Paper 1:

Vegetation, habitats and browse availability in the Waterval section, Augrabies Falls National Park – place of scarcity and diversity.

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Abstract

Factors potentially affecting habitat suitability for large browsers were quantified in 7530 ha of mountainous desert in Waterval, Augrabies Falls National Park, western South Africa. The vegetation was classified and mapped according to plant species associations. In each vegetation community vertical cover, shade, substrate composition as well as canopy volume of each browse species were measured. Furthermore, water availability and steepness of slopes were mapped. The varied topography and soils of Waterval result in a high diversity of browse (D=19.0, H'(ln)=3.45) divided into ten vegetation communities including seven shrublands (61.7 % by area), two woodlands (37.1 %) and a riverine forest (1.1 %). The average browse availability 0-200 cm above ground is 1 096 ±90 m^3/ha, ranging from 597 to 14 446 m^3/ha among vegetation communities. The browse includes *Acacia mellifera* (15.0 %), *Schotia afra* (12.7 %), *Monechma spartioides* (4.5 %), *Acacia karroo* (4.2 %), *Boscia albitrunca* (3.8 %), *Euphorbia rectirama* (2.9 %) and *Indigofera pechuelii* (2.6 %). The riverine forest provides easy access to water, browse, shade and vertical cover. However, some 97 % of Waterval has scarce browse and vertical cover as well as little to no shade. In addition, the northeastern area is steep, 4-6 km from water and bordered by a low-use road. Fortunately, with the exception of community 3, browse is diverse, generally palatable and deciduousness limited to 2-3 months in one major browse species. Research and monitoring

is recommended to balance mega-herbivorous black rhino and giraffe with scarce, diverse and endemic vegetation.

Keywords

Augrabies, vegetation communities, browse availability, water, shade, slope, substrate, habitat suitability.

Introduction

Managing arid conservation areas for both biodiversity and large mammals is a complex and potentially conflicting task (Novellie *et al.,* 1991; Lombard *et al.,* 2001; Birkett, 2002). The Orange River Nama Karoo is a species rich desert vegetation type of which only 1.5 % is under formal conservation. Of this two thirds are in the Augrabies Falls National Park (AFNP)(Hoffmann, 1996). AFNP is situated in the Gariep Centre of Endemism, and 54 % of its flowering plant species are not conserved elsewhere (Zietsman & Bezuidenhout, 1999). AFNP aims to conserve 1) a representative sample of the endemic vegetation and the threatened riverine woodland as well as 2) endangered, rare and valuable animal species, including black rhino (*Diceros bicornis*) and Hartmann's mountain zebra (*Equus zebra hartmannae*) and 3) other biodiversity. AFNP encompasses 554 km^2 in which to balance these conservation objectives, but the land is arid, sparsely vegetated and steep or rocky in large parts.

The biggest natural sources of impact on the park's biodiversity are the large mammals, especially the two mega-herbivores: Giraffe (*Giraffa camelopardalis*) and black rhino. Conservation of black rhino is a high priority in the park, because this is a critically endangered species (IUCN, 2003) with only 3100 animals left (*Pers.comm.*: Richard Emslie, Rhino Management Group) and because black rhino is a charismatic species with high tourism potential. Black rhinos were present in the park from 1986 to 1999 and there are plans to reintroduce the species.

To plan and implement the conservation of conflicting components of biodiversity comprised by small, confined populations, it is highly beneficial to map the topographical and ecological variables of the area under protection. Such maps form the basis for understanding the distribution of plant and animal species, as well as for estimating carrying capacities. Habitat suitability modelling for plants and animals as well as interpretation of animal behaviour is also facilitated by resource mapping.

The aim of this study was to describe the Waterval section of AFNP from the perspective of black rhino to acquire data for interpretation of black rhino feeding (Paper 2) and for modelling of black rhino habitat suitability (Paper 3). However, the data may be useful to studies of other browsers or other groups of organisms in the study area.

The specific objectives were 1) to classify and map the vegetation communities (habitats) by their plant species (browse) composition; 2) to describe each habitat by a) the availability of browse of different species, b) the availability of shade, c) the availability of vertical cover and d) the substrate; 3) to map a) steepness of slopes, b) accessible water and c) infrastructure in the study area.

Study area

Location and land use

Augrabies Falls National Park (AFNP) located approximately 120 km west of Upington at 28° 25' – 28° 38' S, 19° 53' – 20° 24' E was proclaimed in 1966 and gradually expanded to 55 365 ha bisected by the Orange River (Figure 1). Prior to park status the area was used for extensive small stock grazing. This study concerns the 7 530 ha Waterval section of AFNP, which served as a black rhino reserve (Figure 1).

Topography and land types

Waterval can be divided into four land types (Land Type Survey Staff, 1986)(Figure 6): In the extreme south is the gently sloping upper river valley at 610-630 m above sea level which is of land type Ia(1a) consisting of intrusive rocks, mainly granite, overlain with tertiary to recent alluvial silt and fine sand. The lower river valley and incised gorge area at 420-620 m above sea level and the northeastern mountainous area at 610-750 m above sea level are both of land type Ic(3a). This is mostly comprised of exposed red biotite granite gneiss, which is typically orange brown to reddish on weathered surfaces, but the western gorge area is comprised of grey gneiss. The central basin generally sloping south and west at 550-620 m above sea level is of land type Ag(2d), which has the same geology as Ic(3a), but is overlain with sand and gravel. A small plain in the far north at 705-725 m above sea level is of landtype Ae(110b) with gravel and sand underlain by tectonic intrusive rock including Colston granite (Land Type Survey Staff 1986). Outcrops of quartzite occur in the three latter land types.

Climate

AFNP has a hot desert climate (*BWh* in the Köppen system) with summer rainfall. Annual precipitation at Augrabies Waterfall (622 m above sea level) averaged 123 mm for the period 1945-1999 with a coefficient of variation of 59 % (Weather Bureau, 2001). Annual evaporation at Upington (846 m above sea level) averages 3 384 mm. Mean monthly humidity at Augrabies Waterfall ranges from 10 to 40 %. December to April sees 71 % of the rain, peaking in March with 26.7 mm on 2.7 rain days. For the period 1990-2001 the highest and lowest average monthly maximum and minimum temperatures were 37.1 ^{o}C (January), 21.3 ^{o}C (July), 21.6 ^{o}C (January) and 4.5 ^{o}C (July). Absolute maximum and minimum temperatures during 1984-1990 were 46.0 ^{o}C and –2.0 ^{o}C, with an average annual of 0.9 frost nights in July-August (Weather Bureau 2001).

Vegetation and fauna

AFNP is situated in the Orange River Nama Karoo vegetation type (Hoffman, 1996) in the Gariep Centre of Endemism (Zietsman & Bezuidenhout, 1999). The stocking rate for livestock recommended by the Ministry of Agriculture is 60 ha per large stock unit. Zietsman & Bezuidenhout (1999) listed 364 species of flowering plants recorded in the park, of which 197 were not in the species lists of the three nearest major conservation areas. Bezuidenhout (1996) published a vegetation map of a small section of the park just south of Waterval, while Werger & Coetzee (1977) also included a small part of Waterval (Melkbosrand) in their study without providing a vegetation map.

Preliminary species lists for AFNP include 61 mammalian, 218 avian, 12 amphibian and 53 reptile species (SANParks, 2002). Large, mammalian herbivore species include 1. Medium-long grass feeders: Hartmann's mountain zebra and gemsbok; 2. Mixed feeders: Eland and springbok; 3. Browsers: Black rhino, duiker, giraffe, klipspringer, kudu and steenbok; 4. Selective omnivores: Baboon and vervet monkey. Even the grazers include some browse (5-20 %) in their diet during dry season and droughts (Estes, 1991; Owen-Smith, 1999). The largest predator is caracal and vagrant leopard. Black rhino was introduced into Waterval in 1986 and numbers averaged about six until their removal from AFNP in 1998. The western and eastern parts of the Waterval section had livestock on it until 1974 and 1992, respectively.

Methods

Waterval was classified into vegetation communities according to the composition and availability of browse from 0 to 200 cm above ground, which is the normal approximate height range of browsing in kudu and black rhino (Du Toit, 1990; Smithers, 1983, paper 2). Vertical cover, shade and substrate are closely related with the species composition of the non-grass plants, so vegetation communities were used as stratification for measuring these parameters. Grasses were given a low priority in this study for three reasons. Firstly, in arid areas the quantity and composition of grasses fluctuate strongly with rainfall (Bezuidenhout, 1997), so only long-term monitoring can provide a meaningful quantification. Secondly, the grass layer is extremely limited in Waterval in a year of average rainfall. Thirdly, the main emphasis of this study was on the habitats of black rhinos and other browsers.

Sampling

The study area was stratified into relatively homogenous preliminary phyto-sociological units based on visual classification of 1:50 000 panchromatic aerial photographs and extensive ground-truthing. Sampling plots were placed randomly within each phyto-sociological unit and geo-referenced with a Global Positioning System (GPS) receiver. The proportion of plots in each unit was determined by unit size, browse availability and statistical considerations.

Data collection in the sampling plots took place during November 1999 – May 2000. The plots consisted of an adaptation of belt transects (Mueller-Dombois and Ellenberg, 1974) in which all plants, except grasses, 100 cm or taller were measured. Each adapted belt transect was terminated when 30 plants had been included, and plot length was determined as the equidistance between the 30th and 31st plant. Small, square plots were placed randomly inside the belt transect and all plants less than 100 cm tall were measured, except for grasses. The number of small plots inside each belt transect was increased until they included a minimum of 50 plants. The 58 belt transects thus contained 1740 large plants and the smaller plots more than 2900 small plants. The rationale for employing different plots for different plant sizes was to efficiently acquire just enough data for each size class. The use of transects ensured that sampling cut across clumped distributions of plants, while the randomly placed small plots sampled different microhabitats within the transect.

Each plant was identified to species *in situ* if possible. Alternatively, a specimen was collected for herbarium identification (SANParks, Kimberley; MacGregor Museum Herbarium, Kimberley; National Museum Herbarium, Bloemfontein and National Botanical Institute, Pretoria). Taxon names in this paper are in accordance with Arnold & de Wet (1993). One to three plant canopy heights (top, widest point and bottom) and one or two sets of perpendicular canopy diameters were recorded with measuring tapes as in Smit (1996). For grasses, only the presence of the more dominant species and their estimated canopy cover was noted. For the major browse species presence/absence of leaves, growing shoots, flowers and fruits were recorded.

At 25 regularly spaced points along the western boundary of each plot a pointed metal dropper was dropped from 1 metre with eyes closed. At each point of impact depending on what was struck the following data was recorded: for soil the predominant soil particle size was recorded, for a loose rock two diagonal measurements were recorded, while if dead organic material or bedrock was hit this was simply noted. Substrate classification based on soil particle size (soil texture grades) follows U.S. Department of Agriculture (Strahler 1975).

Data analysis

The percentage projected plant canopy cover was calculated for all species and for each vegetation community, as were canopy volumes using a spreadsheet modification of Smit (1996). Simpson (D) and Shannon diversity (H') were calculated for the study area based on browse volume 0-200 cm above ground. Shannon diversities were compared using Hutcheson's method (Zar, 1999). Simpson equitability (E) was calculated for each vegetation community, but to reduce any bias from small sample sizes, calculations were based on browse volume of the 10 most abundant species only (Begon *et al.,* 1986). Shade for large mammals was calculated as projected canopy cover of plants taller than 2 metres minus the basal area, provided this doughnut shape was minimum 1 metre from inner edge to outer edge. Height of each plant strata (trees, shrubs or herbs) was calculated as the average top height of the plants in each stratum, excluding trees less than 1 metre. No correction was made in cover and shade for overlapping plants.

The projected plant canopy cover and the plant canopy volumes 0-200 cm above ground were entered into two separate TWINSPAN analyses (McCune & Mefford, 1997). For convenience estimated plant canopy cover is usually used for phyto-sociological classification, but three dimensions (canopy volume) better represents what determines vertical cover and availability of food for browsers. The pseudo-species cut off levels (intervals) for plant cover followed the Braun-Blanquet cover classes (Whittaker, 1980), while those for plant canopy volume were 0 m^3/ha (value=0), <1 m^3/ha (1), 1-5 m^3/ha (2), 6-10 m^3/ha (3), 11-30 m^3/ha (4), 31-100 m^3/ha (5), 101-300 m^3/ha (6), 301-1000 m^3/ha (7), 1001-2000 m^3/ha (8) and >2000 m^3/ha (9). The TWINSPAN outputs were refined applying Braun-Blanquet procedures to form phyto-sociological tables (Whittaker, 1980). An ordination (DECORANA)(McCune & Mefford, 1997) was performed to see whether the phyto-sociological units were properly differentiated, or should rather be amalgamated. The initial phyto-sociological classification was changed according to these analyses. The resulting vegetation communities were named by the two most diagnostic or characteristic taxonomic entities in order of prominence. Structural terminology for the communities and vertical plant strata (trees, shrubs, herbs) follows Edwards (1983).

Mapping

The boundaries of the phyto-sociological units were corrected following data analysis and ground-truthing to delineate the final vegetation communities. The aerial photos and the vegetation community boundaries were geo-referenced based on GPS readings entered into a Geographical Information System computer programme (GIS), and the community boundaries digitised on-screen to produce a vegetation map. The size of the area covered by each community was extracted from the GIS file. Points of accessible water were derived from fieldwork.

Results

Vegetation communities cum browser habitats

The vegetation classification yielded 10 vegetation communities in the study area. Using either plant canopy cover or plant canopy volume 0-200 cm above ground resulted in identical classification of plots and communities. Using plant canopy volume in the phyto-sociological table facilitates an overview of available browse and its intra-community variation (Table 1). Below is a brief description of each vegetation community *cum* browser habitat including results on substrate composition and availability of browse, shade and vertical cover.

1*. Schotia afra – Indigofera pechuelii* low, open woodland occurs on red biotite granite gneiss, which is typically orange brown to reddish, and largely falls within the crest, midslope and footslopes of land type Ic3a (Land Type Survey Staff, 1986). This community covers 36 % of the study area (Figure 2, table 2). Bedrock and large rocks make up 58 % of the **substrate** (Table 2) interspersed with 0.3 – 0.6 m deep Hutton soil form (Land Type Survey Staff 1986). **Slope** in this community varies from 0 to 90 degrees, with the median being 7 degrees and 5 % being steeper than 38 degrees (Table 2).

The *Schotia afra – Indigofera pechuelii* low, open woodland community is characterised by species group A (Table 1). The diagnostic species are primarily the tree *Schotia afra* and the herbs *Indigofera pechuelii* and *Hibiscus englerii*. **Browse availability**, expressed as plant canopy volume from 0-200 cm above ground, is 975 m^3/ha, which is 11 % below the average for the study area (Table 4). Simpson equitability (E) among the 10 most abundant browse species is intermediate for the study area at 0.55 (Table 4). This means Simpson's diversity index is 55 % of the potential maximum among 10 species. Simpson's diversity index expresses the inverse of the chance of sampling the same species in two consecutive samples. Thus, the chance of randomly picking the same species twice in a row is 1/(0.55x10)=0.18. *Schotia afra* makes up 28 % of the browse by volume followed by the herb

Forsskaolea candida (10 %), the soft shrub or herb *Indigofera pechuelii* (10 %), the succulent shrub *Euphorbia rectirama* (6 %) and the tall herb *Hibiscus englerii* (5 %).

The tree stratum reaches 5 m (average=270 cm), but its canopy cover is only 3.6 %, while the herbaceous cover is 15.9 % and herbs make up 55 % of the browse volume (Table 3). **Vertical cover** for large mammals is generally low in Waterval, and vegetation community 1 is average in this respect with 596 m^3/ha of browse at 0-100 cm above ground and 379 m^3/ha at 101-200 cm, with another 454 m^3/ha 201-500 above ground (Table 2). In other words, plant canopies occupy 6.0 % of available space from the ground to 1 m and 3.8 % between 1 and 2 metres. **Shade** for large mammals only occurs at 4.4 points per ha (Table 3).

This community is similar to the *Rhus populifolia* – *Schotia afra* Open Woodland of Bezuidenhout (1996) and resembles the *Schotia afra* community described by Werger & Coetzee (1977).

2. *Adenolobus garipensis* – *Boscia albitrunca* tall, open shrubland covers 11.7 % of Waterval, occurs on grey granite and largely falls within the crest, midslope and footslopes of land type Ic3a (Land Type Survey Staff 1986)(Figure 2, table 2). The **substrate** is a mixture of gravel (33 %), bedrock (21 %), rocks (21 %) and pebbles (21 %)(Table 2). The terrain varies from level to vertical, with the median **slope** being 8 degrees and 5 % steeper than 40 degrees (Table 2).

The *Adenolobus garipensis* – *Boscia albitrunca* high, open shrubland community is primarily characterised by the presence of species group B, D, M, R and X and the virtual absence of groups A, F and T (Table 1). The diagnostic species are the shrub *Adenolobus garipensis*, the small tree *Boscia albitrunca* and the succulent shrub *Ceraria namaquensis*. **Browse availability** is 1 076 m^3/ha, which is 2 % below average, and Simpson equitability (E) is high at 0.65 (Table 4). Browse is dominated by the shrub *Adenolobus garipensis* (23 %), the herb

Osteospermum microcarpum (18 %), the herb *Monechma spartiodes* (9 %) and the tree *Boscia albitrunca* (9 %). The tree stratum reaches 5 m (average=274 cm), but its canopy cover is only 1.1 %, while the herbaceous cover is 32.3 % and herbs make up 62 % of the browse volume (Table 3). **Vertical cover** for large mammals is 821 m^3/ha of browse at 0-100 cm above ground and 254 m^3/ha at 101-200 cm (Table 2). **Shade** for large mammals only occurs at 3.4 points per ha (Table 3)

3. *Euphorbia gregaria – Osteospermum microcarpum* tall, sparse shrubland covers 6.7 % (Figure 2, table 2) and occurs exclusively on substrates with a high content of quartz in the form of bedrock (33 %) and large rocks (28 %) interspersed with gravel (11 %) and sand (22 %)(Table 2). Thus, this community is typically found on the crests and slopes of the quartzitic outcrops that occur in any of the non-alluvial land types. Median **slope** is 4 degrees (Table 2).

The *Euphorbia gregaria – Osteospermum microcarpum* tall, sparse shrubland community is characterised by the consistently high presence of the conspicuous succulent shrub-like *Euphorbia gregaria* (Table 5). **Browse availability** is 918 m^3/ha, which is 16 % below average, and Simpson equitability (E) is very low at 0.25 (Table 4). *Euphorbia gregaria* makes up 57 % of the browse followed by the small herb *Tribulus cristatus* (11 %). The tree stratum is virtually absent. Canopy cover of shrubs in the strict sense of woody multi-stemmed plants (Edwards 1983) is only 0.9 %, but *Euphorbia gregaria*, which can be considered a shrub by structure, covers 5.7 % (Table 3). **Vertical cover** is 735 m^3/ha of browse at 0-100 cm above ground and only 183 m^3/ha at 101-200 cm (Table 2). **Shade** for large mammals was not encountered in the five plots (Table 3).

The *Euphorbia gregaria – Osteospermum microcarpum* tall, sparse shrubland is similar to the *Enneapogon scaber-Euphorbia gregaria* community described by Werger & Coetzee (1977).

4. *Acacia mellifera – Euphorbia* spp. tall, open shrubland covers 14.6 % and largely falls within the foot slopes and valley bottoms of land type Ag2d (Land Type Survey Staff 1986)(Figure 2, table 2). The dominant substrate is gravel (48 %) strewn with rocks (9 %) and pebbles (16 %) interrupted by outcropping bedrock (16 %) and sandy (12 %) drainage lines (Table 2). The soil is predominantly of the Hutton form (Land Type Survey Staff 1986). Median **slope** is 3 degrees.

The *Acacia mellifera – Euphorbia* spp. high, open shrubland community is primarily characterised by the presence of species group E, F, H, and T and the limited occurrence of group G (Table 1). The diagnostic species are primarily the large shrub *Acacia mellifera*, the succulent shrubs *Euphorbia rectirama* and *Euphorbia gregaria* as well as the herbs *Blepharis furcata*, *Indigofera pungens*, *Hermannia spinosa* and *Trianthema triquetra*. **Browse availability** is 852 m^3/ha, which is 22 % below average, and Simpson equitability (E) is high at 0.67 (Table 4). Browse consists of *Acacia mellifera* (24 %), *Schotia afra* (10 %), *Indigofera pechuelii* (11 %), *Euphorbia rectirama* (9 %), *Indigofera pungens* (8 %) and *Monechma spartiodes* (8 %)(Table 4). Herbs make the biggest contribution to both canopy volume and cover (Table 3). **Vertical cover** is 608 m^3/ha of browse at 0-100 cm above ground and only 244 m^3/ha at 101-200 cm (Table 2). **Shade** for large mammals only occurs at 1.3 points per ha (Table 3).

This community falls within the *Acacia mellifera* community of Bezuidenhout (1996), but does not match any of the two described sub-communities. The closest community in Werger & Coetzee's (1977) description is the *Monechma spartioides* sub-community of the *Indigofera heterotricha-Zygophyllum suffruticosum* community.

5. *Acacia mellifera – Zygophyllum dregeanum* tall, open shrubland occurs in two variants:

5.1. *Acacia mellifera – Zygophyllum dregeanum – Euphorbia rectirama* tall, open shrubland covering 11.7 % of the study area (Figure 2, table 2) occurs on the foot slopes of land type Ag2d (Land Type Survey Staff 1986) on red biotite gneiss, mostly overlain with gravel (55 %) and pebbles (11 %)(Table 1) of the same material. The gravel in this community features a structure peculiar of arid areas referred to as "schaumboden" in Werger & Coetzee (1977). The top 1-2 mm forms a relatively hard, "polished" crust over 10-20 mm of more porous, compactable material, making this substrate unfavourable for plant establishment. "Schaumboden" gravel (55 %) and pebbles (17 %) dominate the convex surfaces between numerous lightly incised sand (11 %) and gravel filled drainage lines, which are more densely vegetated. Outcrops of red gneiss bedrock (13 %) and rocks (4 %) also occur, with vegetation affiliated with community 1. **Slope** is 1 degree or less in 75 % of the community (Table 2).

The *Acacia mellifera – Zygophyllum dregeanum – Euphorbia rectirama* community is primarily characterised by the high occurrence of the diagnostic species in its name (Table 2). **Browse availability** is only 597 m^3/ha, which is 46 % below average, and Simpson equitability (E) is low at 0.31 (Table 4). Browse consists of *Acacia mellifera* (24 %), *Schotia afra* (10 %), *Indigofera pechuelii* (11 %), *Euphorbia rectirama* (9 %), *Indigofera pungens* (8 %) and *Monechma spartiodes* (8 %)(Table 3). "Schaumboden" impedes herbaceous cover to just 5.4 % and 54 % of browse volume thus consists of shrubs. **Vertical cover** is only 343 m^3/ha of browse at 0-100 cm above ground and only 254 m^3/ha at 101-200 cm (Table 3). **Shade** for large mammals only occurs at 1.3 points per ha (Table 3).

5.2 *Acacia mellifera – Zygophyllum dregeanum – Monechma spartioides* tall, open shrubland differs from the previous sub-community by being dominated by pebbles (57 %) at the expense of "schaumboden", bedrock and drainage lines (Table 2). This results in higher herbaceous cover (12.4 %) and in higher browse availability (861 m^3/ha) as well as in the virtual absence of *Euphorbia rectirama* and much higher occurrence of *Monechma spartioides* (13 %). *Acacia mellifera* (49 %) and *Zygophyllum dregeanum* (18 %) dominate the sub-community. Vertical **cover** is 495 m^3/ha at 0-100 cm above ground and 366 m^3/ha at 101-200 cm. **Shade** occurs at 6.3 point/ha.

Communities 5.1 and 5.2 are similar to the *Zygophyllum dregeanum* sub-community of the *Indigofera heterotricha*-*Zygophyllum suffruticosum* community described by Werger and Coetzee (1977). Community 5 falls within the *Acacia mellifera* community of Bezuidenhout (1996).

6. *Acacia mellifera* – *Stipagrostis hochstetteriana* tall, open shrubland covers 12.5 % of the study area in land type Ag2d (Land Type Survey Staff, 1986)(Figure 2, table 2). The dominant substrate is a mixture of 53 % sand and 41 % gravel (Table 2) classified as Hutton soil form (Land Type Survey Staff, 1986). The **slope** is 5 % or less in 75 % of the community (Table 2).

The *Acacia mellifera* – *Stipagrostis hochstetteriana* tall, open shrubland community is characterised by the combination of the species *Acacia mellifera* (Species group S), *Boscia albitrunca* (group M), *Boscia foetida*, the smallish shrub *Rhigozum trichotomum* (group L), the shrub *Lycium bosciifolium* (group AB), and the herb *Monechma spartioides* (Table 1). None of these are good character species as they show a low degree of community fidelity (Whittaker 1980), but in combination with the virtual absence of species groups A through I (differential species) nevertheless form a set of diagnostic species (Table 1). After good rains the otherwise sparse herbaceous layer becomes completely dominated by the grass *Stipagrostis hochstetteriana*.

Browse availability is 1 078 m^3/ha, which is 2 % below average, and Simpson equitability (E) is low at 0.35 (Table 4). The main browse species are *Acacia mellifera* (44 %), *Monechma spartiodes* (10 %), *Boscia albitrunca and B.foetida* (8 %) and *Rhigozum trichotomum* (5 %) (Table 4). Shrubs account for 61 % of canopy volume and a canopy cover of 9 % . **Vertical cover** is 622 m^3/ha (0-100 cm) and 456 m^3/ha (101-200 cm) (Table 3). **Shade** for large mammals only occurs at 12.6 points per ha (Table 3).

This community resembles the *Stipagrostis hochstetteriana* community described by Werger and Coetzee (1977).

7. *Sisyndite spartea – Forsskaolea candida* tall, open shrubland occurs on wide drainage lines and plains occasionally subject to flooding, which only covers 0.7 % of the study area in one patch (Figure 2, table 2). The **substrate** is 95 % washed gravel (Table 2).

The *Sisyndite spartea – Forsskaolea candida* tall, open shrubland community is characterised by one character species, the shrub *Sisyndite spartea*, plus by high availability of *Acacia mellifera* and *Schotia afra*. **Browse availability** is 1 071 m^3/ha - just 2 % below average - and Simpson equitability (E) is only 0.33 (Table 4). The main browse species are *Sisyndite spartea* (26 %), *Acacia mellifera* (15 %) and clumps of *Schotia afra* (45 %)(Table 4). Trees contribute 50 % of canopy volume and canopy covers for trees (4.5 %) and shrubs (5.8 %) are higher than for herbs (2.6 %). **Vertical cover** is 420 m^3/ha (0-100 cm) and 652 m^3/ha (101-200 cm) (Table 2). **Shade** for large mammals only occurs at 9.4 points per ha (Table 3).

This community resembles the *Sisyndite spartea* communities described by Bezuidenhout (1996) and Werger & Coetzee (1977).

8. *Acacia erioloba* short, closed woodland occurs in two variants:

8.1 *Acacia erioloba – Schmidtia kalahariensis* short, closed woodland is limited to areas where the **substrate** is sand mixed with some gravel (Table 2). It only covers 0.4 % of the study area (Figure 2, table 2).

The *Acacia erioloba – Schmidtia kalahariensis* short, closed woodland community is characterised by the predominance of the species in its name (Table 1). **Browse availability** is around 1 150 m^3/ha (Table 4). The herbaceous layer is poorly developed except for the ubiquitous, opportunistic creeper *Tribulus cristatus* and the annual grass *Schmidtia kalahariensis*, the preponderance of which is highly dependant on summer rainfall. *Acacia erioloba* provides abundant shade (Table 3), but because of its raised canopy reaching eight metres it contributes little to browse availability at 0-200 cm (Table 3 and 4). *Acacia mellifera* and *Monechma spartiodes* also contributes significant amounts of browse.

8.2 *Acacia erioloba – Zygophyllum microcarpum* short, closed woodland is a community variant that differs by occurring on a **substrate** of pure gravel near large drainage lines. Only 0.1 % of the study area falls in this sub-community (Figure 2), and due to its tiny size was pooled with 8.1 for most analyses.

This community variant differs by the high availability of *Zygophyllum microcarpum* (a small shrub) and *Zygophyllum simplex* (a succulent creeper). Otherwise the herbaceous layer is poorly developed. *Acacia mellifera* is also present.

Community 8 is very similar to the *Monechma australe – Acacia erioloba* community of Werger & Coetzee (1977).

9. *Tamarix usneoides - Maytenus linearis* tall, open shrubland occurs on floodplains where the **substrate** is a dusty mixture of pure silt and clay (Table 2). The land type is Ia1a

(Land Type Survey Staff, 1986). The community covers 1.0 % of the study area (Figure 2, table 2). **Slope** is 1 degree or less in the three quartiles (Table 2)

The *Tamarix usneoides - Maytenus linearis* tall, open shrubland community is clearly defined by the diagnostic species of species group U (Table 1). The group comprises the smallish tree *Tamarix usneoides*, the succulent herb *Mesembryanthemum guerichianum* and two succulent *Psilocaulon* herbs. *Maytenus linearis* is also very conspicuous in this community.

Browse availability is 2 581 m^3/ha or more than twice the average. Equitability is intermediate at 0.49. Browse consists of *Tamarix usneoides* (28 %), *Sueda fruticosa* (28 %), which occurs densely on the transition to the riverine community, *Maytenus linearis* (13 %) and *Psilocaulon absimile* (12 %). Shrubs account for 45 % of canopy volume and cover 16 % (Table 3). Large **shade** occurs at 11.6 points/ha and **vertical cover** is 1 747 m^3/ha (0-100 cm) and 834 m^3/ha (101-200 cm)(Table 2).

This community is very similar to the *Tamarix usneoides-Ziziphus mucronata* sub-community described by Bezuidenhout (1996).

10. *Acacia karroo – Ziziphus mucronata* short forest occupies a 5 – 30 m wide strip along the Orange River and a few tributaries, equal to 1.1 % of the study area, where terrain and hydrology allows soil to build up (Figure 2, table 2). The **substrate** is an alluvial silt-clay combination (48 %) highly enriched with humus (48 %). Three quartiles have a **slope** of 1 degree or less (Table 2).

The *Acacia karroo – Ziziphus mucronata* short riverine forest community is characterised by species group Y (Table 1). Within the study area the trees *Acacia karroo* and *Ziziphus mucronata* are diagnostic for this community, but *Rhus pendulina* and *Salix mucronata* are more typical riverine tree species on a regional scale.

At 14 446 m^3/ha **browse availability** is 13 times the average for the study area, such that this small community (1.1 %) holds 14.6 % of the entire browse up to 2 metres (Table 4). Most abundant is climbing *Asparagus* species (27 %), *Acacia karroo* (25 %), *Salix mucronata* (10 %), *Rhus pendulina* (9 %), *Ziziphus mucronata* (8 %), *Maytenus linearis* (6 %) and the smallish tree *Euclea pseudobenus* (5 %). Equitability is 0.56 (Table 4). Other than *Asparagus* species and *Tribulus cristatus* (2 %) the herbaceous layer contributes relatively little to browse due to the abundance of woody plants. Tree canopies overlap totalling 140 % cover and reach 530 cm on average (Table 3). **Shade** is almost continuous as tree canopy covers overlap by about 40 % (Table 3). **Vertical cover** is extremely dense at 5 878 m^3/ha (0-100 cm), 8 569 m^3/ha (101-200 cm) and 31 221 m^3/ha (201-500 cm), which means plant canopies circumscribe 59, 86 and 104 % of the available space at the respective height intervals (Table 3).

This community is very similar to the *Diospyros lyciodes – Ziziphus mucronata* sub-community of Bezuidenhout (1996) and the *Ziziphus mucronata – Euclea pseudebenus* community of Werger & Coetzee (1977).

Browse availability in Waterval

Average browse availability for the study area is 1 096 ± 90 m^3/ha (±SEM) 0-200 cm above ground. Equitability for the 10 most abundant browse species based on volume is 0.76 while Simpson and Shannon diversity indices for browse in the study area are D=19.0 and H'(ln)=3.45 (Table 4).

Different measurements of availability for 10 of the most important browse species are shown in Figure 3. The average density of these 10 species in Waterval is not correlated with their average canopy cover (Pearson, p=.50, n=10) nor canopy volume (p=.39, n=10). The average canopy cover of these 10 species is significantly correlated with canopy volume 0-

200 cm above ground (Pearson, r=.83, p=0.003, n=10), but some species, including *Indigofera pungens* and *Maytenus linearis*, deviate very much from this correlation (Figure 3).

Browse is vertically distributed with 38 % at 0-100 cm, 24 % at 101-200 cm and 38 % at 201-500 cm above ground (Figure 4, table 2). The riverine community 10, which covers 1.1 % of the study area, contributes 51 % of the canopy volume at 201-500 cm. The lower stratum is more equitable and diverse in species composition than the higher strata (Figure 4).

The most abundant browse species, *Acacia mellifera*, which contributes 15 % of canopy volume at 0-200 cm is subject to annual leaf fall. During this time its preference by black rhino is reduced (Paper 2). However, the time span without leaves is only two to three months (Figure 5).

Water availability, slope and human disturbance.

Due to very steep gorges water is only accessible at certain sections of the Orange River in Waterval in addition to at a natural spring and two artificial waterpoints (Figure 6). Thus, 31 % of Waterval is within 1 km of water, 61.2 % within 2 km, 81.8 % within 3 km, 91.1 % within 4 km, 97.2 % within 5 km and 100.0 % within 6 km. The northwestern area of Waterval is the only area more than 4 km from water. This area also has the largest concentration of steep slopes (Figure 6). In addition, a public high-speed gravel road runs along the northwestern boundary and probably constituted the biggest source of human disturbance. It had less than 100 vehicles per day. Vehicle tracks were present throughout most of the study area, but only in the area just north of the southern “panhandle” (Figure 6) were the tracks used frequently. There was simple accommodation for rangers, visitors and researchers as well as holding pens in this area accessed by 0-15 vehicles a day.

Discussion

Scarcity and diversity

In addition to endemism, scarcity and diversity characterises plant life in Waterval and AFNP. Two other arid South African national parks and rhino reserves can serve as comparison: the Doornhoek section of Karoo National Park which receives 260 mm rain/year and Than-Droogeveld section of Vaalbos National Park which receives 418 mm rain/year. The browse availability of Waterval (1 095 ±90 m^3/ha) is significantly lower than that of the Doornhoek section of Karoo National Park (1 924 ±141 m^3/ha; Mann-Whitney, U=607, p=0.0002) and the Than-Droogeveld section of Vaalbos National Park (1 890 ±174 m^3/ha; Mann-Whitney, U=1447, p<0.0001). The browse diversity of Waterval (D=19.0) is higher than in Doornhoek (D=12.7; Hutcheson, p<0.2) and significantly higher than in Than-Droogeveld (D=5.6; Hutcheson, p<0.001)(Buk, *in prep.a*; Buk, *in prep.b*). In Waterval the three most abundant browse species make up only 31 % of the browse volume, whereas in Doornhoek, and Than-Droogeveld the figures are 38 and 70 % (Buk, *in prep.a*; Buk, *in prep.b*). Waterval also has a high diversity of habitats with a wide range of soils, moisture regimes and topographic conditions as well as browse availabilities varying from 597 to 14 446 m^3/ha.

The regressions between volume and dry leaf mass of Smit (1996) only applies to regular shrubs and trees, but only 40 % of the Waterval browse falls in this category. Hence, dry leaf mass could not be calculated.

Habitat parameters and suitability

The distribution of habitat parameters described by this study was used to analyse food preferences (Paper 2) and habitat use of black rhino in Waterval (Paper 3). While only such detailed studies can reveal how each species of browser respond to habitat parameters, some general expectations can be discussed.

The low browse availability in Waterval will affect suitability of each habitat and the overall carrying capacity, but a favourable combination of plant palatability, species composition, diversity, phenology and canopy height increases the value of the browse. In Waterval no unpalatable plant species makes up a large percentage of the browse, leaf fall is limited to two to three months in one major species (Table 5) and high plant diversity allows a high degree of selectivity and seasonal switching of diet. The only exception is community 3, where *Euphorbia gregaria* dominates. This species has milky latex that makes it unpalatable to many browsers, except klipspringer (Own obs.)

Furthermore, most of the browse is 0-2 metres above the ground within reach of a large browser, except in communities 8 and 10 where large amounts of browse are only available to giraffes and arboreal herbivores (Table 2, figure 4). A large proportion of the browse above 1 metre is comprised of a few species of trees and shrubs, whereas below 1 metre browse is largely composed of a diverse array of herbs (Figure 4).

Community 10 has 14 times higher browse availability (from 0 to 200 cm above ground) than the average for Waterval and may be expected to be highly suitable for browsers. However, black rhino density was hardly affected by total browse availability, but by the availability of a few preferred species (Paper 3).

The north-eastern corner of Waterval (8.9 % of the area) is more than 4 km from water. The north-eastern area also has some steep slopes only exceeded by the near vertical Orange River Gorge. This is expected to make the north-east less utilised and the Orange River Gorge inaccessible to most browsers, with the exception of klipspringer. This held true in the study of black rhinos, which were less than 20 % as frequent on slopes exceeding 8 degrees and only about 5 % as frequent 4 km from water as next to water (Paper 3). Density of giraffe in Amboseli, Kenya was at its maximum 0-2 km from water, 75 % at 2-4 km and 25 % at 4-10 km and 0 % beyond 10 km (Western 1975).

Loose rocks exceeding 20 % in vegetation community 2 and 3 may affect the movement of herbivores and thus the habitat suitability. The high bedrock percentages of communities 1-3 are expected to be less of a problem because bedrock forms a stable substrate, although crevasses can cause injuries. Black rhino density in Waterval was significantly affected by total rock cover (Paper 3).

Disturbance in the form of passing vehicles on the low use public road along the northeastern boundary is expected to affect at least daytime distribution of large mammals. Black rhino density did in fact appear affected by this road as well as one of the park roads (Paper 3).

Vertical cover in the form of plant canopies is low in Waterval, except for community 9 and 10. In some communities topography and bedrock provides some hiding and thermal cover. Several communities, especially 3 and 5.1, have such low shade availability that it must be expected to affect daytime use in the hot summer months. The dense canopy cover of community 10 endows it with a moderated microclimate. Black rhinos were not affected by vertical cover, while shade was only border-line significant (Paper 3).

The riverine forest provides easy access to water, browse, shade and vertical cover. In contrast, the northeastern area is steep, 4-6 km from water and bordered by a public road, while community 3 is rocky, low in palatable browse and lacks shade. Browser habitat utilization is expected to reflect this. However, while black rhino did largely avoid the northeast, they preferred community 4 and 5.1 (Paper 3), which have the lowest browse availability, but are high in the plants rhino prefer (Paper 2).

Vegetation classification and measurements of browse availability

Using measured canopy cover or measured canopy volume 0-200 cm above ground resulted in the same classification into ten vegetation communities. This is because canopy cover and canopy volume are correlated. Thus, the much faster method of an experienced observer visually estimating cover is sufficient for classifying browser habitats. However, cover is not sufficiently correlated with canopy volume across a range a species to be used to estimate available canopy volume through regression. This is unfortunate because rather than the two dimensions of canopy cover, the three dimensions of canopy volume or biomass, are essential measures of browse availability used in measuring browsing preferences, modelling habitat use, estimating stocking rates and more.

Measuring canopy volume using BECvol (Smit, 1996) or similar methods of manual measuring is extremely time-consuming. It would therefore be useful to test whether visual estimation would also work for canopy volume and be sufficiently accurate for most applications. Alternatively, computerised or computer-assisted interpretation of aerial photography may be or become a viable option. In fact, in order to give better answers about browsing there is a need to move from the three dimensional snapshot of browse availability towards acquiring data on the four dimensions of browse growth. There is a big challenge in finding rapid and accurate methods for this purpose.

Conclusions and recommendations

Ten vegetation communities and some of the eco-geographical variables associated with them, including browse availability, were described. Browse availability, slope, water availability, shade, rockiness, vertical cover and disturbance are among the factors potentially affecting habitat suitability for herbivores in Waterval. Their geographical distribution leads to the expectation that utilization is high in and around community 10, while it is low in the northeast. GIS based inventories of habitat parameters, such as this study, should be available in all conservation areas to improve understanding of the area and facilitate research.

Rapid, but accurate methods of estimating browse availability and production are needed for studying aspects of browsing in more depth.

Conservation biology is the science of scarcity and diversity (Soulé 1986), and should be engaged to manage the scarcity and diversity of life in Watervaal and AFNP. To balance conservation of a unique and diverse plant life with that of large and rare herbivores, research on feeding and habitat suitability as well as monitoring of vegetation is recommended. This study provides the eco-geographical variables needed for research on diet preference and key plants to monitor (Paper 2) and habitat suitability (Paper 3) for browsers.

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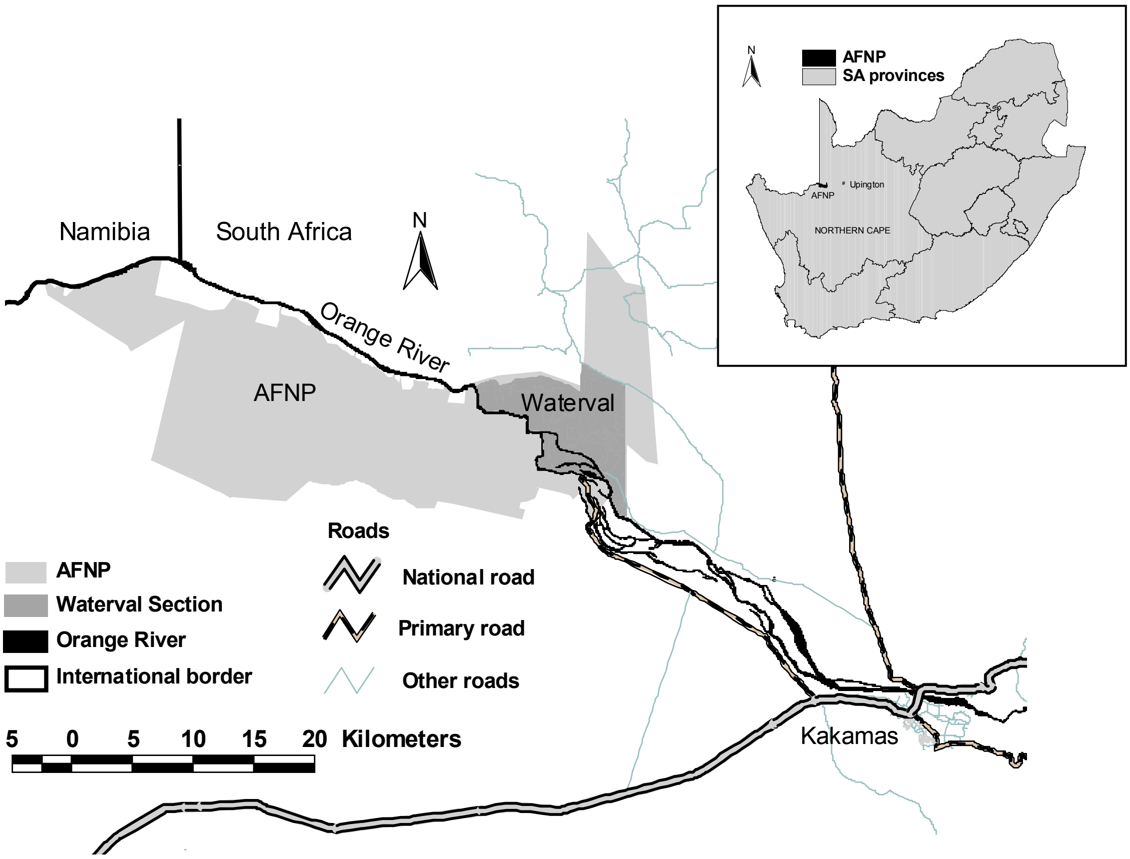


Figure 1.

The location of Waterval and Augrabies Falls National Park (AFNP).

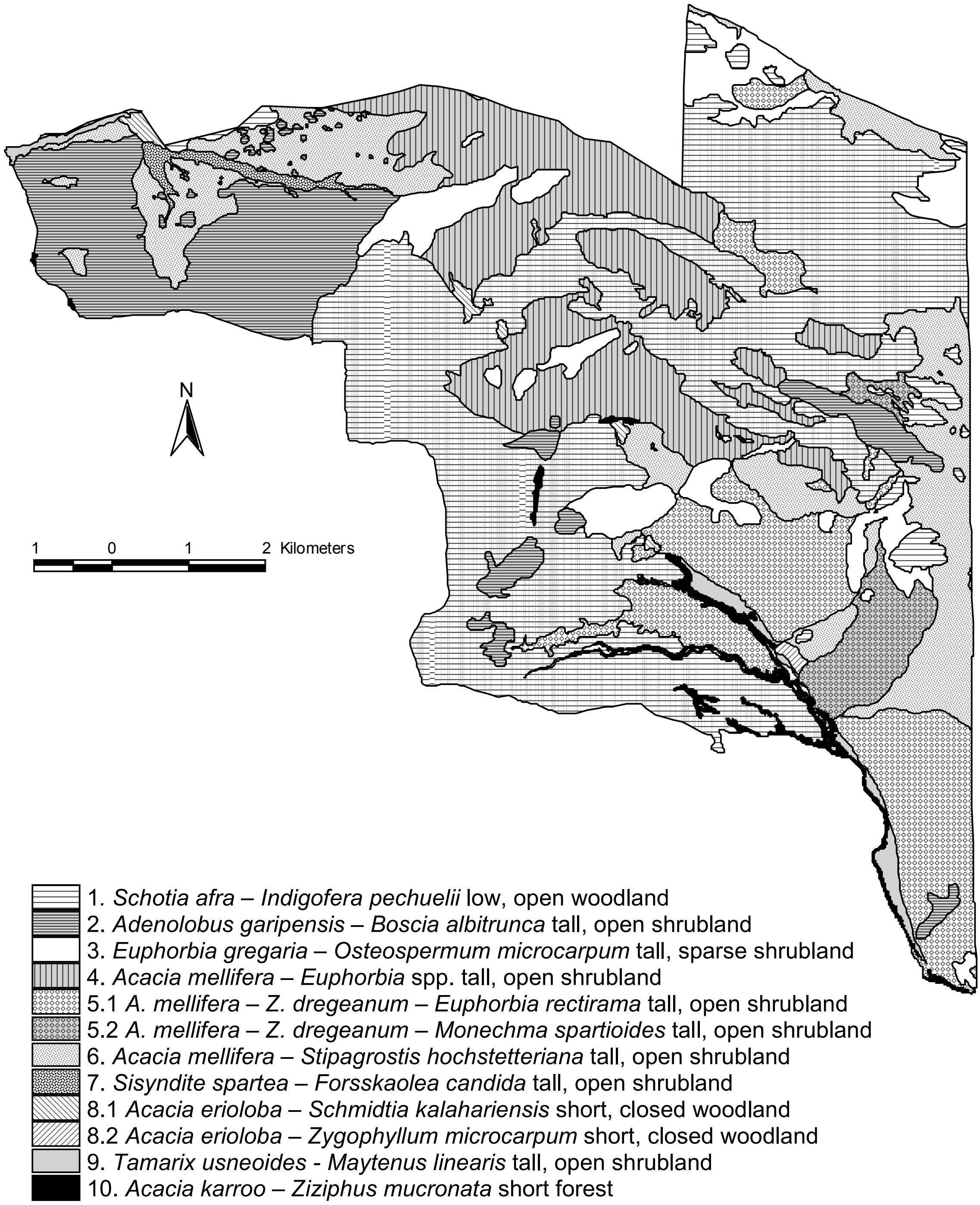


Figure 2.

Vegetation communities in the Waterval section of Augrabies Falls National Park.

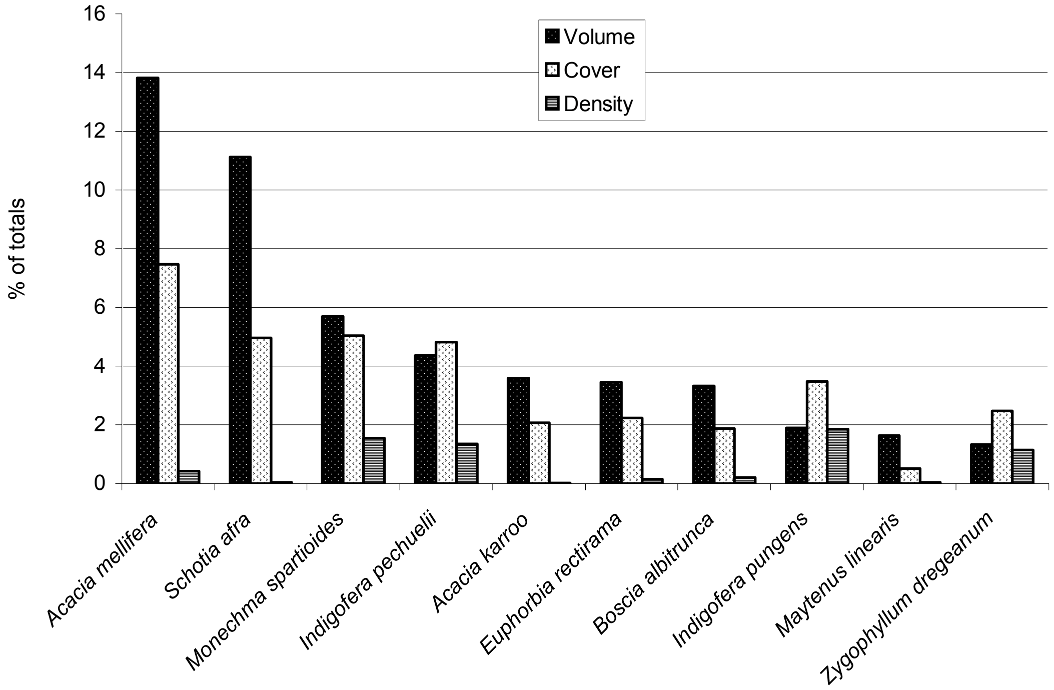


Figure 3.

The canopy volume (0-200 cm above ground), cover and density as percent of their totals for the study area for 10 of the most important browse plant species.

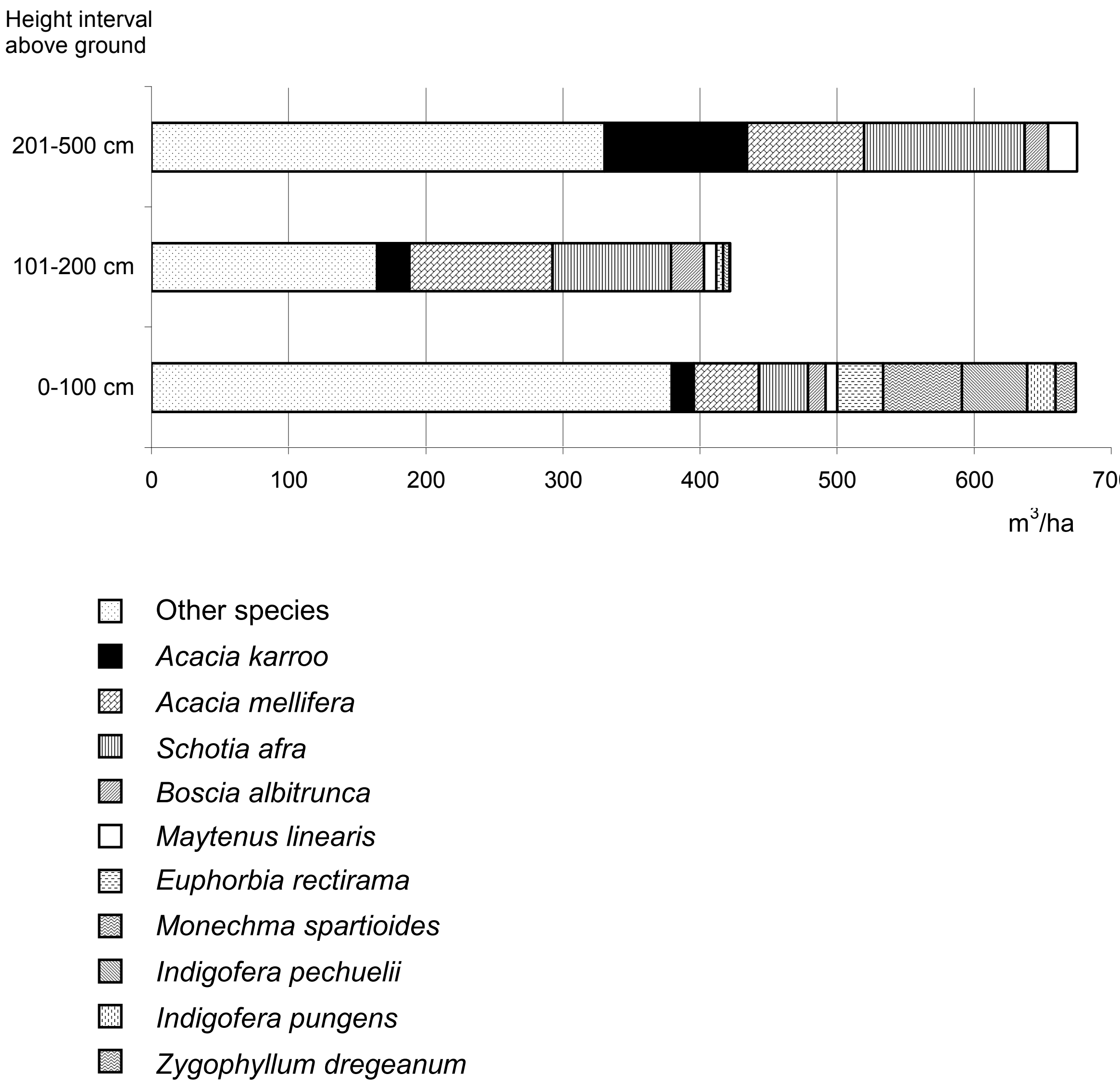


Figure 4.

A vertical profile of the canopy volume for 10 of the most important browse species in the Waterval section of Augrabies Falls National Park.

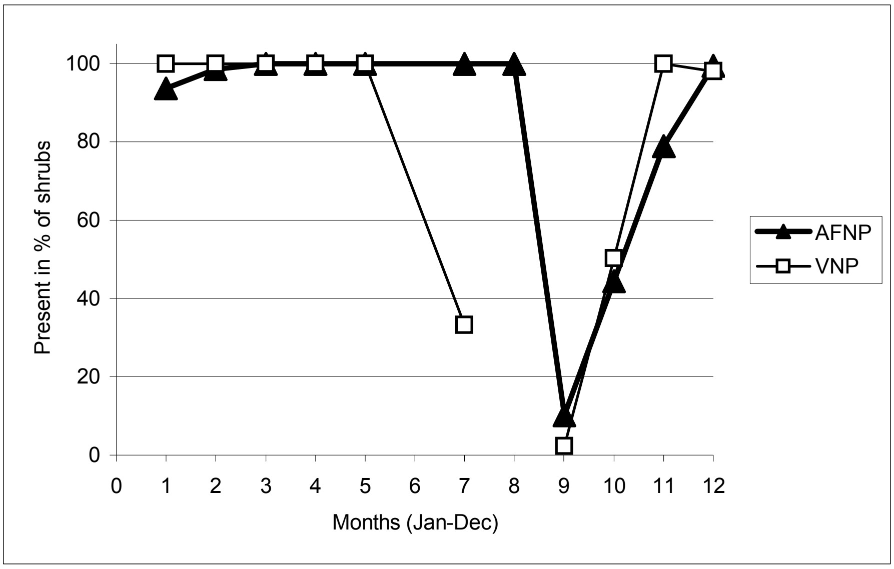


Figure 5.

The monthly presence of leaves on *Acacia mellifera* in Augrabies Falls National Park (n=937) and Vaalbos National Park (n=729).

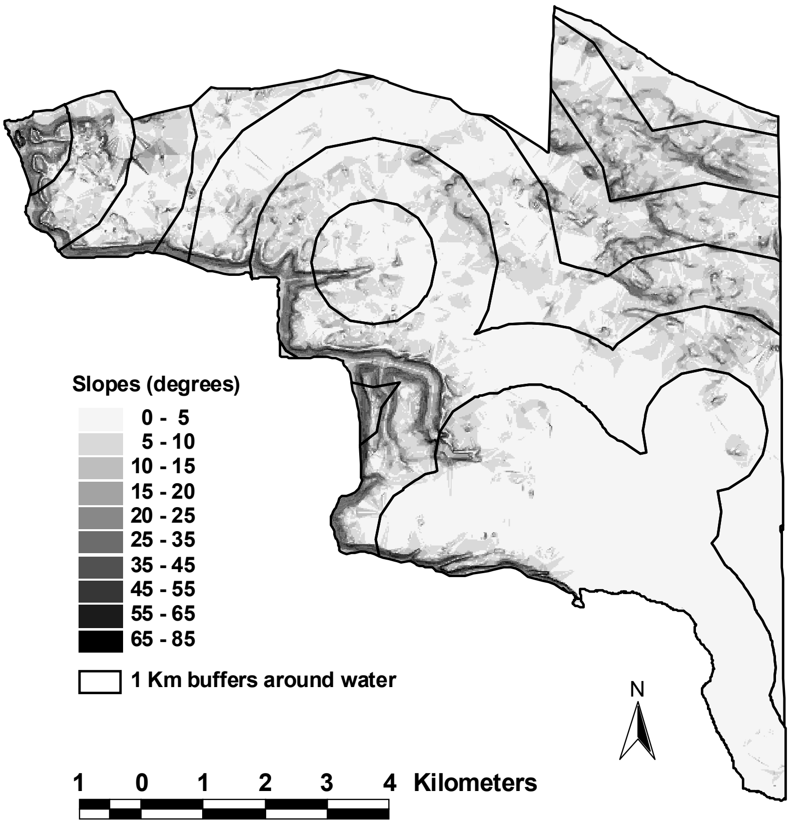


Figure 6.

The distance to accessible water and the slope in the Waterval section of AFNP.

Table 1.

Phytosociological table of the vegetation of the Waterval section of Augrabies Falls National Park based on canopy volume 0-200 cm above ground. The table is continued on the following page.

Species group	Vegetation community number	1	2	3	4	5.1	5.2	6	7	8	9	1 0
	Vegetation plot number	44 20 24 45 57 40 19 56 10	54 55 32 34 35 36	25 8 9 49 38	43 18 41 15 16 17 21 23 42 53	12 13 11 14 48 26 22	51 52	37 33 4 5 7 6	1 2 3	39 58	50 27 31 29	47 30 46 28
A	*Schotia afra*	- 6 7 7 6 4 - 7 7	- - - - - -	- - - - -	- - - - 4 7 - - - -	6 6 - - - - -	- -	- - - - - -	- - 8	- -	- - - -	- - - -
	Indigofera pechuelii	7 - 4 3 6 3 - 5 -	5 - - - - -	- - - - -	7 - - - - - - 3 - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Hibiscus englerii	7 - - 5 5 2 - 2 -	2 - - - - -	- - - - -	4 - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Trichodesma africana	6 1 - 4 - 2 2 - 2	- - 5 - - -	- - - - -	- - - - - - - - - -	1 - - - - - -	- -	5 - - - - -	- - 1	- -	- - - -	- - - -
	Codon royeni	2 - 1 - 2 3 5 4 -	- - - - - -	- - - - -	- - - - - - 1 - - -	1 - - - 2 - -	- -	- - - - - -	- - 1	3 -	- - - -	- - - -
	Euphorbia virosa	6 - 4 - - - - - 2	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Berkheya spinosisima	- - 2 - 1 - 1 3 -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
B	*Adenolobus garipensis*	- - - - - 7 2 5 -	6 7 7 7 5 5	- - - - -	- - - - - - - - - -	5 - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Commiphora gracilifrondosa	- 4 4 - 2 - 4 - -	- - 5 5 - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Rhus populifolia	- 5 - - 4 - 2 - -	2 - 5 3 - -	- - - - -	- - - - - - - - - -	- 3 - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
C	*Euphorbia gregaria*	- - - - - 5 4 6 5	6 4 - - - -	7 7 6 7 7	5 - - - 4 - 5 - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Leucosphaera bainesii	- - - - - - - - -	- - - - - -	- 1 4 - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
D	*Ceraria namaquensis*	- - 5 - - - - 5 -	4 6 - - 3 -	- - 5 - -	- - - - - - 5 - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Nymannia capensis	- - - - 3 4 - - -	- - - - - -	- - - 5 -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
E	*Stachys burchelliana*	6 1 4 3 5 3 - 5 -	4 - - - - -	- - - - -	5 - - - 1 - - 1 - -	- - - - - - -	- -	- 1 - - - -	- - -	- -	- - - -	- - - -
	Hibiscus elliotiae	- - 3 3 - 4 2 - 5	- - - - - -	2 - - - -	- - 2 - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Petalidium lucens	- - - - - - - - 2	- - - - 6 5	- 4 4 - -	3 5 - - 4 - - - - -	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Barleria rigida	- - 2 - - - - - -	- - - - - -	- - - - -	4 - - 1 - - - - - 2	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Galenia aethiopicum	- - - - - - - - -	2 2 - - - -	- - - 3 -	- - - - - - - - - 5	- - - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
F	*Euphorbia rectirama*	7 - 4 - - 4 - 5 4	- - - - 2 -	- - - - -	5 - 7 6 3 5 2 - 5 -	- 4 - - - 6 6	- -	- - - - - -	- - -	- -	- - - -	- - - -
G	*Zygophyllum dregeana*	- - - - - - - - -	4 - - - - -	- - 1 - -	- - - - - - - 4 6 -	- 1 6 5 6 5 4	6 5	- - - - - -	- - -	- -	- 4 - -	- - - -
H	*Blepharis furcata*	- - - - - - - 1 -	- - - - - 4	- - - - -	- 5 4 2 2 4 3 4 3 1	2 - - - 3 1 -	2 2	- 1 - - - -	- - -	- -	- - - -	- - - -
	Hermannia spinosa	- - - - - - - - 1	- - - - - -	- 1 - - -	1 - - 1 1 1 - 2 - 3	- 1 1 1 2 1 -	1 3	- - - - - -	- - -	- -	- - - -	- - - -
	Polygala cf. seminuda	- - - - - - - - -	3 - - - - -	- - - - -	- - - 5 3 3 5 - - -	1 - - - - - -	- 4	- - - - 1 -	- - -	- -	- - - -	- - - -
	Aptosimum spinescens	- - - - - - 2 - -	1 - - - - 1	- - - - -	- - - 1 - 3 - - - -	1 - - 1 2 - -	- 4	- 1 - - - -	- - -	- -	- - - -	- - - -
	Sarcostemma viminale	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - 2 - -	- - - 2 4 - 2	2 4	- 4 - - - -	- - -	- -	- - - -	- - - -
I	*Trianthema triquetra*	- - - 2 - - - - 1	- - - - - -	4 1 2 3 -	6 1 4 1 1 1 - - - 4	1 1 - - - - 1	- 1	- - - - - -	- - -	4 -	- - - -	- - - -
	Rhyncosia totta	- - - - - - - - -	- - - - - -	- - - 4 -	- 2 - - 3 3 - 2 - -	- - - - - 2 2	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Peliostomum leucorrhizum	- - - - - - - - -	- - - - - -	1 - 1 - -	- - - - - - 3 - - -	3 1 - - - - -	- -	- - - - - -	- - -	- -	- - - -	- - - -
	Indigofera heterotricha	- - - - - - - - -	- - - - - -	- - - 3 -	- - - - - - - - - -	- - - - 6 - -	- 6	- - - - - -	- - -	- -	- - - -	- - - -
J	*Lebeckia spinescens*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - 5 3 -	- - -	- -	- - - -	- - - -
K	*Microloma sagittatum*	- - - - - - 2 - -	- 6 - - - -	- - - - -	- 2 - 3 2 4 - 1 4 -	2 1 - 1 - 3 -	- 1	- 1 - - - -	- - -	- -	- - - -	- - - -
	Sericocoma avolans	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - 4 -	- - 2 - - - -	- -	3 - - - - -	- - -	- -	- - - -	- - - -
L	*Boscia foetida*	- - - - - - - - 5	- - - - - -	- 5 5 - -	- - - 3 - - - - 2 -	- 5 - 4 - - -	4 -	- - 5 5 - 6	- - -	- -	- - - -	- - - -
	Monechma geneistifolium	- - - - - - - - -	- - - - - -	- - 5 - -	- - - - - - - - 4 -	- - - 1 - 3 -	2 1	- - - - 4 6	- - -	- -	- - - -	- - - -
	Rhigozum trichotomum	- - - - - - - - -	- 4 - - - -	2 - - - -	- - - - - - - 2 - -	- 1 5 - - 2 -	3 5	- - 7 4 - -	- - -	- -	- - - -	- - - -
M	*Boscia albitrunca*	- 4 6 6 - 5 4 - -	1 - 6 6 6 6	- - - - 5	5 5 4 - 5 6 - 1 - -	- - - - - - -	- -	5 6 - 4 - -	- - -	1 -	- - - -	- - - -

N	*Sisyndite spartea*	- 1 - - - - 6 - -	- - 4 - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	6 - - - - -	6 7 6	-	-	6 - - -	- - - -
O	*Hermannia stricta*	- - - - - - - - -	2 - - - - 5	- - - - -	- - - 2 - - - - 4 -	1 - 5 1 5 1 -	- -	2 - - - - -	4 - 5	-	-	- - - -	- - - -
P	*Forsskaolea candida*	4 3 2 - 7 7 1 6 4	2 - 6 - 6 -	2 3 1 - -	- - - - - - 2 - - -	- - - - - - -	- -	7 - - - - -	3 4 2	-	-	- - - -	- - - -
	Indigofera pungens	- - 1 - - - 6 - 7	- - - - 5 5	- - - - -	- 5 7 4 5 4 5 - - -	- 4 - - - - -	- -	- - - - - -	- 4 -	-	-	- - - -	- - - -
	Dyerophytum africanum	- - 5 - - 3 2 5 4	2 - - - - -	4 - - 4 5	- - - - - - - - - -	- - - - - - 3	- -	5 - - - - -	- 2 4	-	-	- - - -	- - - -
	Kohautia cynanchica	- - - - - - - 1 -	2 - - - - -	- 1 - - -	- - - - - - 2 - - -	1 - - 1 5 - -	- -	- - - - 2 1	1 - -	-	-	- - - -	- - - -
Q	*Limeum aethiopicum*	- - - - - - - - -	- - 2 - - 5	- 1 1 - 3	6 2 5 1 1 2 1 3 - -	1 1 - 1 - 1 1	- -	- 2 2 1 1 2	- - 1	5	-	- - - -	- - - -
R	*Monechma spartioides*	6 - - 4 - 6 1 4 2	4 5 4 - 7 4	3 4 5 6 5	5 4 7 4 4 4 5 5 2 6	4 - 5 3 5 3 4	5 6	6 7 4 2 - -	4 5 5	5	-	- - - -	- - - -
	Ostespermum microcarpum	2 - - - - - - - -	- 6 - 2 7 2	2 2 2 6 4	- - 2 - - - - - - -	1 1 - - - - 1	- -	5 - - - 1 -	2 - -	4	-	- - - -	- - - -
	Lotononis platycarpa	- - - - 3 - 1 - -	- 2 - - 2 -	- - - - 2	- - 5 - - - - - - 2	- - - - - - -	- -	2 - - - - -	- - -	4	-	- - - -	- - - -
S	*Acacia erioloba*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - 4 5	- - -	6	6	- - - -	- - - -
T	*Acacia mellifera*	- - - - - 5 6 - 5	- - - - - -	1 4 - 6 -	6 7 6 5 6 6 5 5 7 6	7 7 7 6 6 5 6	6 7	7 7 6 5 6 7	7 4 5	6	6	4 3 - -	7 - 6 -
U	*Tamarix usneoides*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	9 5 7 6	- - - -
	Psilocaulon absimile	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- 2 8 -	- - - -
	Mesembryanthemum	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- 2 - 2	- - - -
	Psilocaulon cf. coririum	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- 3 - -	- - - -
V	*Zygophyllum simplex*	- - - - - - - - -	2 - - - - 2	- - - - 3	- - 2 - - - - - 3 -	- - - - - - 1	- -	4 4 - 1 - -	- - -	-	8	5 1 4 -	- - - -
X	*Cleome foliosa*	- - - - - - 1 - 2	- - 6 6 5 4	- - - - 3	- 2 2 - - 1 1 2 - -	1 - - - - - -	- -	6 2 - - - -	1 2 -	5	-	6 - - -	- - - -
Y	*Acacia karroo*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	9 9 - 9
	Ziziphus mucronata	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- 6 9 8
	Salix mucronata	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	9 8 - -
	Asparagus capensis	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	4 - 2 -
	Asparagus retrofractus	- - - - - - - - -	- - - - - -	- - - - -	- - - 3 - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	4 - 2 2
	Combretum erythrophyllum	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- 7 - -
	Nidorella residifolia	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- 1 - 6
	Gomphostigma virgatum	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- 6 - -
	Maytenus heterophylla	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	6 - - -
	Diospyros lyciodes	- - - - - - - - 3	- - - - - -	- - - - -	- - - - - - - - - -	- - 3 - - - -	- -	- - - - - -	- - -	-	-	- - - -	4 5 - -
Z	*Rhus pendulina*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	6 - - -	8 9 - 7
	Suaeda fruticosa	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - 9 5	- - - 8
AA	*Maytenus linearis*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - 5 6 - 4	- - -	-	-	7 5 6 7	8 6 8 5
AB	*Lycium bosciifolium*	- - - - - - - - -	- - - - - -	- - - - -	- - - - - 2 - - - -	5 - - - - - 2	- -	- - - 5 6 5	- - -	-	-	- - - -	- - 6 -
	Euclea pseudobenus	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	2 - 4 2 - - -	- -	- - - - - -	- - 6	-	3	5 - 4 5	7 9 6 3
	Zygophyllum microcarpum	- - 1 - - - - - -	- - - - - -	- - - 2 -	- - - - - - - - - -	- - - - - - 3	- -	- - - 3 5 -	- - -	-	6	- 2 7 -	- - 5 -
AC	*Tribulus cristatus*	- - - - - 5 2 - 1	2 6 - 6 6 4	- 1 2 7 5	7 2 2 1 3 4 - - - 5	1 1 - - - - 1	- -	5 1 4 5 2 5	1 2 1	7	-	- 3 2 7	- - 8 -
	Asparagus sp.	- - - - - - 2 - 2	- 2 - 2 - 2	3 - - - 4	- 4 4 3 2 2 - - 2 2	- 4 4 2 2 2 -	4 4	- 4 - 1 - -	- - -	-	-	- - - -	9 6 9 5
	Thesium lineatum	5 - - - - - - - -	- - - - - -	- - - - -	- 2 - - - - - - - -	- 2 4 - 3 - -	2 -	- - - - - -	- - -	2	-	- - - -	6 - - 5
	Pappea capensis	- 1 - - 1 - 1 - -	- - - - - -	- - - - -	- 1 - - 1 - - 1 - -	- 1 - - 1 - -	- 1	- - - - 1 -	- - -	-	-	- - - -	- - 2 -
	Indigofera argyroides	- - - - - - - - -	- - 2 1 - -	- - - - -	- - 1 - - - - - 1 -	- - - - - - -	- -	2 1 - - - -	- - -	-	-	- - - -	- - - -
	Cadaba aphylla	- - - - - - - - 3	- - 5 - 2 -	- - - - 5	- - 6 - - - - - - -	- - - - - - -	- -	- - - - - 4	3 - -	-	-	- - - -	- - - -
	Cullen obtusifolia	- - 1 - - - - - -	- 3 - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - 1
	Hypertelis salsoloides	- - - - - - - - -	- - - - - -	- - - - -	3 - - - - - - - - -	- - - - 1 - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Phyllanthus maderaspatensis	- - - 1 - - - - -	- - - - - -	- - - - -	4 - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Euclea undulata	- - - - 2 - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Ornithoglossum cf. viride	- - - - - - 1 - -	1 - - - - -	- - - - -	- - - - - - - - - -	- - - - - - 1	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Cleome angustifolia	- - - - - - - - -	- - - - 1 1	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Cucumis dinteri	- - - - - - - - 2	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Abutilon pycnodon	- - - - - - - - -	- 2 - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Portulaca trianthemoides	- - - - - - - - -	- - - - - -	- - - - -	1 - 1 - - - - - - -	- - - - - - -	- -	- - - - - 1	- - -	-	-	- - - -	- - - -
	Curroria decidua	- - - - - - - 4 -	- - - - - -	4 - - - 5	- - - - - - - - - -	- - - - - - -	4 5	- - - - - -	- - -	-	-	- - - -	- - - -
	Ptycholobium biflorum	- - - - - - - - -	2 - - - - -	- - - - -	- - - - - - - 1 - -	- - - - - - 1	- 3	- - - - - -	- - -	-	-	- - - -	- - - -
	Zygophyllum stapfii	- - - - - - - - -	- - - - - -	- - - 3 -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Aizoon asbestinum	- - - - - - - - -	- - - - - -	- - - - -	- - - - 2 1 - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Dicoma capensis	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - 1 - -	- -	- - - - - -	- - -	4	-	- - - -	- - - -
	Geigeria ornativa	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - 2	- - - - - - -	- -	- - 1 - - -	- - -	-	-	- - - -	- - - -
	Aloe dichotoma	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - 2 - - -	- -	- - - - - -	- - -	-	-	- - - -	- - - -
	Pegularia daemia	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - 4	- - -	-	-	- - - -	- - - -
	Maerua gilgii	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - 4 2 -	3 -	- - - - - -	- - -	-	-	- - - 2	- - - -
	Gisekia pharnacioides	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- 2 1	-	-	- - - -	- - - -
	Tetragonia arbuscula	- - - - - - - - -	- - - - - -	- - - - -	- - - 2 - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	- - - -	- - 1 -
	Amaranthus praetermissus	- - - - - - - - -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- 1 -	-	-	- 1 - 1	- - - -
	Phaeoptilum spinosum	- - - - - - - - -	- - - 4 - -	- - - - -	- - - - - 3 - - - -	- 2 - - - - -	- -	- - - - - -	4 - -	-	4	- 6 - -	- - - -
	Solanum nigrum	- - - - - - - 2 -	- - - - - -	- - - - -	- - - - - - - - - -	- - - - - - -	- -	- - - - - -	- - -	-	-	3 - - -	- - - -

Table 2.

Size, sampling intensity, vertical distribution of canopy volume, substrate particle size and slope for each vegetation community.

			Vegetation communities												
Characteristics		Units	1	2	3	4	5.1	5.2	6	7	8.1	8.2	9	10	Study area
Area		ha	2753.5	878.2	507.3	1098.3	879.2	210.0	938.8	51.7	31.5	8.1	76.1	83.4	7529.6
		%	36.6	11.7	6.7	14.6	11.7	2.8	12.5	0.7	0.4	0.1	1.0	1.1	100.0
Veg. plots		#	9	6	5	10	7	2	6	3	2		4	4	58
		%	15.5	10.3	8.6	17.2	12.1	3.4	10.3	5.2	3.4		6.9	6.9	100.0
Canopy Volume	0-1 m	m^3/ha	596	821	738	608	343	495	622	420	863		1747	5878	674
	1-2 m	m^3/ha	379	254	183	244	254	366	456	652	284		834	8569	422
	2-5 m	m^3/ha	454	299	7	112	107	180	520	1043	2581		804	31221	675
Substrate - particle size	Bedrock	%	47	21	33	16	13	4	1	0	0	0	0	3	26
	Rocks	%	11	21	28	9	4	4	0	1	0	0	0	0	10
	Pebbles	%	9	21	6	16	17	57	5	0	0	0	0	0	13
	Gravel	%	18	33	11	48	55	35	41	95	36	100	0	0	32
	Sand	%	13	3	22	12	11	0	53	4	64	0	0	0	17
	Silt & clay	%	0	0	0	0	0	0	0	0	0	0	100	48	2
	Organic material	%	1	1	0	0	0	0	0	0	0	0	0	48	1
	Av. rock diameter	cm	32.3	9.4	17.8	12.5	4.4	5.0	-	5.0	-	-	-	-	-
Slope	25 percentile	Deg.	4	4	2	2	1	1	1	3	1	1	0	0	2
	Median	Deg.	7	8	4	3	1	1	2	4	3	1	1	0	4
	75 percentile	Deg.	15	16	6	5	1	2	5	6	6	1	1	1	9
	95 percentile	Deg.	38	40	13	9	6	6	12	10	9	1	12	12	29

Table 3.

Characteristics of the tree, woody shrub and herbaceous strata of each vegetation community.

Plant community	Stratum											
	Tree			Woody shrubs			Herbaceous			Combined		
	Height (cm)	Cover (%)	Volume (m^3/Ha)	Height (cm)	Cover (%)	Volume (m^3/Ha)	Height (cm)	Cover (%)	Volume (m^3/Ha)	Cover (%)	Shade (%)	Shade (#/Ha)
1	270	3.6	322.6	141	1.3	117.7	26	15.9	535.0	20.8	0.5	4.4
2	274	1.1	112.2	163	2.7	297.0	22	32.3	666.6	36.1	0.5	3.4
3	162	0.4	39.6	201	0.9	87.1	16	22.4	791.1	23.6	0.0	0.0
4	203	1.3	118.7	130	2.9	233.9	15	21.5	499.1	25.7	0.2	1.3
5.1	235	1.0	85.5	132	3.1	322.7	21	5.4	189.0	9.5	0.2	0.5
5.2	151	0.2	12.8	190	5.6	462.2	22	12.6	386.0	18.4	0.7	6.3
6	233	1.2	98.1	107	8.9	641.1	22	13.0	338.7	23.2	2.1	12.6
7	522	4.5	530.5	179	5.8	448.6	42	2.6	92.0	12.9	3.4	9.4
8	590	12.7	232.0	220	4.1	185.0	52	57.2	729.7	71.9	11.4	15.8
9	287	7.0	803.3	122	16.2	1162.6	65	34.6	615.4	57.8	3.0	11.6
10	533	139.2	8364.5	124	9.1	1575.7	42	47.7	5889.6	196.0	98.0	256.2

Table 4.

Available browse for the 10 most abundant species in each community expressed as canopy volume 0-200 cm above ground.

		Vegetation community													
		1	2	3	4	5.1	5.2	6	7	8	9	10	Study area		
Species		m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3	m^3/ha±SEM	% ± SEM
Acacia mellifera		27.6		32.5	207.2	293.6	418.2	483.9	159.9	122.7			1143242	151.8 ±21.2	15.00 ±1.70
Schotia afra		270.1			86.0	65.4			484.1				922661	122.5 ±33.0	12.70 ±3.31
Monechma spartioides		42.5	96.4	67.1	71.4	30.4	108.2	109.1	42.3	33.8			469723	62.4 ±16.7	4.50 ±0.94
Forsskaolea candida		100.7	55.5					75.1	7.3				386401	51.3 ±21.6	4.30 ±1.95
Euphorbia gregeria			21.3	520.4									370514	49.2 ± 9.5	5.15 ±0.71
Indigofera pechuelii		92.9			89.0								360920	47.9 ±28.0	2.58 ±1.19
Asparagus sp.							25.0					3903.3	349519	46.4 ±31.3	3.65 ±2.25
Adenolobus garipensis		43.8	243.1			7.5							340611	45.2 ±15.2	4.42 ±1.34
Acacia karroo												3558.4	296769	39.4 ±15.2	4.15 ±1.75
Euphorbia rectirama		59.2			74.0	46.1							285158	37.9 ±17.4	2.87 ±0.93
Boscia albitrunca		40.4	98.5	18.1	31.4			36.5					275781	36.6 ± 8.3	3.75 ±0.87
Tribulus cristatus			80.1	99.7	45.7			29.4		235.5	149.2	285.3	258874	34.4 ± 9.6	2.70 ±0.64
Osteospermum microcarpum			194.7	37.9						14.2			198345	26.2 ±17.2	1.44 ±0.82
Indigofera pungens					63.8				5.2				156940	20.8 ± 9.9	1.90 ±0.75
Hibiscus englerii		50.1											140383	18.6 ±14.1	0.99 ±0.58
Maytenus linearis								39.1	7.6		341.0	881.2	136986	18.2 ± 6.2	1.98 ±0.69
Salix mucronata												1375.5	114717	15.2 ± 9.8	1.38 ±0.90
Rhus pendulina											57.9	1305.6	113295	15.0 ± 8.1	1.41 ±0.70
Cleome foliosa			71.4					44.6		36.7			110266	14.6 ± 6.8	1.13 ±0.48
Zygophyllum dregeanum					24.2	55.5	151.3						109979	14.6 ± 4.9	1.63 ±0.53
Trichodesma africana		35.2											108664	14.4 ±11.4	0.72 ±0.46
Ziziphus mucronata												1189.1	99173	13.2 ± 7.9	1.17 ±0.61
Suaeda fruticosa											723.8	453.9	92936	12.3 ± 8.7	1.02 ±0.72
Ceraria namaquensis			27.0	20.0									87834	11.7 ± 5.0	1.32 ±0.54
Sisyndite spartea									274.1		33.9		83580	11.1 ± 6.4	1.58 ±1.12
Boscia foetida				21.6		10.8	9.2	48.0					81834	10.9 ± 3.8	1.18 ±0.36
Rhigozum trichotomum						8.6	20.2	59.2					70985	9.4 ± 6.9	1.07 ±0.80
Euclea pseudobenus									46.4		36.3	711.1	68586	9.1 ± 6.0	0.78 ±0.54
Dyerophytum africanum									8.1				61533	8.2 ± 3.7	0.83 ±0.43
Tamarix usneoides											708.4		53906	7.2 ± 5.2	0.55 ±0.31
Petalidium lucens			42.2										48583	6.5 ± 3.4	0.66 ±0.34
Lycium bosciifolium								31.1					39258	5.2 ± 2.2	0.73 ±0.39
Limeum aethiopicum										17.1			38840	5.2 ± 2.8	0.53 ±0.33
Cadaba aphylla				13.6									35510	5.7 ± 2.5	0.31 ±0.15
Trianthema triquetra					25.8								32520	4.3 ± 3.3	0.25 ±0.13
Hermannia stricta						16.5			25.7				30150	4.0 ± 2.0	0.47 ±0.31
Indigofera heterotricha						14.7	68.4						28116	3.7 ± 2.6	0.27 ±0.19
Zygophyllum microcarpum										126.6	99.0		27067	3.6 ± 1.9	0.44 ±0.28
Psilocaulon absimile											301.8		22966	3.1 ± 3.0	0.15 ±0.14
Acacia erioloba										253.1			22725	3.0 ± 1.2	0.32 ±0.13
Curroria decidua				14.0			23.1						17667	2.3 ± 1.0	0.29 ±0.13
Combretum erythrophyllum												210.3	17537	2.3 ± 2.3	0.21 ±0.21
Zygophyllum simplex										262.2			19518	2.6 ± 1.5	0.21 ±0.12
Polygala cf. seminuda							7.0						13864	1.8 ± 0.9	0.34 ±0.19
Lotononis platycarpa										7.3			11729	1.6 ± 1.0	0.10 ±0.06
Phaeoptilum spinosum										11.6	54.9		9241	1.2 ± 0.7	0.42 ±0.36
Sarcostemma viminale							7.7						8017	1.1 ± 0.5	0.10 ±0.04
Dicoma capensis										5.2			2160	0.0 ± 0.0	0.00 ±0.00
Browse from top 3 spp.	%	47.5	49.9	74.9	44.9	69.5	78.7	61.1	85.7		68.7	61.2	30.7		
Browse from top 10 spp.	%	78.2	86.5	92.1	84.4	92.1	97.4	87.5	99.0		97.1	96.0	59.8		
Equitability, top 10 spp.	E	0.55	0.65	0.25	0.67	0.31	0.33	0.35	0.33		0.49	0.56	0.76		
Browse diversity	D(H')													18.95 (3.45)	
Total available browse	m^3/ha	975.3	1075.8	917.8	851.7	597.2	861.0	1077.9	1071.1	1146.6	2581.3	14446.2		1095.8	
	±SEM	181.1	259.6	284.1	206.3	116.6	265.7	219.2	488.6	101.5	1083.7	1645.0		89.6	
Total available browse	m^3	2685395	944768	465599	935448	525065	180808	1011955	55375	45407	196435	1204811	8251064		
Total available browse	%	32.5	11.5	5.6	11.3	6.4	2.2	12.3	0.7	0.6	2.4	14.6	100.0		

Photos on the following page:

Top left: Community 1 – *Indigofera pechuellii* shrubs in front, *Schotia afra* trees behind

Top right: Community 2 – *Adenolobus garipensis* shrub at the front, right

Second row, left: Community 3 – *Euphrobia gregaria* shrub-like succulent

Second row, right: Community 4 – *Euphorbia rectirama* shrub-like succulent middle, left and *Acacia mellifera* shrub middle, right

Third row, left: Community 5 (Variant 5.1) – *Zygophyllum cf. dregeana* succulent forb front, right; *Acacia mellifera* shrub top, left and *Euphorbia rectirama* shrub-like succulent top, right

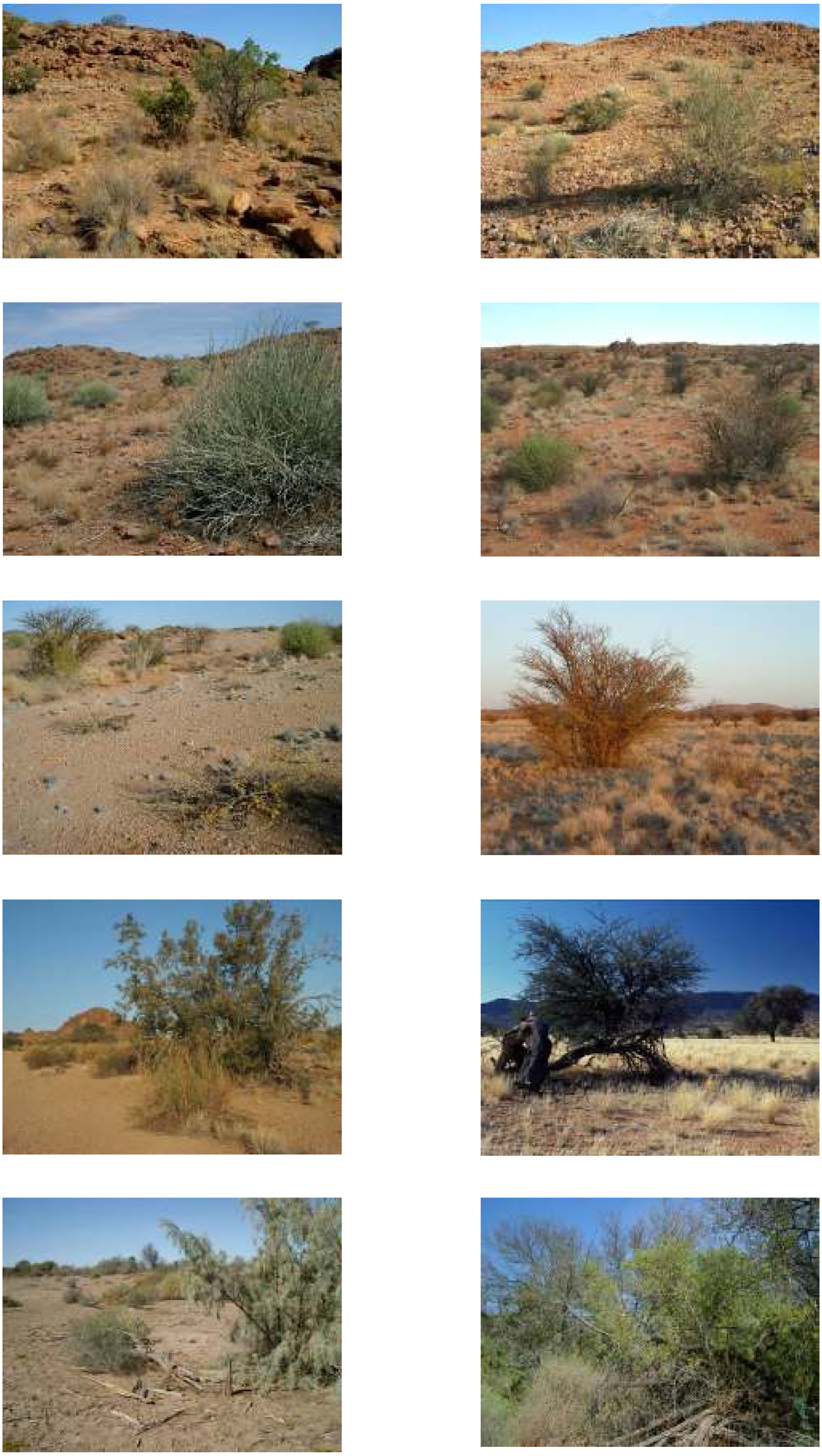
Third row, right: Community 6 - *Acacia mellifera* shrubs

Fourth row, left: Community 7 – *Sisyndite spartea* shrub in front and *Schotia afra* tree behind

Fourth row, right: Community 8 (variant 8.1) – *Schmidtia kalahariensis* grass and *Acacia erioloba* trees

Bottom row, left: Community 9 – *Tamarix usneoides* tree on the right

Bottom row, right: Community 10 – *Ziziphus mucronata* (deciduous tree - front, left); *Rhus pendulina* (bright green – center) and *Acacia karroo* (tall trees – top, left)



Vegetation communities 1 to10 left to right, top to bottom.