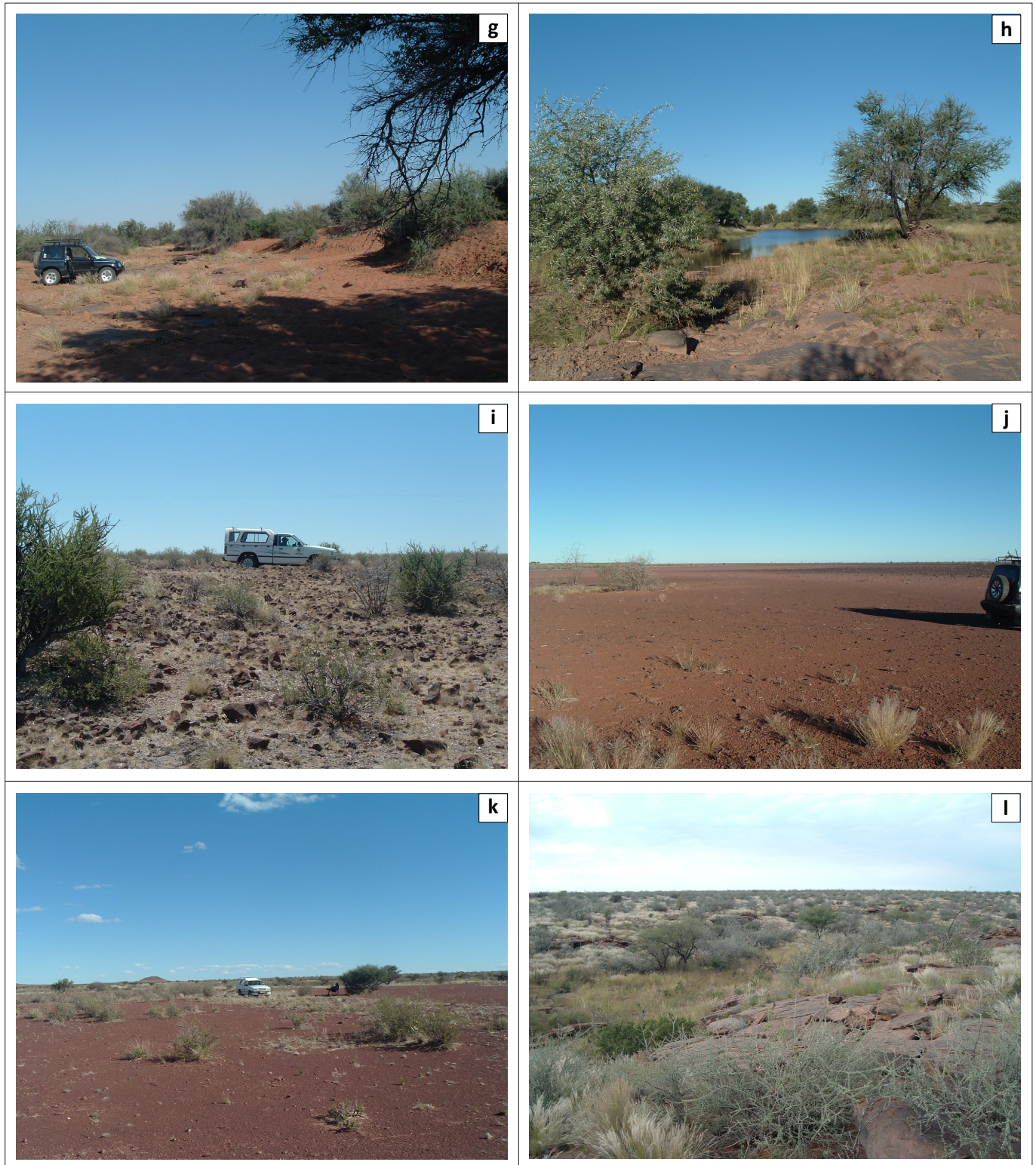


(a) The *Zygophylo simplicis* – *Salsoletum* on the outer fringes of the Haribes pan at plot 2518; (b) The *Lycio cinereum* – *Salsoletum* at the centre of the pan at plot 2514; (c) Soil capping on the Haribes pan. The distinctive pattern indicates a degree of salinisation; (d) The *Eragrostis rotifer* – *Leptochloa fusca* vlei community, as seen at plot 2599; (e) The *Salsolo* – *Tetragonietum schenckii* on low hummock dunes, as seen at plot 2501; (f) The *Cullen obtusifolia* – *Leptochloa fusca* vlei community, as seen at plot 2674; (g) The *Ehretia alba* – *Ziziphodetum mucronatae* along the smaller washes, here at plot 2574; (h) The *Heteropogo contorti* – *Ziziphodetum mucronatae* along the Riet River at plot 2649; (i) The *Zygophylo pubescentis* – *Leucosphaeretum bainesii* at plot 2526; (j) The *Monsonio umbellatae* – *Boscietum foetidae* on torras at plot 2632; (k) The *Schmidtio kalahariensis* – *Boscietosum foetidae* on plains as seen at plot 2546; (l) The *Acacio senegal* – *Catophractetum alexandri* on the ranteveld at plot 2606.

**FIGURE 4:** Typical vegetation at different sampling sites on the farm Haribes.

Figure 4 continues on the next page →





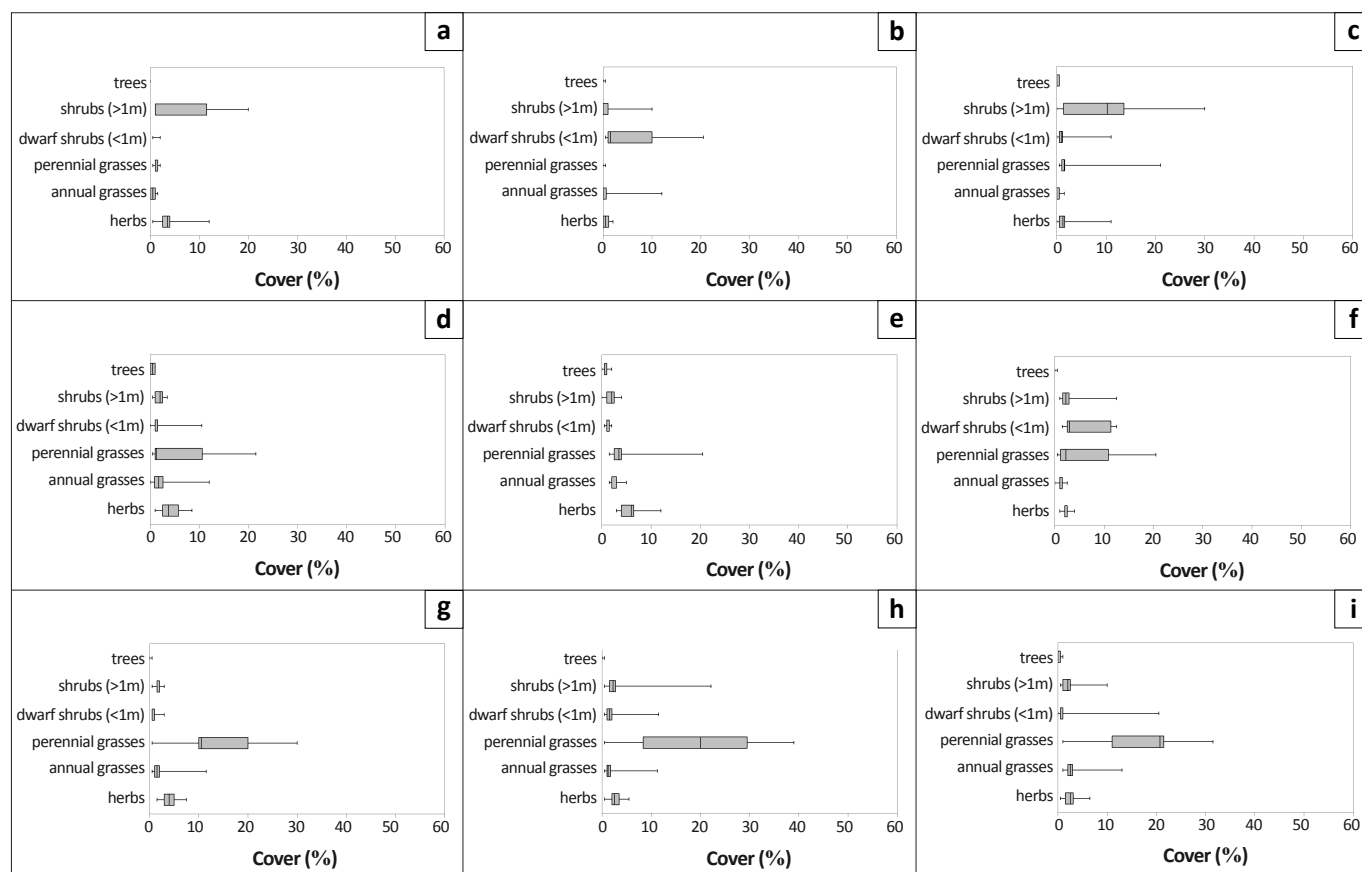
(a) The *Zygophylo simplicis* – *Salsolietum* on the outer fringes of the Haribes pan at plot 2518; (b) The *Lycio cinereum* – *Salsolietum* at the centre of the pan at plot 2514; (c) Soil capping on the Haribes pan. The distinctive pattern indicates a degree of salinisation; (d) The *Eragrostis rotifer* – *Leptochloa fusca vlei* community, as seen at plot 2599; (e) The *Salsolo* – *Tetragonietum schenckii* on low hummock dunes, as seen at plot 2501; (f) The *Cullen obtusifolia* – *Leptochloa fusca vlei* community, as seen at plot 2674; (g) The *Ehretia alba* – *Ziziphodetosum mucronatae* along the smaller washes, here at plot 2574; (h) The *Heteropogo contorti* – *Ziziphodetosum mucronatae* along the Riet River at plot 2649; (i) The *Zygophylo pubescentis* – *Leucosphaeretum bainesii* at plot 2526; (j) The *Monsonio umbellatae* – *Boscietum foetidiae* on torras at plot 2632; (k) The *Schmidtia kalahariensis* – *Boscietum foetidiae* on plains as seen at plot 2546; (l) The *Acacia senegal* – *Catophractetosum alexandri* on the ranteveld at plot 2606.

**FIGURE 4 (Continues...):** Typical vegetation at different sampling sites on the farm Haribes.

processes such as erosion and capping) to *Monsonio umbellatae* – *Boscietum foetidiae*. This hypothesis needs to be tested and described in a paper in which dynamic trends are considered.

With reference to biodiversity patterns, species density is comparable to other descriptions within the Nama-Karoo biome in southern Namibia. The Nico observatories (Nico





The numbers represent the community numbers, as used in the description of the vegetation types. (a)1.1; (b) 1.2; (c) 3; (d) 5.1; (e) 5.2; (f) 6; (g) 7; (h) 8.1; (i) 8.2.

**FIGURE 5:** Box-and-whisker plots of the various structural components for each of the described associations or subassociations.

**TABLE 1:** Landscapes and associated vegetation associations or subassociations on the farm Haribes.

Landscape	Vegetation association or subassociation	Area (ha)	Area (%)
Pan	<i>Lycio cinereum</i> – <i>Salsolium</i>	3 711.2	6.69
Hummock dunes	<i>Salsola</i> – <i>Tetragonietum schenckii</i>	3 774.4	6.80
Plains and torras	<i>Monsonio umbellatae</i> – <i>Boscietum foetidae</i> as well as <i>Schmidtio kalahariensis</i> – <i>Boscietum foetidae</i>	5 410.7	9.75
Ranteveld	<i>Acacio senegal</i> – <i>Catophractetum alexandri</i>	41 739.0	75.22
Rivers	<i>Antheophoro pubescentis</i> – <i>Ziziphodetum mucronatae</i>	820.0	1.48
Dam	–	31.9	0.06

North and Nico South) of the BIOTA Southern Africa project are the nearest to Haribes and are also situated on relatively stony soil, albeit of origin from the Dwyka formation (Geological Survey 1980). The Nico observatories display an average of 21 and 20 species per 1000 m<sup>2</sup>, respectively (Jürgens *et al.* 2010), compared with the 17–19 species per 1000 m<sup>2</sup> for the *Zygophylo pubescentis* – *Leucosphaerum bainesii*, *Monsonio umbellatae* – *Boscietum foetidae* and *Acacio senegal* – *Catophractetum alexandri*. The slightly lower values observed during the current study can be related to the survey being conducted during a single, comparatively dry year, whilst the Nico observatories had been resurveyed over a period of seven years (but unfortunately not in 2005). However, the overall number of species observed at Haribes (218) is higher than the total number of species observed at both Nico North (166) and Nico South (204). This can, in turn, be attributed to the fact that the area sampled at Haribes is far bigger and more diverse than the 1 km<sup>2</sup> sample areas of the BIOTA observatories. Comparing the *Zygophylo pubescentis*

– *Leucosphaerum bainesii* to the Narais and Duruchaus observatories, which also have shallow soils on calcretes (thus a comparable edaphic habitat), a far lower species density was observed (19 vs 36–37 per 1000 m<sup>2</sup>). The climatic environment at the Narais and Duruchaus observatories is, however, far more moist, with a mean annual rainfall of 289 mm (Jürgens *et al.* 2010).

## Conclusion

Haribes is unlikely ever to become a conservation area. On the contrary, the recent change in ownership also introduces an entirely different land use, with the farm being targeted for resettlement. Some 13 families have already been resettled on small parcels of the farm, each ranging between 1700 ha and 7500 ha (Cloete 2010b; Kleinhans 2010). These units, meant to support the livelihoods of these families (Werner & Odendaal 2010), have been calculated according to grazing capacity maps from the 1970s (Department Landbou

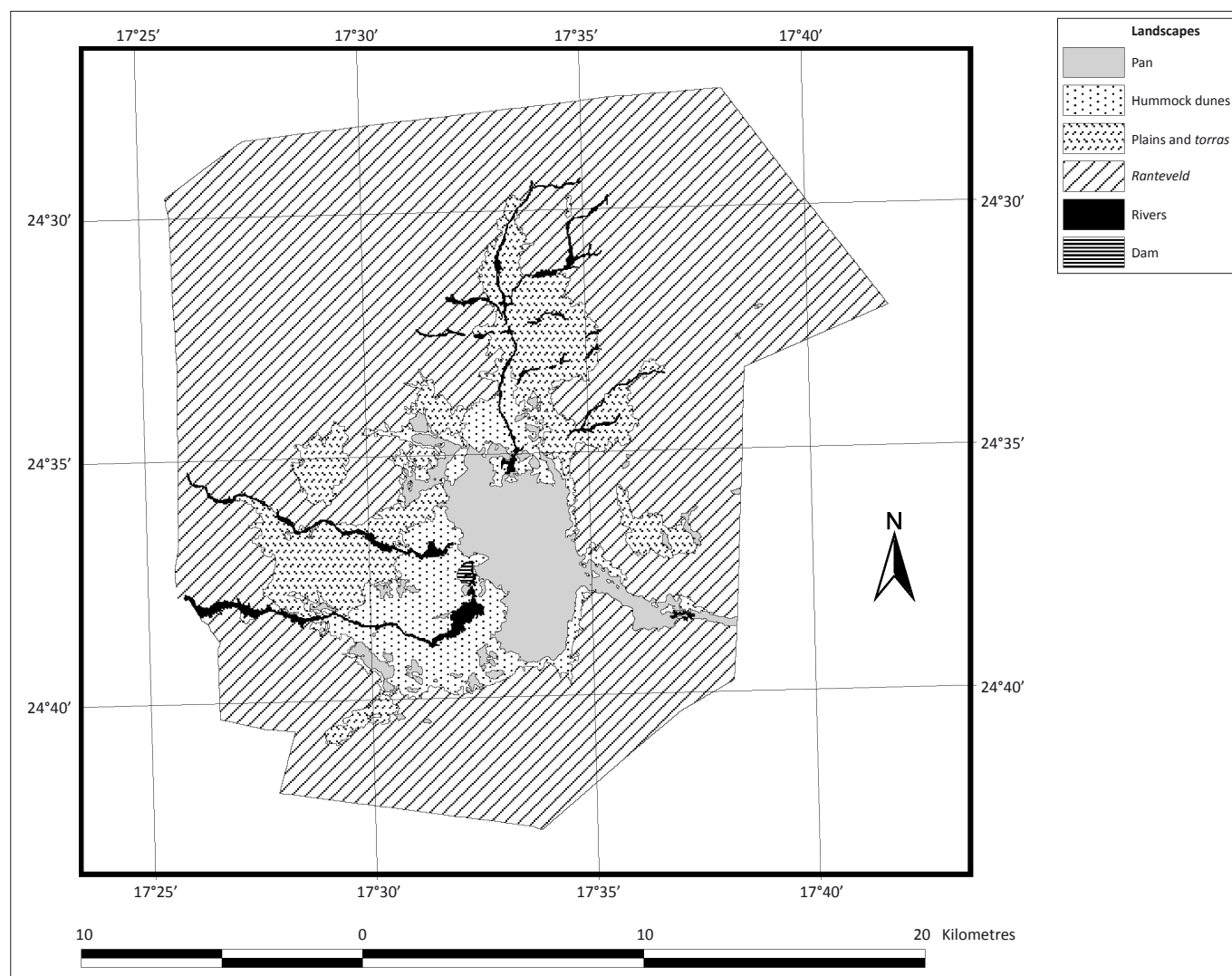


FIGURE 6: Map of the major landscapes on the farm Haribes.

Tegniese Dienste 1979). However, the general indications are that the grazing capacity has drastically reduced throughout the entire country over the past decades (Espach *et al.* 2010). This is due to a multitude of factors generally associated with land degradation [e.g. bush encroachment (De Klerk 2004)]. It is thus unlikely that these small farming units will be sustainable and severe degradation of grazing resources may result (Werner & Odendaal 2010).

Within the Nama-Karoo biome in Namibia, livestock farming depends mainly on browsing of dwarf shrub species (Espach *et al.* 2006), with grazing playing a secondary role. This does not hold true for Haribes. A comparison of the shrub, dwarf shrub, grass and total vegetation cover of the various associations (Figure 5) shows that farming on Haribes is more dependent on grazing than browsing. The pans and surrounding dunes are mostly covered by shrubs dominated by *Salsola* spp. and *T. schenckii*, which are both known to be poisonous (Mannheimer, Marais & Schubert 2008). This makes roughly 13% of the farm unsuitable for grazing. The *Zygophylo pubescentis* – *Leucosphaeretum bainsii* on the calcrete ridges provide some dwarf shrub browse, but is very

limited in extent. The *Monsonio umbellatae* – *Boscietum foetidae* (torras) and the *Acacio senegal* – *Catophractetum alexandri* (ranteveld) provide the main grazing resources on the farm. However, as pointed out in the discussion, these seem to form a degradation gradient from each other; thus, extensive overgrazing will lead to desert-like torra plains.

Global climate change has been identified as a reality in recent years. Temperature increases coupled with less precipitation, in more erratic events, are predicted for southern Africa (Parry *et al.* 2007). Based on these forecasts, it is predicted that large parts of southern Namibia will become unsuitable for livestock farming, as it will turn into a virtual desert (Midgley *et al.* 2005). Similar scenarios have been developed for the Kalahari basin, with forecasts of remobilisation of sand dunes as far north as southern Angola (Thomas, Knight & Wiggs 2005). In addition, a human-induced drought, as described for other Nama-Karoo regions (Booyesen & Rowsell 1983), threatens. This is aggravated by the fact that farming on Haribes depends largely on grazing, meaning that protection of the perennial grass cover is essential for sustainable use of the farm in the long term. Perennial grasses have been shown





to be able to withstand prolonged droughts (i.e. periods of below-normal precipitation), but are unable to withstand heavy grazing together with arid conditions (O'Connor 1991, 1994). It is thus likely that overgrazing in the *ranteveld* may lead to a composition (and vegetation cover) similar to that of the present *torras*. When planning the redistribution of the farm Haribes, it should be kept in mind that only 75% of the farm (the *ranteveld*) provides adequate grazing and that even this grazing needs to be utilised judiciously to prevent severe degradation to desert-like conditions.

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## Competing interests

The authors declare that they have no financial or personal relationship(s) which may have inappropriately influenced them in writing this paper.

## Authors' contributions

B.J.S. (National Botanical Research Institute) initiated the project. W.J.J. (School of Natural Resources and Tourism) was responsible for the vegetation surveys and the habitat and structural descriptions of the associations, whilst B.J.S. (National Botanical Research Institute) was responsible for data analysis, diagnostic descriptions of the associations, and mapping.

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