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A baseline description of the soils and vegetation of Farm Klein Boesman, Khomas Region, Namibia

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ABSTRACT

The Farm Klein Boesman, south of Dordabis in the Khomas Region of Central Namibia, is situated on the ecotone between the Central Highlands/Central Plateau and the southern Kalahari. Whereas a considerable amount of information is available for the Kalahari Duneveld in South Africa, little is known of the same ecosystem in Namibia, specifically the northern extent of this ecosystem. We stratified the farm according to visible terrain features identified on aerial images, aided by a Shuttle Radar Topography Mission (SRTM) digital terrain model. Based on these initial stratification units, 35 minipits and/or soil augerings were done to sample the typical soil units. From these, soil samples were analysed for soil chemical and physical properties. In addition, 158 relevés were compiled across all initial stratification units. These were classified with modified Two-Way Indicator Species Analysis (TWINSPAN) using a synusial approach. From the results we described and mapped twelve landform and ten soil units, as well as six vegetation associations, of which two were subdivided into two and three subassociations each. We compare these associations with related vegetation types described in the Khomas Hochland as well as in the Kalahari Gemsbok National Park (KGNP) in South Africa. Although several similarities to units described for the KGNP were identified, several discrepancies were also identified, necessitating a thorough revision of the vegetation descriptions for the greater southern Kalahari.

Keywords: Dordabis mountainveld; Kalahari Duneveld; Namibia; phytosociology; soil characterisation; soil and terrain mapping; southern Kalahari; vegetation

INTRODUCTION

The Vegetation Survey of Namibia project as well as the Agro-Ecological Zoning (AEZ) project were initiated to provide much-needed baseline information for land-use planning purposes (De Pauw & Coetzee 1998, Strohbach 2001). Both projects followed an approach of both small-scale (nationwide or regional) overview mapping, as well as large-scale mapping of smaller areas (e.g. at farm level) to highlight specific features. In this sense, the AEZ project produced an initial Agro-ecological Zones (AEZ) and later a soils map for Namibia (De Pauw et al. 1998, ICC et al. 2000), whilst at a local scale the soils of several research stations of the Ministry of Agriculture, Water and Forestry were mapped (Coetzee et al. 1998, Kutuahupira et al. 2001a, b). Likewise, for the Vegetation Survey of Namibia project, regional descriptions and maps were completed for the Omusati and Oshana regions, the Central Namib, the Eastern Communal Areas and Namaland (Kangombe 2010, Jürgens et al. 2013, Strohbach 2014a, Strohbach & Kutuahupira 2014, Mbeeli 2018), whilst several large-scale studies have been published for Alex Muranda Livestock Development Center (Kavango West), Haribes (Hardap), Auas-Oanob Conservancy (Khomas) and Erichsfelde (Otjozondjupa) (Strohbach & Petersen 2007, Strohbach & Jankowitz 2012, Strohbach 2017, Strohbach 2019).

The Farm Klein Boesman south of Dordabis afforded the opportunity for a combined large-scale soil- and vegetation survey. The farm is of interest as it forms a transition between the Central Plateau and the Kalahari basin (in the sense of agro-ecological zones - De Pauw et al. 1998), as well as an ecotone between the Highland Savanna and mixed Tree- and Dwarf shrub savanna/southern Kalahari *sensu* Giess (1998). The mountainveld to the south-east of Windhoek had been described by Volk & Leippert (1971), but we regard the Dordabis Mountainveld as far more arid than the mountains south of the Auas Mountain Range. Likewise, a fair amount of information is available for the Kalahari Duneveld *sensu* Mucina & Rutherford (2006) in South Africa, in particular the Kalahari Gemsbok National Park (Leistner 1959, Leistner & Werger 1973, Van Rooyen et al. 1991a, Van Rooyen & Van Rooyen 1998, Van Rooyen et al. 2008, Van Rooyen 2008). Very little is however known from the same ecosystem in Namibia, in particular the northern extent of this ecosystem.

METHODS

Study area

The farm Klein Boesman (FMM/58/2) is situated south of Dordabis in the Khomas Region in central Namibia, near the M33 road between Dordabis and Uhlenhorst (Figure 1). The farm is 2196 ha in size and was split off the farm Compromise (FMM/58/1 and FMM/58/REM) in the 1990s. It has been used as a cattle farm with extensive rotational grazing.

Klein Boesman lies within agro-ecological zone (AEZ) CPL5 – a 'flat plain on metamorphic rock, of the Central Plateaux' (De Pauw et al. 1998). To the south, this is bordered by the Rooirand mountain, part of the Kamtsas formation (Geological Survey 1980), designated as AEZ 'R' – 'undifferentiated rocky hills and inselberg mountains'. South of the Rooirand and Klein Boesman, the AEZ is 'Kalahari Sand Plateau with longitudinal dunes in Growing Period Zone 2' (KAL 2-7) (De Pauw et al. 1998). Although Klein Boesman lies outside KAL 2-7, Kalahari sands dominate the plains habitats of the farm (Figure 2).

The climate of Klein Boesman is a typical subtropical steppe climate following Köppen (1936). On average, precipitation is 260 mm per annum, falling as summer rainfall between December and April, with a coefficient of variation of more than 50%. Frost can occur during the winter months (May to August), with between 20 and 30 frost days a year (Mendelsohn et al. 2002). The average growing period is limited to 41 to 60 days, with no dependable growing period (Coetzee 1998, De Pauw et al. 1998). The vegetation forms an ecotone between the Highland Savanna and the Mixed Tree and Shrub Savanna (southern Kalahari) *sensu* Giess (1998).

Initial stratification

Preliminary landform units were mapped with QGIS software (QGIS 3.2.0-Bonn 2018) by visual interpretation, based on colour and texture differences, using Bing Maps – Aerial (Microsoft, 2019) satellite image, and terrain analysis using the Shuttle Radar Topography Mission (SRTM) 1 arc second digital elevation data (NASA JPL 2013). These preliminary units were used for a stratified systematic sampling approach for both soil- and vegetation surveys (Figure 3)

Landform and soil mapping

Visual and augering observations of the landforms and soils of the farm were followed by full site and soil profile descriptions at 35 points (Figure 3), using the FAO Guidelines for Soil Profile Description

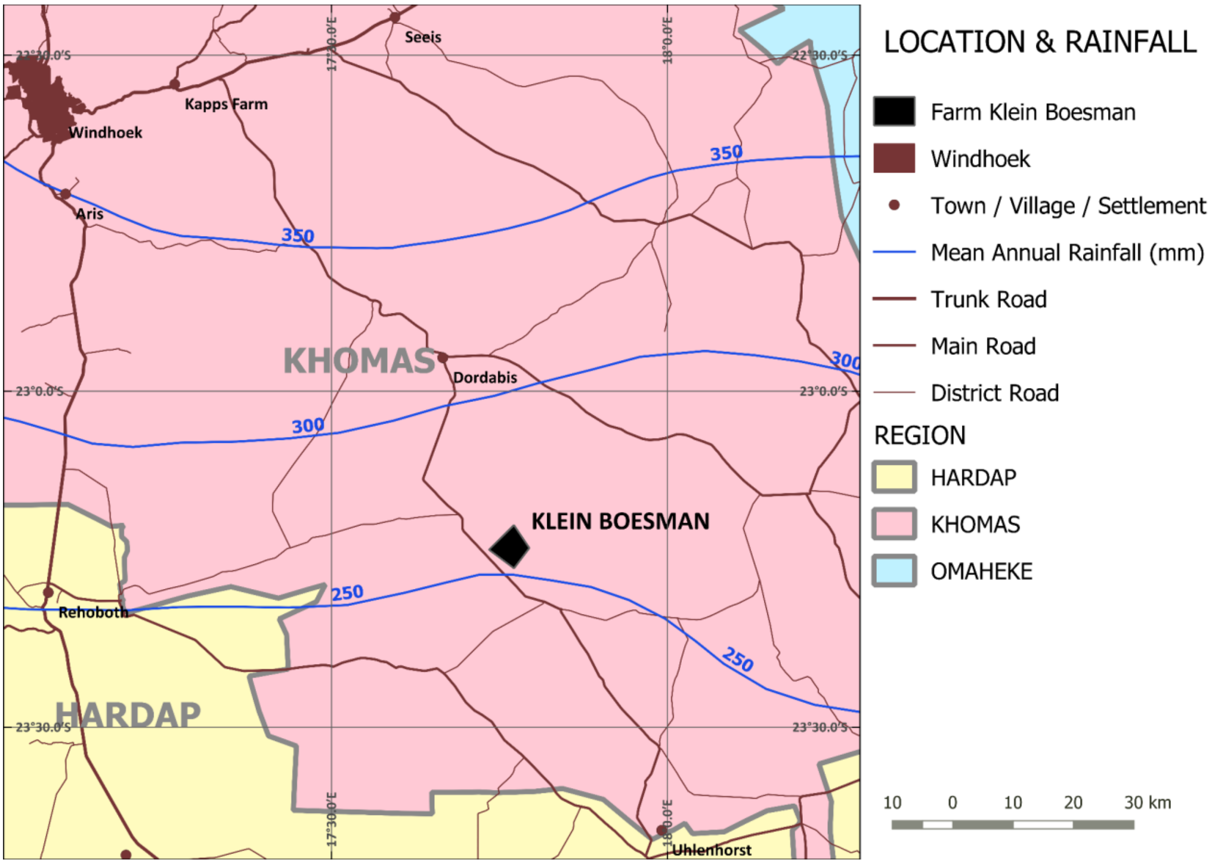

***Figure 1**: Location of farm Klein Boesman in south-eastern Khomas Region, in relation to long-term mean annual rainfall. Data sources: NARIS (2001); Office of the Surveyor General (2019).*

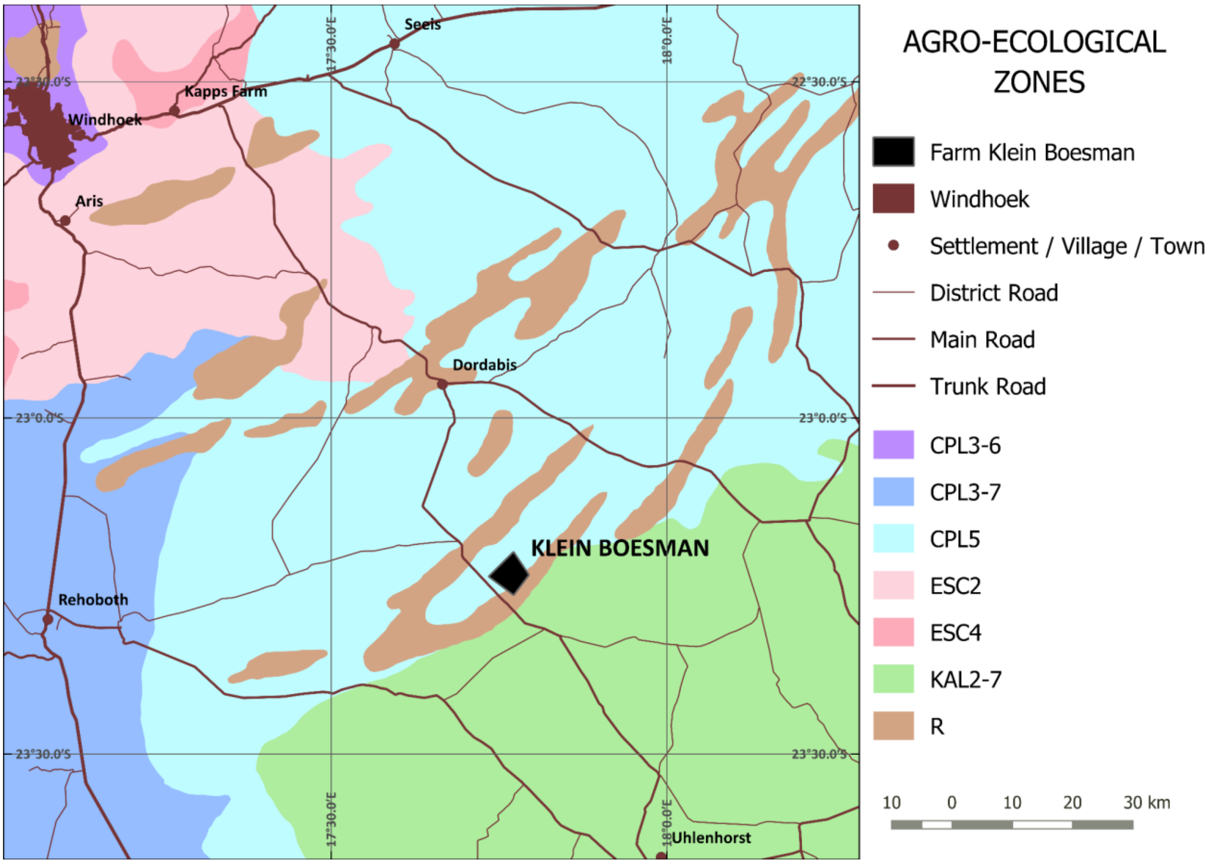

Figure 2*: Location of farm Klein Boesman, in relation to agro-ecological zones. Data sources: De Pauw et al. (1998); NARIS (2001); Office of the Surveyor General (2019).*

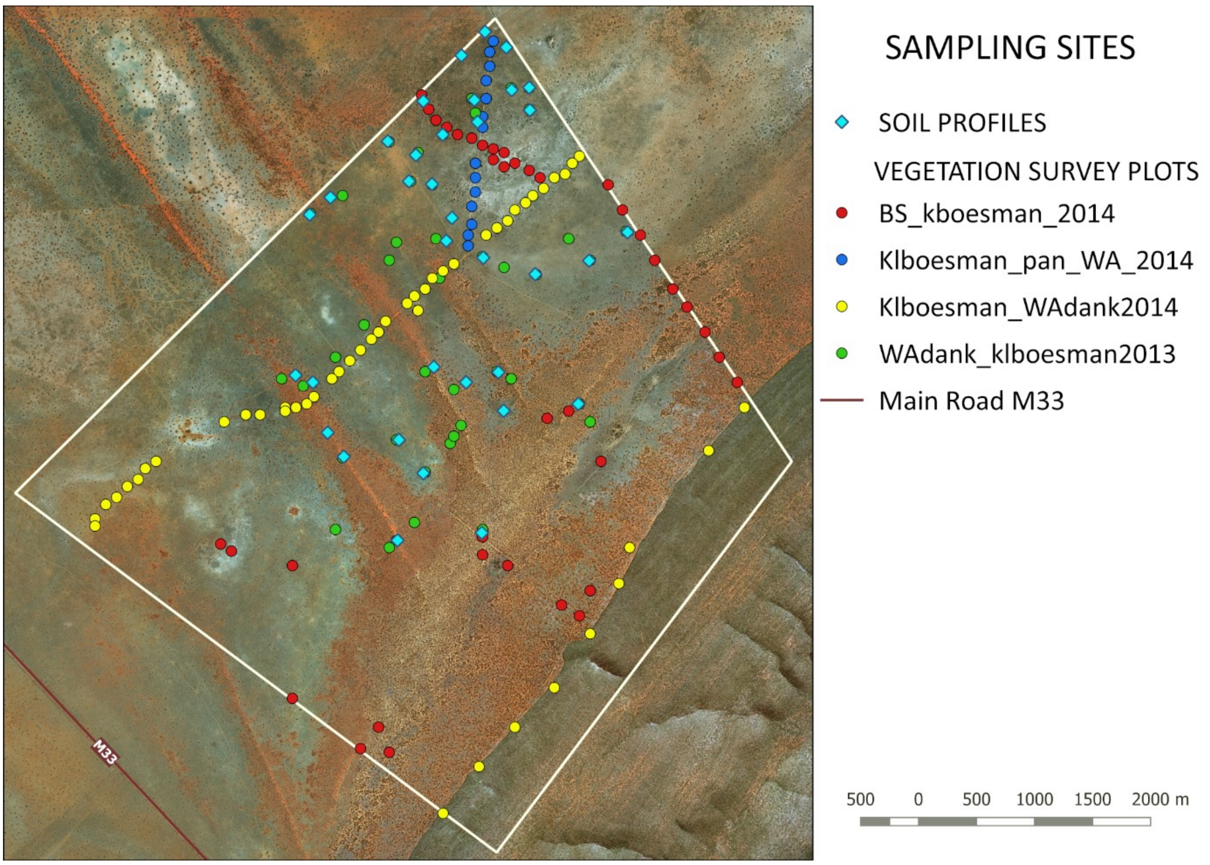

Figure 3*: Location of vegetation and soil sampling sites. Data sources: Microsoft (2019); Office of the Surveyor General (2019).*

(FAO 2006). Soil colour was determined with Munsell Soil Colour Charts (Munsell Color 2010). Chemical and physical analysis of 70 soil samples – 30 from A horizons and 40 from B horizons – were carried out by the Agricultural Laboratory of the Namibian Ministry of Agriculture, Water and Forestry, using their standard operating procedures (MAWF 2000). Samples were analysed for pH(H_2O); electrical conductivity; organic carbon; plant available phosphorus, potassium, calcium, magnesium and sodium; percentages sand, silt and clay; and an estimation of carbonates. Preliminary landform and soil mapping units were verified by ground observation and augerings, and adjustments made to unit boundaries and preliminary classes.

Vegetation surveys

Surveying followed the general method employed for the Vegetation Survey of Namibia project (Strohbach 2001, 2014b). At each survey plot (Figure 3) of 20 m x 50 m, a Braun-Blanquet type relevé was compiled. All vascular plant species occurring were noted down, as well as their typical growth forms and estimated crown cover. Habitat descriptors included the position by way of a GPS-reading, the landforms, local topography, slope and aspect, lithology, degradation indicators, as well as a photograph. Unknown species and reference specimens were collected, identified and deposited at the National Herbarium of Namibia (WIND). Nomenclature follows Klaassen & Kwembeya (2013) throughout. The relevé data were captured on TurboVeg (Hennekens & Schaminée 2001) as four different subsets of GIVD AF-NA-001 (Strohbach & Kangombe 2012) (Table 1). Data was cleaned following procedures described by Strohbach (2014b) prior to classification and mapping.

Data analysis

As considerable observer bias, combined with seasonal bias (see seasonal rainfall in Table 1), was evident, it was decided to reduce the matrix for classification to phanerophytes, chamaephytes and graminoids only (i.e. the main components of a savanna ecosystem). Non-graminoid forbs, specifically ephemeral forbs, were removed. This follows the synusial approach of vegetation classification described by Gillet & Julve (2018) (i.e. a classification using only some (semi-permanent) components of the floristic composition rather than including all species as per classical Braun-Blanquet approach). In addition, the growth form data were ignored (i.e. different growth forms of individual species combined). The matrix used for classification thus consisted of 158 relevés and 75 species. Classification was done with Modified Two-Way Indicator Species Analysis (TWINSPAN) within the Juice package (Tichý 2002, Roleček et al. 2009), using average Sørensen as distance measure without any pseudospecies. Classification was stopped after eight clusters were formed, giving the ecologically best interpretable results.

During analysis, it was found that cluster 3 (the *Acacia mellifera–Acacia erioloba* association) represented two structurally distinct units, on different habitats. These could not be differentiated purely on species composition. Therefore, the relevés for cluster 3 were re-extracted from the database with full growth form data. Again a synusial classification was done using Modified TWINSPAN and average Sørensen as distance measure. However, for this classification, pseudospecies cut levels were set at 0, 5 and 20%. With these pseudespecies levels, the units dominated by *Acacia erioloba* trees could easily be differentiated from units dominated by *Acacia mellifera* shrubs, and thus also differentiating between the two structural types.

Table 1: *Metadata for the GIVD AF-NA-001 data subsets used for this study, as shown in Figure 3.*

Surveyor	Data sets	Relevé sequence numbers	Number of relevés	Survey dates	Rainfall for season (September to August)
Jankowitz & Adank	WAdank_klboesman2013 (initial reconnaissance survey)	11424 – 11434	11	February & May 2012	342 mm
Jankowitz & Adank	WAdank_klboesman2013 (survey of main habitats)	11435 – 11474	40	April & May 2013	56 mm
Jankowitz & Adank	Klboesman_WAdank2014 (cross-section of farm)	11915 – 11968	53	April 2014	246 mm
Strohbach	BS_klboesman_2014 (cross-section of pan and gap-filling survey)	11746 – 11786	40	April 2014	246 mm
Jankowitz & Adank	Klboesman_pan_WA_2014 (cross-section of pan)	2161 – 2174	14	April 2014	246 mm

From the final classification, a phytosociological and a synoptic table were created, using the original full matrix with 240 species (including herbs and forbs). Diagnostic species were determined using the phi co-efficient of association (Chytrý et al. 2002). For this calculation the numbers of relevés were standardised following Tichý & Chytrý (2006). Species with phi≥40 were considered as diagnostic and with phi≥60 as highly diagnostic; however, species with a non-significant fidelity at $\alpha=0.05$ using Fisher's exact test were omitted. Species occurring with at least a 60% frequency were regarded as constant and with at least an 80% frequency as highly constant.

Box-and-Whisker plots were constructed to illustrate the structure for each grouping (i.e. tree, shrub, dwarf shrub, perennial grass, annual grass and herb cover), using available growth form data. Description of the vegetation structure follows Edwards (1983). The Shannon Index (as an index of evenness) ($H'=-\Sigma p_i \ln p_i$) and Simpson's Index (as an index of dominance) ($D=\Sigma(n/N)^2$) (Peet 1974) were calculated for each relevé using Juice (Tichý et al. 2011).

Vegetation Mapping

The landform and soil maps were used as a baseline for the vegetation map. Soil mapping units were assigned to specific vegetation associations based on the positions of the classified relevé data. In some cases, the mapping units had to be adjusted based on the findings of the vegetation classification results. This was done by visual interpretation of Bing Maps – Aerial (Microsoft 2019) satellite images and adjusting the digitised mapping units.

RESULTS

Landforms and soils

The landscape is dominated by a quarzite ridge (the Rooirand) along the south-eastern border of the farm as part of the Kamtsas formation of the Nosib group (Geological Survey 1980, Killick 1983). This ridge rises to 1605 m above mean sea level at its highest peak on the SE corner of the farm, or 206 m above the lowest point of the surrounding plain (NASA JPL 2013). The plains to the north of this ridge are extensively covered by wind-deposited sands of the adjacent southern Kalahari, forming a series of dunes in the typical NW-SE orientation (Bullard et al. 1995). These rise to between 15 and 33 m (highest is 43 m) above the surrounding plain (NASA JPL 2013). Parallel to the quartzite ridge, a low-angle (3-6% slope) sand ramp has formed (Lancaster & Tchakerian 1996, Rowell et al. 2017). In the far north-eastern corner of the farm, limestones of the Buschmannsklippe Formation of the Kuibis subgroup are covered by a thin soil veneer (Geological Survey 1980, South African Committee for Stratigraphy 1980, Hegenberger 1993). Here, a pan has formed through deflation. The blown-out material had been deposited to the south as a low lunette dune, grading into the more acidic sands of the Kalahari dunes (Hipondoka et al. 2004, Wang et al. 2007, Bhattachan et al. 2015).

Twelve landforms were identified (Figure 4): mountain (quartzite ridge), dune crest; dune slope; dune footslope; interdune valley; plain; sand drift plain; sand ramp; pan; pan rim; depression; lunette dune. Footslopes grade into interdune valleys, locally known as 'streets'. A sand ramp lies between the northwest-southeast trending linear dunes and the north-western flank of the mountain. The large pan in the northeast quadrant grades into a shallow lunette dune to the south. The western corner of the farm is a sandy plain with shallow (<25 cm) to moderately deep (25-50 cm) sand cover and a shallow depression. Two other small depressions occur in one of the interdune valleys.

A detailed listing of soil characteristics is presented in online Appendix 1. These are mapped in Figure 5.

1. Shallow, very stony brown soil of the mountain slope

The **Brunic Skeletic Leptosol (Colluvic)** of the moderately steep (24-30% slope) mountain slope was formed *in situ* from weathering of the quartzitic parent material. The steepness, and surface and subsurface stoniness make this unit less suitable for livestock farming, although game, especially kudu (*Tragelaphus strepsiceros*), were seen on the slopes.

2. Very deep, red sand of the dune crests

Protic Chromic Arenosol (Aeolic) occurs on the convex-sloped dune crests. Slight erosion activity (both raindrop splash and aeolian) is visible over more than 50% of the surface. This soil is very deep (>700 cm), with a red colour (2.5YR4/6 – 2.5YR4/8). There is no significant difference in colour with increasing depth. Moistening results in a slight increase in chroma. Soil horizon development is very poor, with a 40-60% increase in clay content to mark the transition from the thin A horizon (3-8 cm thick) to the deep B horizon. Though the percentage increase in clay seems high, the clay content is actually very low: less than 2% in the A horizon, increasing to 2-6% in the B horizon. Both horizons are sandy, with more than 92% sand content (coarse sand in the topsoil and medium sand in the subsoil) and virtually no silt. This soil is structureless (single grain) with loose consistency of the topsoil in both the wet and moist states, and loose to very soft or friable consistency of the subsoil in the dry and moist states respectively. The low clay content means that it is non-sticky and non-plastic when wet. There are no impediments to root development. Chemical analysis shows that organic carbon (OC<0.25%) and phosphorus (P<2 ppm) contents are very low, on

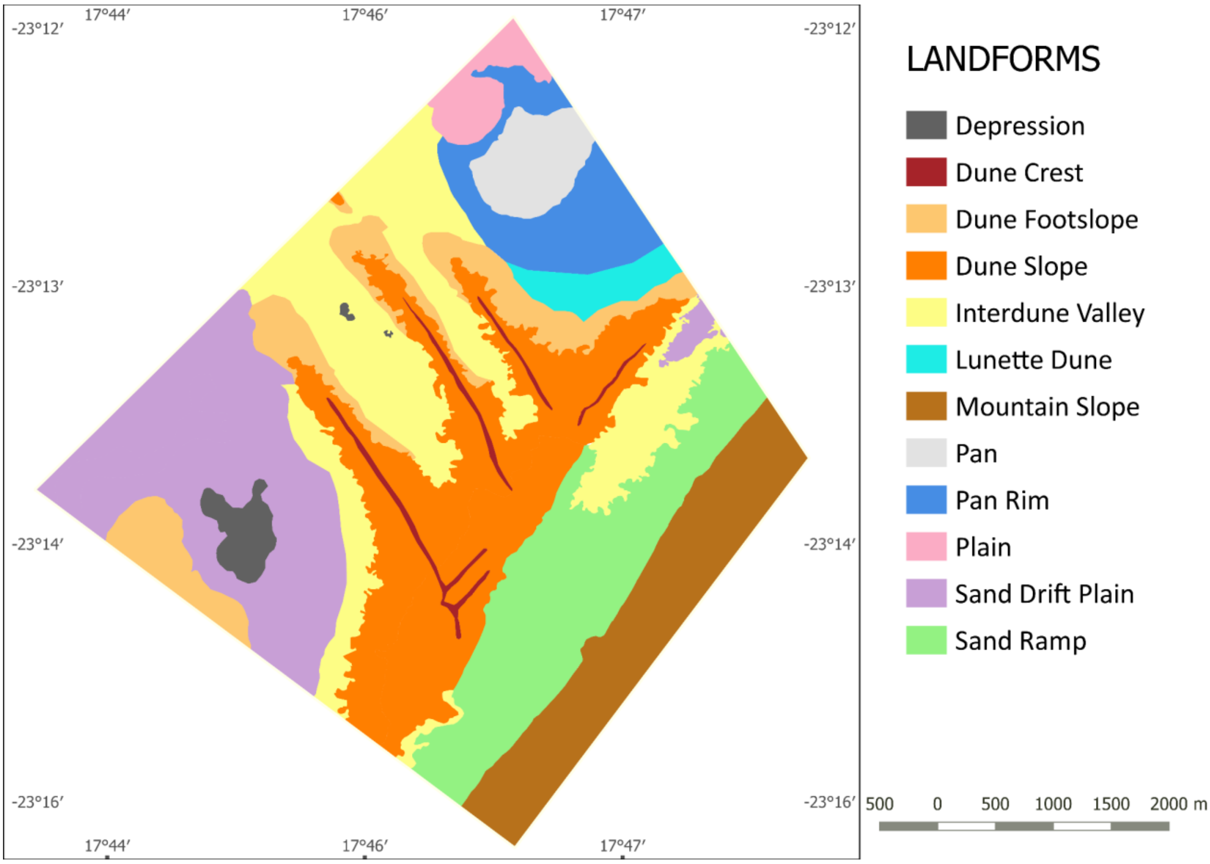

***Figure 4**: Landforms of farm Klein Boesman.*

account of the low vegetation cover on dune crests. Basic cation concentrations are very low, as can be expected from the parent material – single grained quartz of aeolian origin – and the sandy texture: topsoil water-soluble potassium (K) 17-22 parts per million (ppm), calcium (Ca) 99-208 ppm, magnesium (Mg) 28-42 ppm, sodium (Na) 10-14 ppm; subsoil water-soluble potassium (K) 21-35 ppm, Ca 58-134 ppm, Mg 18-46 ppm, Na 4-16 ppm. This also accounts for the slightly acidic nature of the soil (pH 5.2-5.9). There are no primary or secondary carbonates, no mottling or concretions. Quartz grains have a reddish hematite coating, which implies that water infiltration and internal drainage are very rapid and soil aeration very good. [Representative profiles: 4, 31, 32, 34]

3. Deep, reddish sand of the dune slopes, footslopes and sand ramp

Chromic Arenosol (Aeolic) occurs on dune slopes. Slight erosion activity has been observed (both raindrop splash and aeolian) over more than 50% of the surface. This soil is deep (>200 cm on lower slopes) to very deep (>700 cm on upper slopes), with a red to yellowish red colour (hue 2.5YR-5YR, value 3.5-4, chroma 4-6). There is no significant difference in colour with increasing depth. Soil horizon development is poor, with a 30-40% increase in clay content from the thin A horizon (5-10 cm thick) to the B horizon. Topsoil clay content is higher than on dune crests: 2.3-2.6% in the A horizon, increasing to 3.2-4.5% in the B horizon. Both horizons are sandy, with more than 90% sand content and slightly more silt (1-3%) than on dune crests. This soil has weak, fine, subangular blocky to rounded structure and soft (when dry) or very friable (when moist) consistency in the subsoil, while the topsoil is structureless (single grain) with loose consistency in both the wet and moist states. The low clay content means that it is non-sticky and non-plastic when wet. There are no impediments to root development. OC (0.2-0.6%) and P (2-7 ppm) contents are low, but slightly higher than on dune crests. Concentrations of bases are very low, but noticeably higher than on dune crests: topsoil water-soluble K 47-178 ppm, Ca 78-253 ppm, Mg 19-62 ppm, Na 3-23 ppm; subsoil water-soluble K 28-169 ppm, Ca 93-182 ppm, Mg 27-38 ppm, Na 0-26 ppm. The slope soils are less acidic than dune crest soils, with pH 5.9-6.6. There are no primary or secondary carbonates, no mottling or concretions. Quartz grains are mainly coated with reddish hematite, but the somewhat more yellowish red colour of some grains reflects the presence of soil water for longer periods than on dune crests. Water infiltration and internal drainage are still quite rapid and soil aeration good. [Representative profiles: 26, 27, 28, 29].

4. Deep, red to dark reddish brown sand of interdune valleys ('streets')

Chromic Arenosol (Aeolic) is found in sandy interdune valleys, generally with a slope of less than 1%. This soil is deep (>200 cm), with an A horizon of about 7-12 cm thick, and red to dark reddish brown colour (2.5YR4/6 – 2.5YR3.5/5). The entire profile is sandy, though the clay content increases with depth: from about 3.2% in the A horizon to 6-8% in the B2 horizon. This accounts for the subsoil's very weak, fine subangular blocky structure, and soft (when dry) and very friable (when moist) consistency. The low clay content means that this soil is non-sticky and non-plastic when wet. There are no impediments to root development. pH is below normal (5.4-6.5) and similar to that of dune slopes. OC (<0.6%) and P (<8 ppm) contents are low, and concentrations of bases are relatively low: topsoil water-soluble K 60-62 ppm, Ca 278-394 ppm, Mg 66-87 ppm, Na 11-12 ppm; subsoil water-soluble K 51-81 ppm, Ca 272-379 ppm, Mg 67-108 ppm, Na 11-15 ppm. These soils are not calcareous. There are no mottles or mineral concretions. Water infiltration, internal drainage and aeration are very good. Slight raindrop splash and aeolian erosion activity is visible over more than 50% of the surface. [Representative profiles: 30, 35]

5. Moderate to deep brownish to yellowish red soil of the sand drift plains

Brunic Arenosol (Aeolic) occurs on level to very gently sloping (0.2-2% slope) sand drift plains. This soil is moderate to deep (50 cm->100 cm), reddish brown to yellowish red (hue 5YR, value 4, chroma 3-6) when moist, and brown to strong brown (hue 7.5YR-5YR, value 4-5, chroma 4-6) when dry. Soil horizon development is poor, but slightly better than that of the dunes. The soil is sandy throughout the profile, with more than 90% sand, while topsoil clay content is 3.0-3.7%, increasing only slightly with depth. The thin (5 cm thick) topsoil is structureless (single grains), with loose consistency, whether dry or moist. Structure of both B1 and B2 horizons is weak, subangular blocky, with B1 structural elements smaller than that of B2. Consistency of B1 and B2 is soft and slightly hard when dry, and friable and firm when wet, respectively. The low clay content means that it is non-sticky and non-plastic when wet. There are no impediments to root development. OC (0.2-0.4%) and P (1-13 ppm) contents are low, but slightly higher than on dunes. Concentrations of bases are low, but noticeably higher than on dune crests: topsoil water-soluble K 185-224 ppm, Ca 145-180 ppm, Mg 54-86 ppm, Na 5-18 ppm; subsoil water-soluble K 243-274 ppm, Ca 144-212 ppm, Mg 67-86 ppm, Na 7-43 ppm. pH ranges from 6.54 to 7.02. There are no primary or secondary carbonates, no mottling or concretions. The brownish colour is imparted by a mixture of reddish hematite and yellowish goethite coatings on quartz grains, reflecting the presence of soil water for longer periods than on dunes. Water infiltration, internal drainage and aeration are good. Slight raindrop splash and aeolian erosion activity is visible over more than 50% of the surface. [Representative profiles: 5, 10, 11, 21].

6. Shallow brownish to yellowish red soil of the sand drift plains, on calcrete

A smaller unit of virtually identical, but shallower (20-50 cm) **Brunic Arenosol (Aeolic)**, underlain by calcrete, occurs within the sand drift plain.

7. Shallow brownish soil on calcrete, underlain by limestone

Brunic Leptosol occurs in the north-eastern corner of the study area. Despite being underlain by shallow pedogenic calcrete (outcropping on <2% of the surface) and containing calcrete nodules, there is little free calcium carbonate in the profiles. Both field and laboratory tests show that this soil is mildly calcareous. The pH is 7.2-8.3. This soil is generally shallow (<50 cm) and brown to strong brown (hue 7.5YR-5YR, value 4-5, chroma 4-6) when dry. There are clear differences between the thin (1-5 cm thick), sandy, single-grained A and the loamy sand to sandy loam, weak subangular to angular blocky B horizons. Clay content of the B horizon is up to 20% just above the calcrete. This clay enrichment of subsoil can be ascribed to the presence of the calcrete hardpan, which impedes water percolation. While topsoil consistency is loose, the subsoil is slightly hard when dry and friable to very friable when wet. OC (0.2-0.9%) and P (<7 ppm) contents are low. Concentrations of bases show higher calcium than in the rest of the study area: topsoil water-soluble K 129-308 ppm, Ca 371-966 ppm, Mg 34-76 ppm, Na 5-11 ppm; subsoil water-soluble K 102-408 ppm, Ca 345-1243 ppm, Mg 38-114 ppm, Na 5-18 ppm. Slight raindrop splash and aeolian erosion activity is visible over more than 50% of the surface. [Representative profiles: 1, 2, 13]

8. Shallow, clayey soil of the pan

The clay pan soil, **Gleyic Cambisol (Clayic, Takyric)**, is non-saline and only mildly calcareous, though it is shallowly underlain by calcrete. The low position in the landscape accounts for the accumulation of finer material and thus the presence of laminar clay at the surface, that cracks into large blocks when dry. The colour grades from light gray (2.5Y7/2), indicating periodic waterlogged, reducing conditions, to light brown (7.5YR6/3-4).

9. Shallow soil of the pan rim and depressions

The **Eutric Cambisols** of the three depressions and pan rim are shallow, non-saline, non-calcareous, light brown (7.5YR6/3-4) to brown (7.5YR4-5/3-4), with slightly higher silt content than the surrounding plains and shallowly underlain by calcrete.

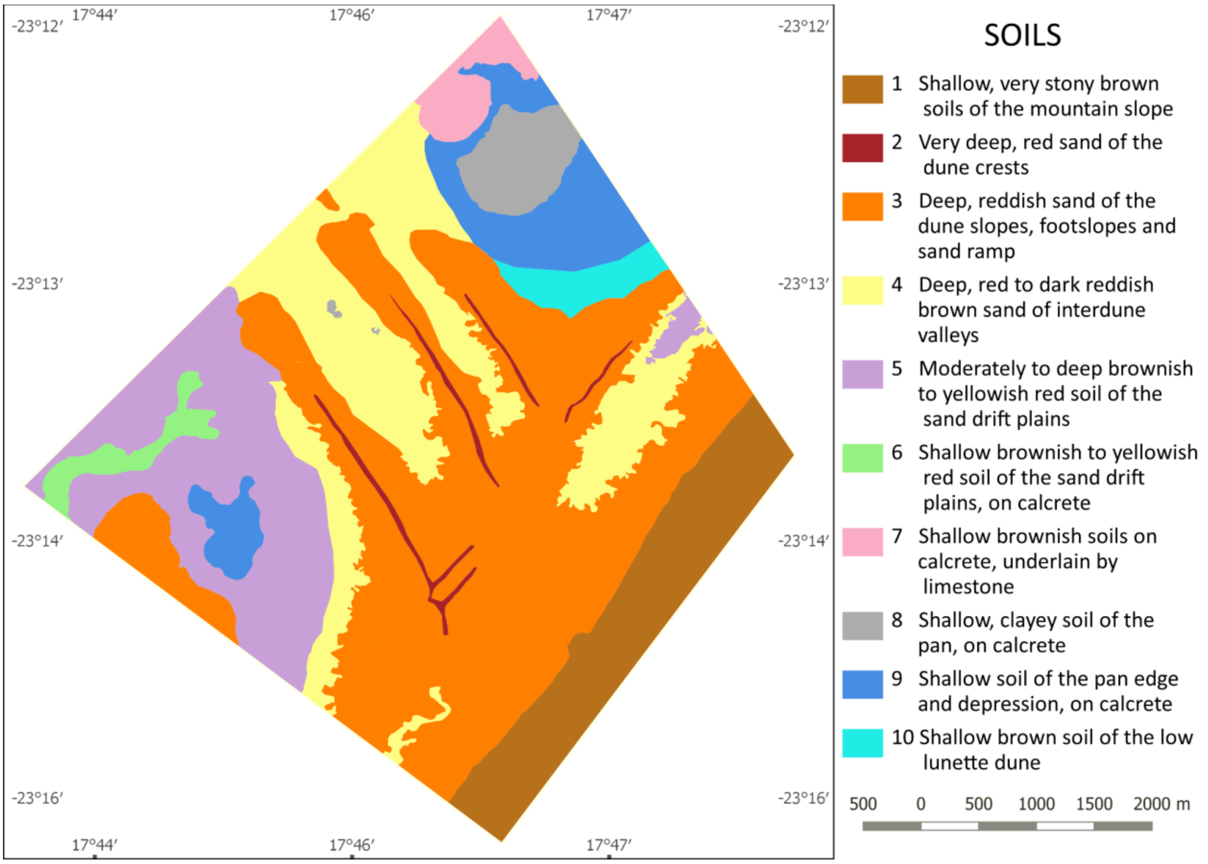

Figure 5*: Soils of farm Klein Boesman.*

10. Shallow brown soil of the low lunette dune

Brunic Arenosol (Aeolic) occurs on the low, very gently sloping (0.2-0.5% slope) lunette dune. This soil is deep (>100 cm), brown to dark brown (hue 7.5YR, value 3-4, chroma 3-4) when moist, and brown to strong brown (hue 7.5YR, value 4-5, chroma 4-6) when dry. The soil surface has a thin (1-2 grain thick) layer of coarse uncoated quartz crystals, which gives the illusion of a much lighter soil when viewed from a distance. Soil horizon development is poor, but slightly better than that of the dunes. The soil is sandy throughout the profile, with around 90% sand and 8-8.6% clay. The thin (6 cm thick) topsoil is structureless (single grains) and consistency is loose, whether dry or moist. Structure of both B1 and B2 horizons is weak to moderate, subangular blocky to blocky. Consistency of B1 and B2 is soft to slightly hard when dry, and very friable when wet. This soil is non-sticky and non-plastic when wet. There is no impediment to root development. OC (0.3%) and P (0-1.4 ppm) contents are low. Concentrations of bases are low: water-soluble K 92-113 ppm, Ca 251-274 ppm, Mg 81-96 ppm, Na 3-4 ppm. pH ranges from 6.88 to 7.12. There are no primary or secondary carbonates, no mottling or concretions. The brownish colour is imparted by a mixture of reddish hematite and yellowish goethite coatings on quartz grains, reflecting the presence of soil water for longer periods than on dunes. Water infiltration, internal drainage and aeration are good. Slight erosion activity was observed (both raindrop splash and aeolian) over more than 50% of the surface. [Representative profiles: 6, 7, 8, 9].

Vegetation Classification

The initial classification based on species composition only, yielded eight clusters, which were found to be ecologically interpretable. The further classification of Cluster 3, based on growth form data and using pseudospecies in the classification procedure, yielded an additional 2 clusters. These classification results are depicted in Figure 6 as a dendrogram. The two subunits of Cluster 3 were interpreted as subassociations of the cluster. Similarly, Clusters 6, 7 and 8 were interpreted as being subassociations of one association due to the similarity in habitat. All other clusters were regarded as being associations.

The full phytosociological table is presented as downloadable online Appendix 2, the synoptic table as online Appendix 3. The associations are not described formally according to the International Code for Phytosociological Nomenclature (ICPN) (Weber et al. 2000), pending a review of vegetation associations described within the southern Kalahari

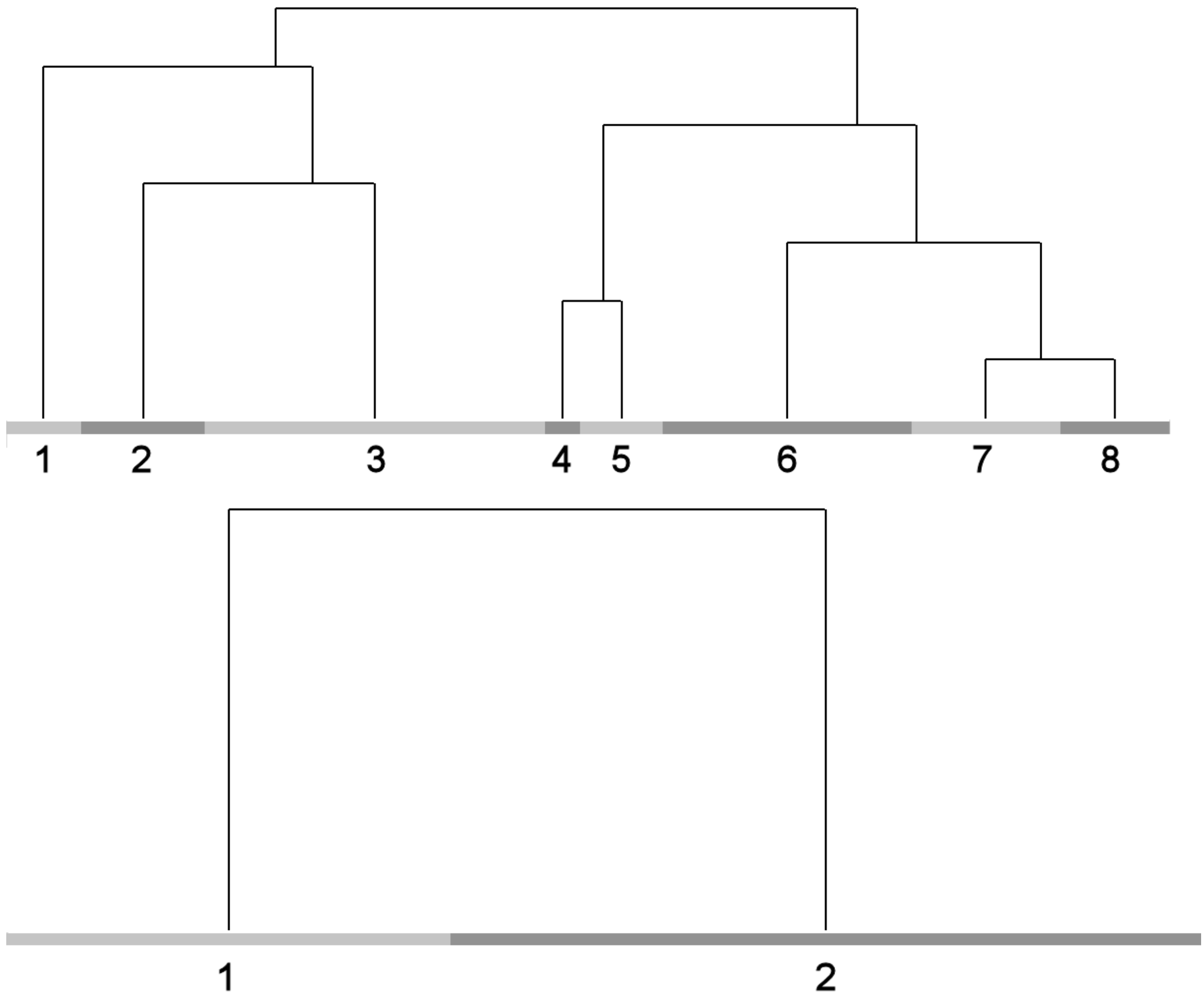

Figure 6: *Dendrogram depicting the classification results. Top: Initial classification of the full synusial dataset (composition only). Clusters 6, 7 and 8 represent sub-associations 6.1, 6.2 and 6.3 respectively. Bottom: Classification of the synusial subset of Cluster 3, using growth form data.*

(*sensu* Giess 1998) and the Kalahari Duneveld Bioregion *(sensu* Mucina & Rutherford 2006). Within this description, highly diagnostic species (with phi coefficient >60), highly constant species (occurring in more than 80% or relevés) as well as strongly dominating species (covering more than 20%) are indicated in **bold**. All structural descriptions follow Edwards (1983).

1. *Triraphis ramosissima–Acacia senegal* association

Synopsis:
Number of relevés: 10
Number of species observed: 47
Estimated number of species: 54
Average species density per 1000 m^2: 19

Diagnostic species: ***Acacia senegal, Nelsia quadrangula, Melinis repens* subsp. *repens, Combretum apiculatum, Eragrostis nindensis, Crotalaria spartioides, Triraphis ramosissima, Gisekia africana, Cheilanthes dinteri, Tribulus terrestris, Cleome rubella,*** *Elephantorrhiza suffruticosa, Phyllanthus pentandrus, Anthephora schinzii, Phyllanthus parvulus, Hibiscus engleri, Boscia foetida, Aristida effusa*
Constant species: ***Schmidtia kalahariensis, Stipagrostis uniplumis* var. *uniplumis,*** *Aristida adscensionis*
Dominant species: ***Acacia senegal, Combretum apiculatum,*** *Schmidtia kalahariensis, Melinis repens* subsp. *repens, Triraphis ramosissima*

General description:
The *Triraphis ramosissima–Acacia senegal* association forms a closed, high shrubland on the slopes of the mountain, with their Brunic Skeletic Leptosols, along the south-eastern edge of the farm (Figures 7a and 8a). Indicative for the mountainous habitat are *Combretum apiculatum, Triraphis ramosissima* and *Cheilanthes dinteri*. The association is however dominated by high shrubs of *Acacia senegal*.

2. *Centropodia glauca–Terminalia sericea* association
Synopsis:
Number of relevés: 17
Number of species observed: 75
Estimated number of species: 82
Average species density per 1000 m^2: 23

Diagnostic species: ***Digitaria seriata, Terminalia sericea, Centropodia glauca, Grewia retinervis, Dichrostachys cinerea, Rotheca uncinata,*** *Sida ovata, Calobota linearifolia, Pollichia campestris, Tapinanthus oleifolius, Searsia tenuinervis, Asparagus suaveolens, Boscia albitrunca, Requienia sphaerosperma, Indigofera charlieriana, Commiphora angolensis, Neorautanenia mitis, Commiphora glandulosa*
Constant species: ***Acacia mellifera* subsp. *detinens,*** *Grewia flava, Eragrostis lehmanniana, Acacia erioloba, Stipagrostis uniplumis* var. *uniplumis*
Dominant species: ***Terminalia sericea, Dichrostachys cinerea, Acacia mellifera* subsp. *detinens,*** *Stipagrostis hirtigluma, Schmidtia kalahariensis, Grewia retinervis, Acacia erioloba*

General description:
The *Centropodia glauca–Terminalia sericea* association forms a tall, moderately-closed bushland on the crest of the dunes, with their Protic Chromic Arenosols (Figures 7b and 8b). By the nature of these crests, the association forms a narrow band, often less than 10 m wide. The scattered tall trees of *Terminalia sericea, Acacia erioloba, Boscia albitrunca* and *Albizia anthelmintica* offer shade to animals, which often results in considerable damage to the understorey vegetation, especially the grass sward. Being at the crest of a loose, unconsolidated sand dune, wind erosion is occurring extensively due to the denuded soil surface (Figure 8c).

3. *Acacia mellifera–Acacia erioloba* association (Van Rooyen et al. 2008)
Synopsis:
Number of relevés: 46
Number of species observed: 133
Estimated number of species: 156
Average species density per 1000 m^2: 22

Diagnostic species: *Hermannia tomentosa, Pogonarthria fleckii*
Constant species: ***Acacia erioloba, Stipagrostis uniplumis* var. *uniplumis, Schmidtia kalahariensis, Pseudogaltonia clavata,*** *Pollichia campestris, Acrotome inflata, Acacia mellifera* subsp. *detinens, Eragrostis lehmanniana*
Dominant species: ***Stipagrostis uniplumis* var. *uniplumis, Schmidtia kalahariensis, Acacia mellifera* subsp. *detinens, Acacia erioloba,*** *Eragrostis lehmanniana, Crotalaria podocarpa, Dichrostachys cinerea, Stipagrostis hirtigluma, Momordica balsamina, Grewia flava*

General description:
The *Acacia mellifera–Acacia erioloba* association has been described for the high parallel duneveld in the Kalahari Gemsbok National Park in South Africa by Van Rooyen et al. (2008). Within the context of the present study, two very distinct forms can be recognised: a shrubland is formed on the slopes of the longitudinal dunes as well as a bushland or woodland dominated by *Acacia erioloba* trees on the sand drift plains. These two forms could not be distinguished based on compositional data, but due to their widely diverging structures, two different subassociations were defined.

3.1 *Acacia mellifera–Acacia erioloba* typical subassociation
Synopsis:
Number of relevés: 17
Number of species observed: 89
Estimated number of species: 106
Average species density per 1000 m^2: 23

Diagnostic species: ***Grewia flava* shrubs, *Dichrostachys cinerea* shrubs,** *Acacia mellifera* subsp. *detinens* shrubs, *Crotalaria spartioides, Boscia albitrunca* trees, *Lycium bosciifolium* shrubs
Constant species: ***Stipagrostis uniplumis* var. *uniplumis, Schmidtia kalahariensis, Pollichia campestris, Pseudogaltonia clavata,*** *Acrotome inflata, Acacia erioloba* trees
Dominant species: *Acacia mellifera* subsp. *detinens* shrubs, *Crotalaria podocarpa, Stipagrostis uniplumis* var. *uniplumis, Stipagrostis hirtigluma* subsp. *hirtigluma, Schmidtia kalahariensis, Grewia flava* shrubs, *Dichrostachys cinerea* shrubs, *Dichrostachys cinerea* trees

General description:
The *Acacia mellifera–Acacia erioloba* typical subassociation occurs on dunes slopes with their Chromic Arenosols, the sand ramp at the foot of the Rooirand mountain as well as occasionally on sand drift plains. It forms a tall, moderately closed shrubland dominated by *Acacia mellifera* (Figures 7c and 8d). In many cases, especially along the bases of dunes, the cover of *Acacia mellifera* reaches near continuous proportions and forms an impenetrable thicket.

3.2 *Acacia mellifera–Acacia erioloba–schmidtia kalahariensis* subassociation
Synopsis:
Number of relevés: 29
Number of species observed: 105
Estimated number of species: 125
Average species density per 1000 m^2: 22

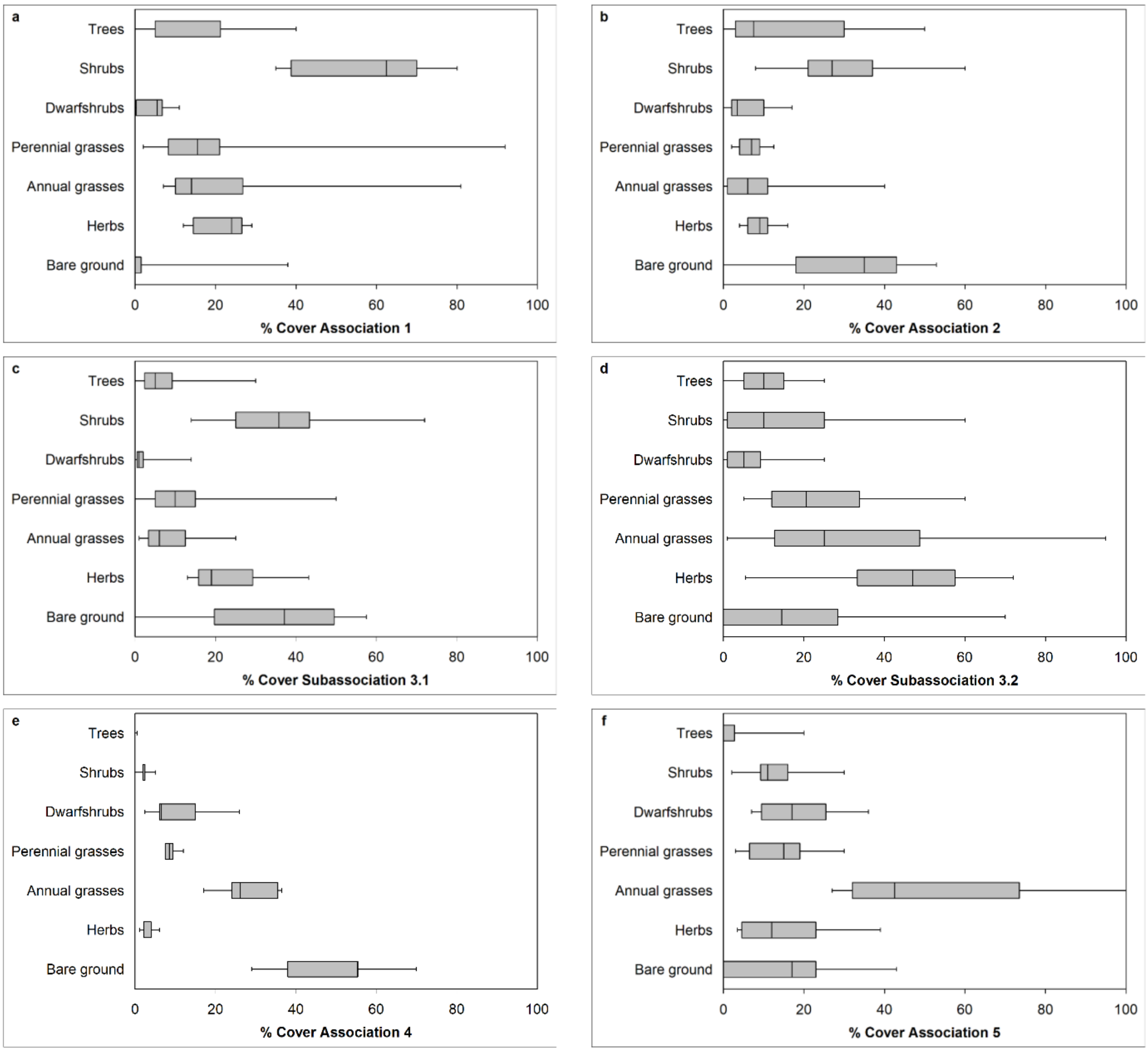

Figure 7: *Structure of the associations. a:* Triraphis ramosissima–Acacia senegal *association; b:* Centropodia glauca–Terminalia sericea *association; c:* Acacia mellifera–Acacia erioloba *typical subassociation; d:* Acacia mellifera–Acacia erioloba–schmidtia kalahariensis *subassociation; e:* Eragrostis truncata–Zygophyllum leucocladum *association; f:* Eragrostis echinochloidea–Leucosphaera bainesii *association.*

Diagnostic species: ***Cleome rubella,*** *Ipomoea obscura* var. *obscura, Indigofera daleoides, Acacia erioloba* trees, *Solanum multiglandulosum, Pentarrhinum insipidum, Grewia flava* shrubs, *Eragrostis lehmanniana*

Constant species: ***Stipagrostis uniplumis* var. *uniplumis, Schmidtia kalahariensis, Pseudogaltonia clavata, Acrotome inflata,*** *Pollichia campestris, Pogonarthria fleckii, Hermannia tomentosa*

Dominant species: *Stipagrostis uniplumis* var. *uniplumis, Schmidtia kalahariensis, Acacia erioloba* trees, *Acacia mellifera* subsp. *detinens* shrubs, *Eragrostis lehmanniana, Momordica balsamina, Dichrostachys cinerea, Acacia erioloba* shrubs

General description:

The *Acacia mellifera–Acacia erioloba–schmidtia kalahariensis* subassociation forms tall, semi-open woodlands or bushlands on the sand drift plains on the western part of the farm, occasionally also in the interdune valleys (Figures 7d and 8e). This subassociation is occurring on Chromic and/or Brunic Arenosols. *Acacia erioloba* trees dominate the landscape, but the presence of *Acacia mellifera*, often at relatively high densities, indicates the susceptibility for encroachment of this subassociation. This, and the compositional high similarity of the two subassociations, indicates that the current typical *Acacia mellifera–Acacia erioloba* subassociation is actually a degraded/bush encroached form of the *Acacia mellifera–Acacia erioloba–schmidtia kalahariensis* woodlands sub-association.

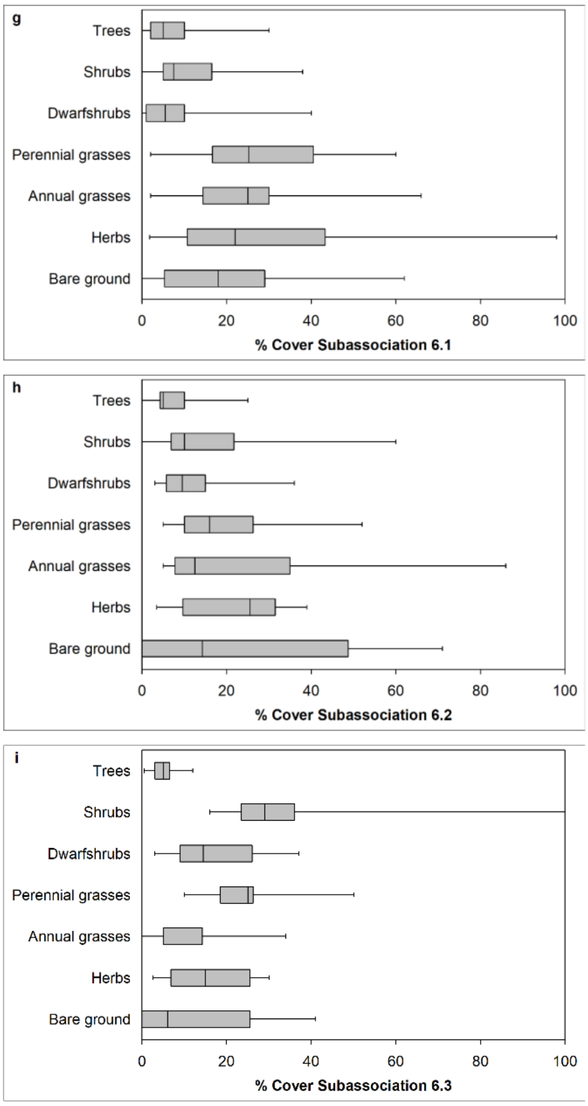

Figure 7 continued: *Structure of the associations. g:* Pseudogaltonia clavata–Rhigozum trichotomum *typical subassociation; h:* Pseudogaltonia clavata–Rhigozum trichotomum–eriocephalus luederitzianus *subassociation; i:* Pseudogaltonia clavata–Rhigozum trichotomum–parkinsonia africana *subassociation*

4. *Eragrostis truncata–Zygophyllum leucocladum* association

Synopsis:
Number of relevés: 5
Number of species observed: 41
Estimated number of species: 41
Average species density per 1000 m^2: 23

Diagnostic species: ***Eragrostis truncata, Zygophyllum leucocladum, Chloris virgata, Tragus racemosus, Platycarphella carlinoides, Heliotropium lineare, Jamesbrittenia canescens, Aizoon schellenbergii, Geigeria pectidea, Eragrostis pilgeriana, Setaria verticillata, Enneapogon desvauxii, Asparagus cooperi, Eragrostis echinochloidea,*** *Schkuhria pinnata, Panicum lanipes, Cyperus amabilis, Aristida adscensionis, Cenchrus ciliaris, Urochloa brachyura, Sporobolus nebulosus, Cyphostemma hereroense, Bidens biternata*
Constant species: *Pseudogaltonia clavata, Eragrostis porosa, Acacia hebeclada* subsp. *hebeclada*
Dominant species: ***Enneapogon desvauxii,*** *Aizoon schellenbergii*

General description:
The *Eragrostis truncata–Zygophyllum leucocladum* association is limited to the clay pan associated with the Boesmanklippe formation in the north-eastern corner of the farm. The structure is a low, semi-open shrubland with a distinct karoid character, both in terms of structure and composition (Figures 7e and 8f). The wetland character is evident from species like *Chloris virgata, Platycarphella carlinoides* and *Sporobolus nebulosus*.

5. *Eragrostis echinochloidea–Leucosphaera bainesii* association

Synopsis:
Number of relevés: 11
Number of species observed: 69
Estimated number of species: 79
Average species density per 1000 m^2: 26

Diagnostic species: ***Limeum argute-carinatum, Leucosphaera bainesii, Stipagrostis obtusa, Rhigozum trichotomum, Eragrostis echinochloidea,*** *Triraphis purpurea, Catophractes alexandri, Eriocephalus luederitzianus, Melolobium candicans, Enneapogon desvauxii, Aptosimum lineare, Gnidia polycephala, Eragrostis porosa, Barleria rigida, Acacia hebeclada* subsp. *hebeclada*
Constant species: ***Pseudogaltonia clavata, Acacia erioloba, Acrotome inflata, Stipagrostis uniplumis* var. *uniplumis, Melinis repens* subsp. *grandiflora,*** *Schmidtia kalahariensis, Cenchrus ciliaris*
Dominant species: ***Eragrostis porosa, Rhigozum trichotomum,*** *Stipagrostis uniplumis* var. *uniplumis, Schmidtia kalahariensis, Enneapogon desvauxii, Acacia erioloba*

General description:
The *Eragrostis echinochloidea–Leucosphaera bainesii* association forms a short, moderately closed to closed shrubland within a depression in the western side of the farm, as well as fringe vegetation around the *Eragrostis truncata–Zygophyllum leucocladum* pan in the north-eastern corner of the farm (Figures 7f and 8g). The very dense stand of *Rhigozum trichotomum* in the depression forms a near-impenetrable shrubland.

6. *Pseudogaltonia clavata–Rhigozum trichotomum* association

Synopsis:
Number of relevés: 69

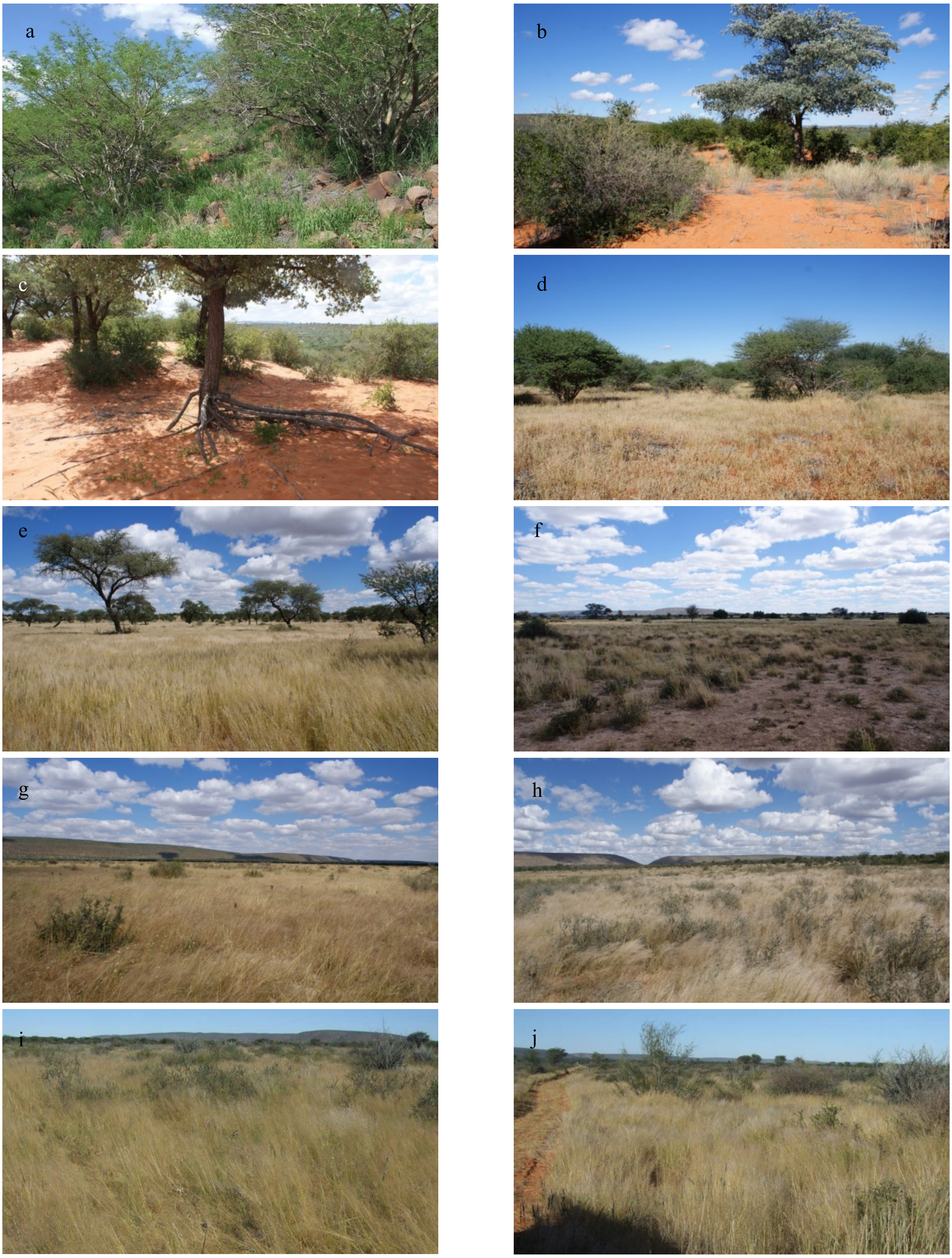

Figure 8: *Typical examples of the described associations: (a)* Triraphis ramosissima–Acacia senegal *association at relevé 11918; (b)* Centropodia glauca–Terminalia sericea *association in good condition at relevé 11776; (c)* Centropodia glauca–Terminalia sericea *association badly wind-eroded at relevé 11783; (d)* Acacia mellifera–Acacia erioloba *typical subassociation on the dune slopes and dune foots at relevé 11774; (e)* Acacia mellifera–Acacia erioloba–schmidtia kalahariensis *subassociation forming an open woodland in the sand drift plains at relevé 11780; (f)* Eragrostis truncata–Zygophyllum leucocladum *association at relevé 11764; (g)* Eragrostis echinochloidea–Leucosphaera bainesii *association at relevé 11755; (h)* Pseudogaltonia clavata–Rhigozum trichotomum *typical subassociation at relevé 11786; (i)* Pseudogaltonia clavata–Rhigozum trichotomum–eriocephalus luederitzianus *subassociation at relevé 11934; (j)* Pseudogaltonia clavata–Rhigozum trichotomum–parkinsonia africana *subassociation at relevé 2161.*

Number of species observed: 175
Estimated number of species: 190
Average species density per 1000 m^2: 25

Diagnostic species: *Rhigozum trichotomum, Hirpicium gazanioides, Parkinsonia africana, Aristida congesta, Ipomoea sinensis, Catophractes alexandri, Ipomoea bolusiana*
Constant species: ***Acacia erioloba, Stipagrostis uniplumis*** **var.** ***uniplumis, Schmidtia kalahariensis,*** *Pseudogaltonia clavata, Acrotome inflata, Acacia hebeclada* subsp. *hebeclada*
Dominant species: ***Stipagrostis uniplumis*** **var.** ***uniplumis, Rhigozum trichotomum,*** *Schmidtia kalahariensis, Acacia erioloba, Eragrostis porosa, Eragrostis lehmanniana, Acacia mellifera* subsp. *detinens, Catophractes alexandri, Pogonarthria fleckii, Parkinsonia africana, Lycium bosciifolium, Leucosphaera bainesii, Indigofera alternans*

General description:
This association forms extensive shrublands within the interdune valleys and the plains on the eastern side of the farm. Due to the structural and habitat similarities, three subassociations have been recognised of this association.

6.1. *Pseudogaltonia clavata–Rhigozum trichotomum* typical subassociation
Synopsis:
Number of relevés: 34
Number of species observed: 140
Estimated number of species: 154
Average species density per 1000 m^2: 26

Diagnostic species: *Aristida congesta, Eragrostis lehmanniana, Pogonarthria fleckii, Chascanum pinnatifidum* var. *pinnatifidum*
Constant species: ***Schmidtia kalahariensis, Acacia erioloba, Stipagrostis uniplumis*** **var.** ***uniplumis, Pseudogaltonia clavata, Rhigozum trichotomum, Acrotome inflata,*** *Acacia mellifera* subsp. *detinens, Cleome rubella, Geigeria ornativa*
Dominant species: ***Stipagrostis uniplumis*** **var.** ***uniplumis, Rhigozum trichotomum, Schmidtia kalahariensis, Eragrostis lehmanniana, Acacia erioloba,*** *Pogonarthria fleckii, Acacia mellifera* subsp. *detinens, Indigofera alternans, Eragrostis porosa*

General description:
The *Pseudogaltonia clavata–Rhigozum trichotomum* typical subassociation forms a short, semi-open bushland, with a moderately-closed understorey of dwarf shrubs dominated by *Rhigozum trichotomum* (Figure 7g and 8h). This subassociation occurs between the dunes in the interdune valleys, mainly on Brunic Arenosols, occasionally underlain by calcretes. The main difference to the sand drift plains towards the west of the farm is the high density of *Rhigozum trichotomum*. The geophyte *Pseudogaltonia clavata* occurs widespread in this association, creating a potential threat to livestock husbandry as it is a known poisonous plant, affecting the heart, nervous systems as well as causing diarrhoea (Mannheimer et al. 2012).

6.2. *Pseudogaltonia clavata–Rhigozum trichotomum–eriocephalus luederitzianus* subassociation
Synopsis:
Number of relevés: 20
Number of species observed: 97
Estimated number of species: 103
Average species density per 1000 m^2: 24

Diagnostic species: *Eriocephalus luederitzianus, Hirpicium gazanioides*
Constant species: ***Stipagrostis uniplumis*** **var.** ***uniplumis, Pseudogaltonia clavata, Acacia erioloba, Schmidtia kalahariensis, Rhigozum trichotomum, Acrotome inflata,*** *Acacia hebeclada* subsp. *hebeclada, Pollichia campestris, Melinis repens* subsp. *grandiflora*
Dominant species: ***Stipagrostis uniplumis*** **var.** ***uniplumis, Rhigozum trichotomum, Eragrostis porosa,*** *Acacia erioloba, Schmidtia kalahariensis, Catophractes alexandri*

General description:
The *Pseudogaltonia clavata–Rhigozum trichotomum–eriocephalus luederitzianus* subassociation forms a tall, semi-open shrubland (Figures 7h and 8i), occurring on the fringes of the pan and associated lunette dune, with its Brunic Arenosols, south of the pan. The occurrence of *Eriocephalus luederitzianus* indicates edaphically drier conditions due to a finer texture and higher pH of the soils.

6.3. *Pseudogaltonia clavata–Rhigozum trichotomum–parkinsonia africana* subassociation
Synopsis:
Number of relevés: 15
Number of species observed: 78
Estimated number of species: 83
Average species density per 1000 m^2: 26

Diagnostic species: ***Parkinsonia africana, Ocimum americanum*** **var.** ***americanum, Ledebouria*** **species,** ***Leucas pechuelii, Ziziphus mucronata,*** *Dipcadi viride, Catophractes alexandri, Lycium eenii, Dipcadi platyphyllum, Talinum caffrum, Ipomoea sinensis, Eriospermum roseum*
Constant species: ***Stipagrostis uniplumis*** **var.** ***uniplumis, Rhigozum trichotomum, Acacia erioloba, Acacia mellifera*** **subsp.** ***detinens, Schmidtia kalahariensis, Lycium bosciifolium,*** *Acacia hebeclada* subsp. *hebeclada*

Dominant species: ***Stipagrostis uniplumis* var. *uniplumis*, *Rhigozum trichotomum*, *Catophractes alexandri*, *Acacia mellifera* subsp. *detinens*,** *Parkinsonia africana, Lycium bosciifolium, Leucosphaera bainesii, Eragrostis porosa*

General description:
The *Pseudogaltonia clavata–Rhigozum trichotomum–parkinsonia africana* subassociation forms a tall, moderately open shrubland (Figures 7i and 8j) with a striking dominance of *Parkinsonia africana.* This subassociation is limited to the Brunic Leptosols associated with the Boesmanklippe formation in the north-eastern corner of the farm.

Biodiversity indicators

The species richness per 1000 m^2, Shannon Index and Simpson's Index are given in Figure 9.

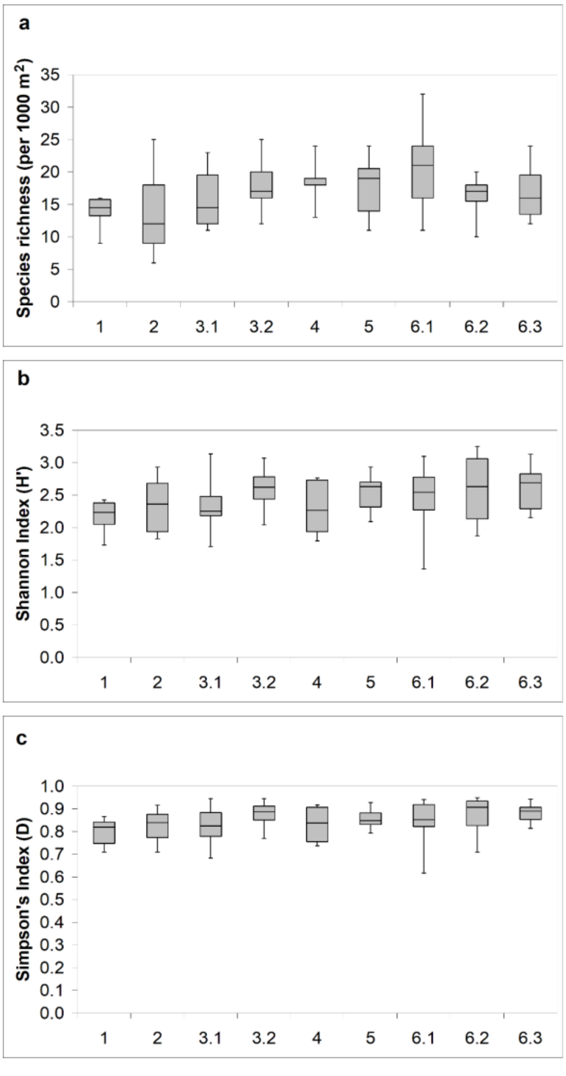

***Figure 9**: Diversity indicators for the various associations described. a) Species richness; b) Shannon index (H') and c) Simpson's Index (D).*

The two diversity indices (H' and D) follow very similar ranges across all associations. Conspicuous is the variability within subassociations 3.1 and 6.1, as indicated by the lower and upper quartiles (whiskers) in Figures 9b and 9c. This is an indication of the variable state of encroachment of these two subassociations. The narrow range of species richness depicted for associations 1 and 4 is likely a result of the limited number of relevés sampled in both associations. This also results in the estimation of species richness for association 4 to be unreliable, as no species were found once only.

Vegetation map

Minor differences between the distribution of vegetation associations and the associated landform- and soil units were found in the western sand drift plain, with the *Acacia mellifera–Acacia erioloba–schmidtia kalahariensis* subassocation not occurring as widely as the mapped sand drift plain, but gradually changing into the *Pseudogaltonia clavata–Rhigozum trichotomum* typical subassociation, with a conspicuous stand of *Acacia erioloba* trees interspersed. Another conspicuous difference is that the mapped pan centre in the north-eastern part of the farm contains two different associations – the *Eragrostis truncata–Zygophyllum leucocladum* association forming a limited area in the absolute centre of the pan, whilst the greater part of the pan centre indicated in the landforms map (Figure 4) is covered by the *Eragrostis echinochloidea–Leucosphaera bainesii* association. This is indicative of changing soil- and soil moisture conditions towards the centre of the pan. The vegetation map is depicted in Figure 10.

DISCUSSION AND CONCLUSION

A fairly close affinity exists between the vegetation types and the described soil types. However, in the transitional habitats (especially along the transition from dune foot to sand drift plain) the alliances are unclear. The vegetation reacts in these sandy environments to the availability of soil moisture, which is a function of the soil texture and the depth of the soil body (Laio et al. 2001a, b, Porporato et al. 2001, 2002, 2003, Strohbach & Kutuahupira 2014). In the north-eastern pan area, our soil sampling was not intensive enough to come to conclusive results regarding soil and vegetation interactions.

A comparison of the presently described associations to other similar associations helps understanding the biogeographical relationships of the vegetation, as well as assisting with the extrapolation about knowledge of the dynamics of the system. In particular, the southern Kalahari ecosystem has been well-studied in South Africa (Van Rooyen et al. 1984, 1990, 1991a, 1991b, Skarpe 1986, Jeltsch et al. 1997a, b, Dougill et al. 1999, 2016, Dreber et al.

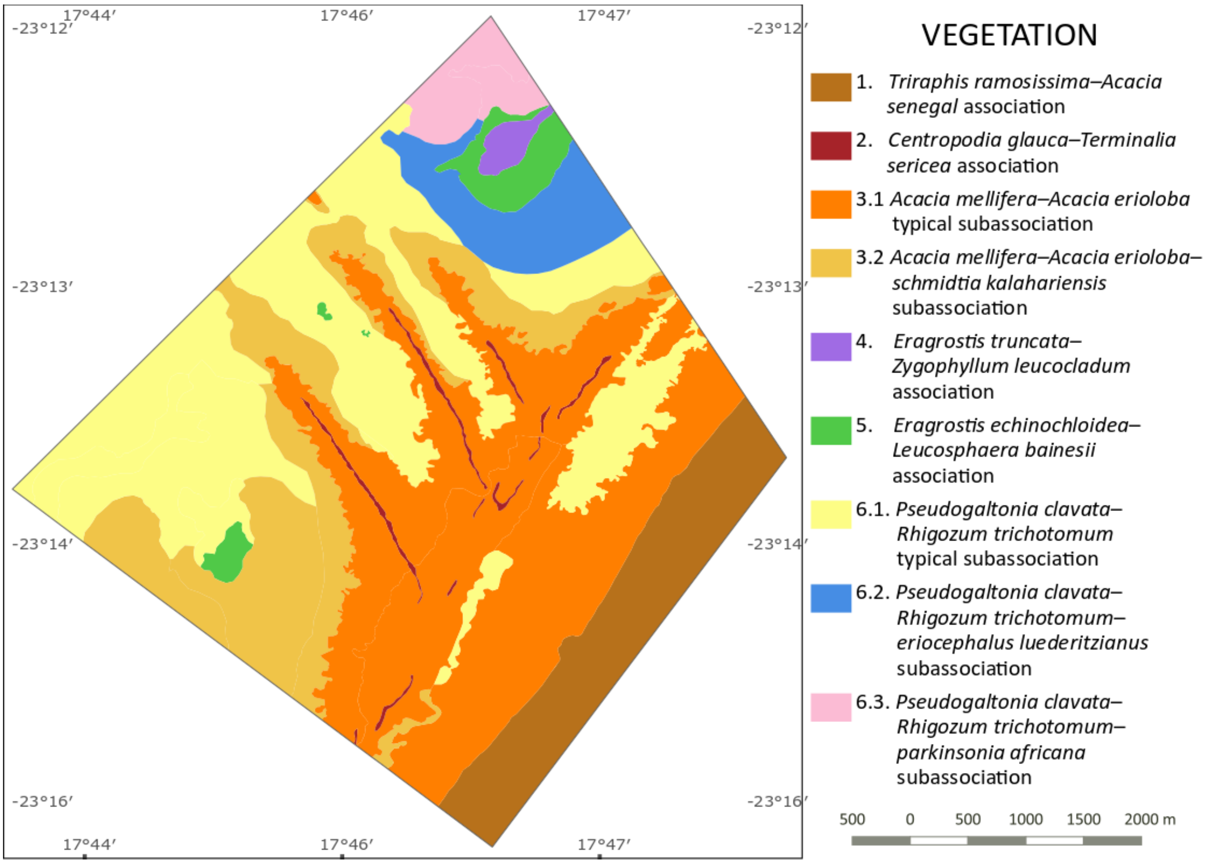

Figure 10*: Vegetation associations of farm Klein Boesman.*

2017), making it possible to apply the existing knowledge for land use and/or farming management purposes in Namibia.

With the occurrence of *Combretum apiculatum* and *Cheilanthes dinteri*, a clear affinity exists between the *Triraphis ramossisima–Acacia senegal* association and the *Bergdornweide* (mountain thorn pastures) described by Volk & Leippert (1971), or the *Acacia hereroensis* veld described by Strohbach (2017). The dominance of *Acacia senegal* (to the apparent exclusion of all other *Acacia* species) however indicates a separate higher syntaxonomy than the *Acacia hereroensis* veld of the Khomas Hochland.

Leistner & Werger (1973) describe the dune crests as *Stipagrostietum amabilis* (*Stipagrostis amabilis* association), and describe a subassociation *Stipagrostietum amabils–terminalietosum* to this, occurring on some high dunes in the northern part of the Kalahari Gemsbok National Park (KGNP) in the RSA. Van Rooyen et al. (2008) also make mention of stands of *Terminalia sericea* on some of the high dunes in the northern parts of the park. The name-giving *Stipagrostis amabilis* however does not occur at Klein Boesman, but rather the grass *Centropodia glauca*. *Terminalia sericea* is also a remnant from more mesic conditions further north, being the dominant species of the extensive *Combreto collini–Terminalietum sericeae* described for the northern Omaheke and eastern Otjozondjupa regions (Strohbach 2014a).

Leistner & Werger (1973) provide no formal description of the dune slopes. Van Rooyen et al. (2008) describe the dune slope vegetation as the *Acacia erioloba–Acacia mellifera* parallel high Duneveld. The major difference to the presently described *Acacia erioloba–Acacia mellifera* typical subassociation is that here no *Acacia haematoxylon* has been observed. For the KGNP, van Rooyen et al. (2008) describe an *Acacia erioloba–Schmidtia kalahariensis* low duneveld for similar habitats as the *Acacia mellifera–Acacia erioloba–schmidtia kalahariensis* subassociation at Klein Boesman. This subassociation is also very similar to the *Acacia erioloba–Schmidtia kalahariensis* woodlands of the Omeya plains south of Windhoek (Strohbach 2017). It is thus likely that what is presently only recognised as a subassociation, should be elevated to a full association occurring widespread in deep sandy plains habitats from central Namibia to the northern Cape in RSA.

Van Rooyen et al. (2008) describe an *Acacia erioloba–Rhigozum trichotomum–Stipagrostis* *obtusa* as well as an *Acacia mellifera–Rhigozum trichotomum–Stipagrostis obtusa* veld for the interdune valleys and river terraces in the KGNP. The occurrence of these two veld types depends on the depth of the underlying calcrete layers of the soils. The typical arid savanna grasses *Stipagrostis obtusa* and *Stipagrostis ciliata* were not found widespread in the *Pseudogaltonia clavata–Rhigozum trichotomum* association on Klein Boesman, whereas the name-giving geophyte *Pseudogaltonia clavata* is very prominent on Klein Boesman, but rare in the KGNP (Leistner & Werger 1973). Although there is a distinct relationship, the *Pseudogaltonia clavata–Rhigozum trichotomum* association is syntaxonomical different from similar units described for the KGNP.

It is clear that the Kalahari duneveld at Klein Boesman forms the northern extent of the southern Kalahari, and has, due to its higher rainfall regime, clear differences to the more arid environments of the KGNP. A review of the entire southern Kalahari/ Kalahari Duneveld (*sensu* Giess 1998 and Mucina & Rutherford 2006 respectively) is thus needed.

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