Floristic composition and species diversity of urban vegetation in Bloemfontein, Free State, South Africa

Background: Urban vegetation studies have, until recently, been relatively uncommon in South Africa. Yet, natural urban vegetation is constantly competing with and greatly impacted by urbanisation. This vegetation requires proper management and needs to be conserved because it is an important ecological infrastructure.

Objectives: The objectives of the study were to identify the main vegetation types within the urban open spaces in the Bloemfontein metropolitan area, and to determine the floristic composition and species diversity of the area.

Methods: A total of 248 relevés were classified using the TWINSPLAN classification algorithm, and relationships between the communities and the environment were determined with the Detrended Correspondence Analysis and Canonical Correspondence Analysis computer programs. Species diversity was partitioned into α-, β- and γ-diversities.

Results: Within the study area, 77 plant families and 248 genera, with a total of 376 plant species, were identified. The largest families are Poaceae, Asteraceae and Fabaceae, whereas the largest genera are Eragrostis, Aristida, Cyperus, Asparagus and Senecio. The study area has high species richness and the most species-rich sites are found adjacent to rivers and streams, and also on the slopes of hills and ridges. The vegetation is classified under five major vegetation types and four sub-units, which show a distinct association with topography and soil texture.

Conclusion: The urban vegetation of Bloemfontein is species-rich and should be properly managed and conserved. In particular, the wetlands and rocky outcrops on hills and ridges, which are the most threatened habitats in the study area, need special management.

Introduction

Bloemfontein is a medium-sized city in the Free State province, and is situated in a region characterised by intensive commercial farming. The farming, coupled with increased urbanisation, resulted in degradation and fragmentation of the natural vegetation. An ecological approach to urban open space planning has been suggested (Florgård 2000; Poynton & Roberts 1985; Thompson 2002), which would ensure that open space areas centrally placed in cities are linked with open spaces towards the periphery of cities by dispersal corridors such as rail and roadside vegetation, including ruderal and disturbed vegetation (Poynton & Roberts 1985). Roadsides and railway tracks can have high species richness, especially in terms of rare and endangered plant species that can be harboured in such habitats (Forman & Alexander 1998; Galera et al. 2014).

The ecological approach to urban open space planning and management is a sensible and achievable objective, but it is constrained in part by lack of ecological expertise from the relevant government authorities, lack of infrastructure and financial support and also by public opinion (Cilliers, Müller & Drewes 2004). Public opinion is especially important because, for example, even though urban dwellers show a general desire for contact with nature, there is a consistently negative public perception when it comes to ruderal and spontaneous vegetation on derelict sites (Millard 2004).

There are immense benefits of conserving urban vegetation, which can be scientific, social and economic (Barbosa et al. 2007; Hunter 2007). Urban green space is also important for the overall well-being of the urban dwellers (Dearborn & Kark 2010; Fuller et al. 2007; Tzoulas et al. 2007). Open space within urban areas has beneficial effects on microclimate, hydrology, biodiversity and...
ecological processes (Bolund & Hunhammar 1999; Federer 1976; Goddard, Dougill & Benton 2009; Godfroid & Koedam 2007). Therefore, cities with relatively large or many conserved open spaces may, for example, have higher species diversity, less water run-off, reduced noise and air pollution (Bolund & Hunhammar 1999; Litschke & Kutlter 2008; Tratalos et al. 2007; Whitford, Ennos & Handley 2001).

The proper management and conservation of urban open spaces requires in-depth knowledge of the spatial distribution, floristic, structural and functional compositions of the major vegetation types (VTs) within the urban environment. The present vegetation study was initiated to identify the main VTs of the open spaces within the Bloemfontein metropolitan area, and to determine the composition and diversity of plant species found in the area. Such urban vegetation studies are relatively few in South Africa, limited to those conducted by among others Roberts (1993), Cilliers, Van Wyk and Bredenkamp (1999) and Grobler, Bredenkamp and Brown (2006).

**Research method and design**

**Study area**

Bloemfontein extends from approximately 29°00' to 29°15' south and 26°07' to 26°21' east, with altitude ranging from 1350 m to 1450 m above sea level. According to the climate statistics from the South African Weather Service, the annual mean maximum and minimum temperatures are 24.6 °C and 7.6 °C, respectively. Rainfall mainly occurs in summer in the form of thunderstorms, and it averages 550 mm annually. The main geologic feature of the study area is the Karoo Supergroup, represented by the Tierberg Formation of the Bredenkamp Group; there are also dolerite intrusions of the post-Karoo formation (Hutton form), and it is part of the Central Variation of the Dry Cynodon-Themeda Veld (Acocks 1988). Other classifications describe Bloemfontein’s vegetation as Dry Sandy Highveld Grassland (Bredenkamp & Van Rooyen 1996) and Dry Highveld Grassland (Mucina et al. 2006).

**Vegetation survey**

The first step of the survey entailed the stratification of vegetation prior to sampling. Stratification of the area was done on 1:50 000 scale maps and 1:30 000 aerial photographs, based on the topography and relative homogeneity of physiognomic units. The topographic units recognised were the watercourses, flat plains as well as the hills and ridges. A total of 248 relevés were compiled; 160 were compiled for the first time, while 88 were from existing data (Muller 1970; Rossouw 1983). Sample plots ranging in size between 16 m² for the grassland vegetation and 100 m² for the woody vegetation were surveyed across the study area. All plant species present in each sample plot were recorded and each was given a cover-abundance value according to the Braun–Blanquet scale (Kent & Coker 1996; Mueller-Dombois & Ellenberg 1974). Plant taxonomy generally follows Germishuizen and Meyer (2003). For each relevé, habitat attributes were also noted, including rock type (geology), terrain type (topographical position) and an estimation of the percentage of rockiness of the soil surface. Soil characteristics such as soil depth, pH, organic matter and texture were used for the study. Other noted observations included the extent of soil erosion and forms of biotic influence such as utilisation by herbivores and management practices.

**Data analysis**

Phytosociological data were first captured and processed in the TURBOVEG database (Hennekens 1996a), and then exported to the MEGATAB computer program (Hennekens 1996b) for classification using TWINSPAN (Hill 1979a). The result was a synoptic table that shows a hierarchical classification of the syntaxa, with each synrelevé representing a plant community. The principle of synoptic tables is based on rating the presence of each species within a community on a constancy scale (Kent & Coker 1996; Mueller-Dombois & Ellenberg 1974). An ordination technique, Detrended Correspondence Analysis (DECORANA) (Hill 1979b), was applied to the data set to illustrate floristic relationships between the plant communities and to detect possible relationships between the communities and the environment. Canonical Correlation Analysis (CANOCO) (Ter Braak & Šmilauer 2009), an extension of DECORANA, was also carried out to further illustrate the correlations between the vegetation data and the environmental variables.

Patterns of species diversity were analysed using two types of diversity, that is, α-diversity and β-diversity, and also evenness. Two aspects of α-diversity were analysed, the first being species richness (S) that is defined as the number of species per sample plot. Because S can be exaggerated by the presence of rare species, α-diversity was also measured with the Shannon–Wiener diversity index (H'). It is a weighted expression of species richness and the proportion in which each species is represented in a sample plot, which is calculated as:

\[ H' = \sum_{i=1}^{S} P_i \ln P_i \]  

where \( P_i \) is the proportion of cover in the \( i \)-th species. The cover values used were based on median values (except Category r & +) of the cover categories derived from the Braun–Blanquet cover-abundance scale: 1% for Category r & + (cf. Ma 2005), 3% for Category 1 (1%–5%), 9% for Category 2a (6%–12%), 19% for Category 2b (13%–25%), 38% for Category 3 (26%–50%), 63% for Category 4 (51%–75%) and 88% for Category 5 (76%–100%). Evenness, defined as the relative abundance of species in a unit area (Stirling & Wilsey 2001; Wilsey & Stirling 2007), was used to measure the
similarity of relative abundances of species within sample plots (Sankaran 2009). It was calculated with the Pielou’s evenness index ($J'$) as

$$J' = H' / \ln S. \quad \text{[Eqn 2]}$$

A one-way analysis of variance (ANOVA) with Tukey’s honestly significant difference (HSD) test (using SPSS® software version 19) was then conducted to compare $S$, $H'$ and $J'$ between the different VTs.

Beta ($\beta$) diversity was calculated to determine species turnover or the extent to which species diversity differs within the VTs. Various measures of $\beta$-diversity have been proposed over the years, but in the present study, the Whittaker’s diversity index ($\beta_w$) was used because it is widely regarded as a simple but highly effective measure of $\beta$-diversity (Magurran 2004; Van der Maarel 2005). It was calculated as:

$$\beta_w = S_{\text{total}} / S_{\text{AVE}}, \quad \text{[Eqn 3]}$$

where $S_{\text{total}}$ is the total number of species present in each VT ($\gamma$-diversity) and $S_{\text{AVE}}$ is the average species richness ($\alpha$-diversity) for each sample plot in a community.

**Results**

**Floristic composition**

The vegetation of Bloemfontein is dominated by the red grass *Themeda triandra* with *Eragrostis lehmanniana* as a constant companion. Other prominent grasses are *Aristida congesta*, *Digitaria eriantha*, *Sporobolus fimbratus* and *Eragrostis curvula*. Forbs such as *Oxalis depressa*, *Hibiscus psillus* and *Felicia muricata* are widespread, but they never attain dominance within the communities. It is only in localised wetland habitats where hydrophytic sedges and other forbs dominate. The vegetation is represented by 77 families and 248 genera (Table 1). The families with the highest number of genera are Poaceae, Asteraceae and Fabaceae (Table 2), while the most diverse genera are *Eragrostis*, *Cyperus*, *Aristida* and *Asparagus* (Figure 1). A total of 376 plant species were identified for the study area: 82 play a diagnostic role, 66 are companion species and a further 228 are either localised or of very rare occurrence. Of these rare species, only 175 are presented in the synoptic table (see Appendix 1); the other 53 are excluded because of their extremely rare occurrence. Eight species are declared invasives (Department of Environmental Affairs 2016), namely *Argemone ochroleuca* subsp. *ochroleuca*, *Verbena bonariensis*, *Gleditsia triacanthos*, *Cestrum laevigatum*, *Cuscuta

| TABLE 1: Composition of the vascular flora of the Bloemfontein urban areas. |
|-----------------------------|------------------|------------------|
| Vascular flora              | Number | % of total | Genera | Number | % of total | Species | Number | % of total |
| Pteridophyta                | 6      | 7.8       | 8      | 3.2    | 10        | 2.7     |
| Monocotyledoneae            | 16     | 20.8      | 74     | 29.8   | 123       | 32.7    |
| Dicotyledoneae              | 55     | 71.4      | 166    | 66.9   | 243       | 64.6    |
| Total                       | 77     | -         | 248    | -      | 376       | -       |

Source: Authors’ own work

| TABLE 2: A list of plant families of Bloemfontein urban areas (listed alphabetically within subdivisions) with the number of genera and species represented. |
|-----------------------------|------------------|------------------|
| Families                    | Genera | Species |
| Pteridophyta                | Aspleniaceae   | 2                |
|                             | Azollaceae     | 1                |
|                             | Equisetaceae   | 1                |
|                             | Marsileaceae   | 1                |
|                             | Ophioglossaceae| 1                |
|                             | Pteridaceae    | 2                |
| Angiosperma                 | Alliaceae      | 1                |
|                             | Amaryllidaceae | 6                |
|                             | Araceae        | 1                |
|                             | Asparagaceae   | 1                |
|                             | Asphodelaceae  | 2                |
|                             | Colchicaceae   | 1                |
|                             | Commelinaceae  | 1                |
|                             | Cyperaceae     | 6                |
|                             | Hyacintaceae   | 7                |
|                             | Iridaceae      | 1                |
|                             | Juncaceae      | 1                |
|                             | Orchidaceae    | 1                |
|                             | Poaceae        | 39               |
|                             | Ruscaceae      | 1                |
|                             | Typhaceae      | 1                |
| Dicotyledoneae              | Acanthaceae    | 2                |
|                             | Aizoaceae      | 6                |
|                             | Amaranthaceae  | 8                |
|                             | Anacardiaceae  | 5                |
|                             | Apiceae        | 2                |
|                             | Apocynaceae    | 8                |
|                             | Araliaceae     | 1                |
|                             | Asteraceae     | 36               |
|                             | Bignoniaceae   | 1                |
|                             | Boraginaceae   | 1                |
|                             | Brassicaceae   | 3                |
|                             | Buddlejaceae   | 2                |
|                             | Cactaceae      | 1                |
|                             | Campanulaceae  | 1                |
|                             | Cannabaceae    | 1                |
|                             | Capparaceae    | 1                |
|                             | Caryophyllaceae| 2                |
|                             | Celastraceae   | 1                |
|                             | Convolvolaceae | 3                |
|                             | Dipsacaceae    | 1                |
|                             | Ebenaceae      | 2                |
|                             | Euphorbiaceae  | 3                |
|                             | Fabaceae       | 14               |
|                             | Gentianaceae   | 1                |
|                             | Geraniaceae    | 1                |
|                             | Lamiaceae      | 3                |
|                             | Lobeliaceae    | 2                |
|                             | Malvaceae      | 6                |
|                             | Menispermacae  | 1                |
|                             | Oleaceae       | 2                |
|                             | Onagraceae     | 1                |
|                             | Oxalidaceae    | 1                |
|                             | Papaveraceae   | 2                |
|                             | Pedaliaceae    | 2                |

Source: Authors’ own work
TABLE 2 (Continues...): A list of plant families of Bloemfontein urban areas (listed alphabetically within subdivisions) with the number of genera and species represented.

| Families                  | Genera | Species |
|---------------------------|--------|---------|
| Plantaginaceae            | 1      | 1       |
| Polygalaceae              | 3      | 4       |
| Portulacaceae             | 2      | 3       |
| Ranunculaceae             | 2      | 2       |
| Rhamnaceae                | 1      | 1       |
| Rosaceae                  | 2      | 2       |
| Rubiaceae                 | 5      | 5       |
| Salicaceae                | 1      | 2       |
| Santalaceae               | 2      | 2       |
| Scrophulariaceae          | 5      | 8       |
| Solanaceae                | 4      | 9       |
| Urticaceae                | 2      | 2       |
| Vahliaeae                 | 1      | 1       |
| Verbenaceae               | 4      | 6       |
| Zygophyllaceae            | 1      | 1       |
| **Total (77 families)**   | **248**| **376** |

Source: Authors’ own work

TABLE 3: Habitat characteristics of the Bloemfontein vegetation types.

| Vegetation types                          | Habitat                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------|
| **1. D. rosea—B. catharthisc Wetland vegetation** | Paraty described by Rossouw (1983)                                      |
| **1.1 R. lanceolatus—C. longus Streambed vegetation** | Mostly restricted to the Modder River and its tributaries               |
| **1.2 V. karroo–A. loricinus Streambank vegetation** | Also found in smaller streams, damps and pans                           |
| **2. O. europae—B. saligna Shrubland**     | Strongly associated with moist and deep soils                           |
| **3. A. diffusa subsp. burkei—C. nuculae Succulent grassland** | Primarily a gramnoid and forb-dominated community, with isolated dense woody stands, especially on the Modder River (species composition: forbs 58%, grasses 27%, shrubs 11% and trees 4%) |
| **3.1 D. potissii—C. orbiculata Grassland** | Associated with relatively drier habitat conditions than R. lanceolatus—C. longus Streambed vegetation |
| **3.2 O. capense—E. nindensis Grassland**  | Found on the streambanks and valleys, also occupies the plains adjacent to the watercourses, extending to the footslopes of hills |
| **4. A. congesta—T. triandra Grassland**   | Associated with deep alluvial soils, especially on the valleys |
| **5. F. muricata—T. triandra Grassland**   | Displays a high degree of species fidelity within the Bloemfontein area, with the highest number of diagnostic species (19 species) |

Source: Authors’ own work

Vegetation classification and ordination

A synoptic classification of the vegetation is presented, showing only the major VTs and not the lower ranked syntaxa constituting each VT. The following five major vegetation units and four subdivisions were recognised from the study area, as summarised in Table 3:

- **VT 1: Oenothera rosea—Bromus catharthisc Wetland vegetation**
  - **VT 1.1: Rumex lanceolatus—Cyperus longus Streambed vegetation**
  - **VT 1.2: Vachellia karroo—Asparagus loricinus Streambank vegetation**
- **VT 2: Oela europae—Buddleja saligna Shrubland**
- **VT 3: Aristida diffusa subsp. burkei—Crassula nudicaulis Succulent grassland**
- **VT 3.1 Delosperma potissii—Cotyledon orbiculata Grassland**
- **VT 3.2 Oropetium capense—Eragrostis nindensis Grassland**

The DECORANA ordination plot (Figure 2) shows a clear grouping of the relevés into the VTs as classified in the synoptic table (Appendix 1). Axis 1 and Axis 2 have eigenvalues of 0.863 and 0.664, respectively. Axis 1 is positively associated with the soil moisture gradient, beginning with the D. potissii—C. orbiculata Grassland and the O. capense—E. nindensis Grassland on the left portion of the ordination plot, which are characteristics of relatively

campestris, Pennisetum villosum, Salsola kali and Convolvulus arvensis. None of the species recorded is threatened (http://redlist.sanbi.org/).

FIGURE 4: The most diverse genera in Bloemfontein, with four or more species. The black and grey bars indicate Dicotyledoneae and Monocotyledoneae, respectively.

http://www.abcjournal.org

Open Access
dry habitats. The *R. lanceolatus–C. longus* Streambed vegetation and *V. karroo–A. laricinus* Streambank vegetation are found towards the right end of the ordination plot because of their occurrence in wetter habitats. Axis 2 does not show any clear environmental trends.

### Soil characteristics of vegetation types

The deepest soils were recorded in the *R. lanceolatus–C. longus* Streambed vegetation (433 mm ± 78 mm) and *V. karroo–A. laricinus* Streambank vegetation (475 mm ± 62 mm); these soils also have the highest pH of 7.2 ± 1.1 and 7.4 ± 0.9, respectively (Table 4). The *O. europaea–B. saligna* Shrubland has the highest clay content (30% ± 5%) and organic matter content (4.65% ± 0.9, respectively) and *H''* (5.2–6.3) was recorded for the *D. pottsii–C. orbiculata* Grassland, *O. europaea–B. saligna* Shrubland and *V. karroo–A. laricinus* Streambank vegetation. The highest *β*_w was recorded for *F. muricata–T. triandra* Grassland (9.3) and *R. lanceolatus–C. longus* Streambed vegetation (7.8), while the lowest *β*_w (5.1) was recorded for *A. congesta–T. triandra* Grassland.

### Patterns of species diversity

The *D. pottsii–C. orbiculata* Grassland, *O. capense–E. nindensis* Grassland, *O. europaea–B. saligna* Shrubland and *V. karroo–A. laricinus* Streambank vegetation have high *α*-diversity (both *S* and *H'*) with *S* of 20.7 ± 5.7, 21.2 ± 8.6, 23.9 ± 6.7 and 24.4 ± 6.2, respectively, and *H'* of 2.51 ± 0.42, 2.44 ± 0.70, 2.17 ± 0.43 and 1.96 ± 0.35, respectively (Table 5). The four VTs also have high *f''* (0.84 ± 0.14, 0.83 ± 0.18, 0.69 ± 0.09 and 0.62 ± 0.08, respectively) and *γ*-diversity (130, 115, 137 and 128, respectively). The *R. lanceolatus–C. longus* Streambed vegetation has the lowest *γ*-diversity (75), *S* (9.6 ± 4.9), *H''* (1.14 ± 0.61) and *f''* (0.50 ± 0.21). With regard to *β*-diversity, relatively low *β*_w (5.2–6.3) and *β*_H (0.50 ± 0.21) was recorded for the *D. pottsii–C. orbiculata* Grassland, *O. capense–E. nindensis* Grassland, *O. europaea–B. saligna* Shrubland and *V. karroo–A. laricinus* Streambank vegetation. The highest *β*_w was recorded for *F. muricata–T. triandra* Grassland (9.3) and *R. lanceolatus–C. longus* Streambed vegetation (7.8), while the lowest *β*_w (5.1) was recorded for *A. congesta–T. triandra* Grassland.

### Discussion

The *R. lanceolatus–C. longus* Streambed vegetation shares similarities with the *Leersia hexandra–Schoenoplectus paludicola* wetland of the slow-draining watercourses in northern Free State (Fuls, Breedenkamp & Van Rooyen 1992a). The other comparable community is the *Echinochloa holubii–C. longus* wetland of the Kroonstad area, described by Kooij et al. (1991). *V. karroo–A. laricinus* Streambank vegetation is comparable to the *V. karroo–A. laricinus* Thornveld of the Kroonstad area (Kooij et al. 1991). This community also belongs to the *V. karroo* class described by Du Preez and Breedenkamp (1991). With regard to *O. europaea–B. saligna* Shrubland, Fuls, Breedenkamp and Van Rooyen (1992b) described a related *Sporobolus fimbristylis–Tarchonanthus camphoratus* community of the dolerite hills of the northern Free State.

The low *S* measured for the *R. lanceolatus–C. longus* Streambed vegetation is typical of wetland communities,
because only a few species are adapted to survive in habitats where the soil is permanently waterlogged. Other wetlands in the Free State are also characterised by low species richness, for example, wetland communities of the central Free State (Muller 2002), northern Free State (Fuls 1993) and north-western Free State (Kooij 1990). In contrast, riparian zones adjacent to the wetlands are ecologically diverse and harbour different plant species. The *V. karroo*-*A. laricinus* Streambank vegetation, in concurrence, has high species richness. Cilliers, Schoeman and Bredenkamp (1998) reported similar species richness patterns, characterised by low species richness in waterlogged soils compared to the drier river banks.

The *R. lanceolatus*-*C. longus* Streambed vegetation has high \( \beta_w \), as there are few common species within the vegetation unit. This high species turnover can mainly be ascribed to the habitat-specific nature of hydrophytic species. The *F. muricata*-*T. triandra* Grassland also has high \( \beta_w \) and according to Lennon et al. (2001), inflated \( \beta_w \) could result from large differences in species richness between sample plots. There is a high variation of \( S \) in the *F. muricata*-*T. triandra* Grassland, ranging from 1 to 19. This variation is possibly because of the disturbed and unstable nature of some habitats where parts of this vegetation unit are found, such as on roadsides and along railway tracks. For example, situations where only one species was encountered in a sample plot were along roadsides where *E. nindensis* was found dominating.

A high \( H' \) was recorded for the *D. pottsii*-*C. orbiculata* Grassland and the *O. capense*-*E. mindensis* Grassland because these communities have a fairly proportionate abundance of the key species, and hence their high evenness (\( J \)) values. On the other hand, both the high \( \gamma \)-diversity and \( S \) as recorded for the *O. europaea*-*B. saligna* Shrubland could possibly be artefacts of sampling size and sample plot size, respectively. \( H' \) for this unit is comparatively lower than for the former two grassland communities because of the overwhelming dominance of *O. europaea, B. saligna, Grewia occidentalis* and *Searsia burchellii*, and hence the relatively lower evenness.

The overall species richness of the study area (376 species) is comparable to that of other urban areas in South Africa. For example, it is comparable to the 350 species reported by Van der Walt et al. (2015) for a study of the grassland fragments in the Tlokwe Municipal area in North-West Province. In the Pretoria–Johannesburg metropolitan area in Gauteng Province, Grobler (2000) reported a higher number of species (a total of 600), but this is most likely because of the larger size of the study area. It is, however, important to acknowledge that urban open spaces in South Africa may generally not harbour levels of species richness similar to those in formally designated conservation areas. For example, higher species richness was recorded in relatively much smaller areas of the Kruger National Park: 450 species in a 139-ha area of the Nkuhlu exclosures (Siebert & Eckhardt 2008) and 233 species in a 129-ha area of the Letaba exclosures (Siebert, Eckhardt & Siebert 2010). Nonetheless, Götze et al. (2008) reported species richness lower than in Bloemfontein and the other aforementioned urban areas: 219 species in the Mapungubwe National Park. Our study therefore confirms that urban vegetation in South

---

**TABLE 5**: Species diversity of the vegetation types of the Bloemfontein area.

| Variable                        | 1.1          | 1.2          | 2            | 3.1          | 3.2          | 4            | 5            |
|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Number of sample plots          | 19           | 31           | 58           | 37           | 34           | 20           | 49           |
| Species richness (\( S_1 \))    | 9.6 ± 4.9a   | 24.4 ± 6.2b  | 23.9 ± 6.7b  | 20.7 ± 5.7bc | 21.2 ± 8.6bc | 16.8 ± 8.3b  | 11.2 ± 3.3a  |
| Shannon–Weiner (\( H' \))       | 1.24 ± 0.61a | 1.96 ± 0.35bc| 2.17 ± 0.43cd| 2.51 ± 0.42e | 2.44 ± 0.70de| 1.59 ± 0.53ab| 1.27 ± 0.46a |
| Pielou’s evenness (\( J' \))     | 0.50 ± 0.21a | 0.62 ± 0.08ab| 0.69 ± 0.09b | 0.84 ± 0.14c | 0.83 ± 0.18bc| 0.58 ± 0.14a | 0.53 ± 0.17a |

\( J' \) refers to the species richness of the study area. The same letters within the lines are not significantly different at \( P \leq 0.05 \); one relevé of Vegetation type 5 was excluded for the statistical analysis because only one species was present.

---

**FIGURE 3**: A Canonical Correspondence Analysis biplot of sample plots and soil variables (depth [soil depth], clay [clay content], silt [silt content], sand [sand content], OM [organic matter content] and pH).

---

http://www.abcjournal.org

Open Access
Africa can also be species rich, and should be properly managed and conserved.

Conclusion

We identified five major VTs and four sub-units in the Bloemfontein area and found the wetlands and rocky outcrops to be most threatened habitats. The O. rosea–B. catharticus wetlands (VT 1) possess a large number of highly palatable species and as a result are subjected to frequent overgrazing and trampling. As a conservation measure, access to these wetlands could be restricted and this can be achieved by fencing off the most vulnerable areas. The A. diffusa subsp. burkei–C. nudaicaulis grassland of the rocky outcrops (VT 3) is threatened by the expansion of Bloemfontein city to the north. This is a botanically diverse VT that occurs exclusively in the Seven Dams Conservancy, and represents an isolated type of vegetation not found in any other parts of Bloemfontein. The area should therefore be regarded as a conservation priority because of its uniqueness and high botanic diversity.

Generally, the urban vegetation of Bloemfontein is species rich and should be properly managed and conserved. There are enormous benefits that can be derived from the conservation of urban vegetation, be they scientific, social or economic. Most importantly, urban vegetation has been linked with overall human health and well-being.

Acknowledgements

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors’ contributions

M.N.V.d. did the vegetation survey and classification, data analysis and wrote the manuscript. P.J.d.P. conceptualised the project, did part of the vegetation survey and assisted with the vegetation classification.

References

Acocks, J.H., 1988, ’Veild types of South Africa’ [3rd ed.], Memoirs of the Botanical Survey of South Africa 57, 1–146.
Barbosa, O., Tratalos, J.A, Armsworth, P.R., Davies, R.G., Fuller, R.A., Johnson, P. et al., 2007, ‘Who benefits from access to green space? A case study from Sheffield, UK’, Landscape and Urban Planning 83, 187–195. https://doi.org/10.1016/j.landurbplan.2007.04.004
Bolund, P. & Hunhammar, S., 1999, ’Ecosystem services in urban areas’, Ecological Economics 29, 293–301. https://doi.org/10.1016/S0921-8009(99)00013-0
Bredenkamp, G. & Van Rooyen, N., 1996, ‘Dry sandy Highveld grassland’, in B. Low & Bolund, P. & Hunhammar, S., 1999, ’Ecosystem services in urban areas’, Trends in Ecology and Evolution 25, 90–98. https://doi.org/10.1016/j.tree.2009.07.016
Godefroid, S. & Koedm, N., 2007, ‘Urban plant species patterns are highly driven by density and function of built-up areas’, Landscape Ecology 22, 1127–1139. https://doi.org/10.1007/s10980-007-9102-x
Götte, A.R., Cilliers, S.S., Bezuudenhout, H. & Kellner, K., 2008, ’Analysis of the vegetation of the sandstone ridges (ib land type) of the north-eastern parts of the Mapungubwe National Park, Limpopo Province, South Africa’, Koedoe 50, 72–81. https://doi.org/10.4102/koedoe.v50i1.136
Grobler, C.H., 2000, ‘The vegetation ecology of urban open spaces in Gauteng’, MSc thesis, University of Pretoria.
Grobler, C.H., Bredenkamp, G.J. & Brown, L.R., 2006, ‘Primary grassland communities of urban open spaces in Gauteng, South Africa’, South African Journal of Botany 72, 367–377. https://doi.org/10.1016/j.sajb.2005.10.008
Hennekens, S.M., 1996a, TURBOVEG: A software package for input, processing, and presentation of phytosociological data, University of Lancaster, IBN-DLO, Wageningen.
Hennekens, S.M., 1996b, MEGATAB: A visual editor for phytosociological tables, Giesen & Geurt, Ulf.
Hill, M.O., 1979a, TWINSPAN: A Fortran program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes, Cornell University, New York.
Hill, M.O., 1979b, DECORANA: A Fortran program for detrended correspondence analysis and reciprocal averaging, Cornell University, New York.
Hunter, P., 2007, ’The human impact on biological diversity’, EMBO Reports 8, 316–318. https://doi.org/10.1038/sj.emboj.7400951
Johnson, M.R., Van Vuuren, C.J., Visser, J.N.J., Cole, D.I., Wickens, H. de V., Christie, A.D.M. et al., 2006, ’Sedimentary rocks of the Karoo Super Group’, in M.R. Johnson, C.R. Anhaeusser & R.J. Thomas(eds.), The geology of South Africa, 2nd edn., The Geological Society of South Africa, Pretoria.
Kojo, M.S., 1990, ’A phytosociological survey of the vegetation of the north-western Orange Free State’, MSc thesis, University of Pretoria.
Kojo, M.S., Scheepers, J.C., Bredenkamp, G.J. & Theron, G.K., 1991, ’The vegetation of the Kroonstad area, Orange Free State. 1: Vlei and bottomland communities’, South African Journal of Botany 57, 213–219. https://doi.org/10.1016/j.sajb.2008.0284
Ma, M., 2005, ‘Species richness vs evenness: Independent relationship and different responses to edaphic factors’, Oikos 111, 192–198. https://doi.org/10.1111/j.0030-1299.2005.13049.x

Maguran, A.E., 2004, Measuring biological diversity, Blackwell, Oxford.

Millard, A., 2004, ‘Indigenous and spontaneous vegetation: Their relationship to urban development in the city of Leeds, UK’, Urban Forestry & Urban Greening 3, 39–47. https://doi.org/10.1016/j.ufug.2004.04.004

Mucina, L., Hoare, D.B., Lötter, M.C., Du Preez, P.J., Rutherford, M.C., Scott-Shaw, C.R., et al., 2006, ‘Grassland biome’, in L. Mucina & M.C. Rutherford (eds.), The vegetation of South Africa, Lesotho and Swaziland, Sthetzaia 19, 348–437.

Mueller-Dombois, D. & Ellenberg, H., 1974, Aims and methods of vegetation ecology, Wiley, New York.

Muller, D.B., 1970, ‘n Planteekologie studie op die terrein van die Botaniese Tuin van die Oranje Vrystaat, Bloemfontein’, MSc thesis, University of the Orange Free State.

Muller, M.E., 2002, ‘The phytosociology of the central Free State’, MSc thesis, University of the Free State.

Poynton, J.C. & Roberts, D.C., 1985, ‘Urban open space planning in South Africa: A biogeographical perspective’, South African Journal of Science 81, 33–37.

Red List of South African Plants, viewed 13 September 2017, from http://redlist.sanbi.org/index.php

Rossouw, F.L., 2005, ‘n Ekologiese studie van die boogemmeenkappe van Bloemfonteingoewig, Oranje Vrystaat’, MSc thesis, University of the Orange Free State.

Rutherford, M.C. & Westfall, R.H., 1994, ‘Biomes of southern Africa: An objective categorization (2nd ed.)’, Memoirs of the Botanical Survey of South Africa 63, 1–94.

Sankaran, M., 2009, ‘Diversity patterns in savanna grassland communities: Implications for conservation strategies in a biodiversity hotspot’, Biodiversity & Conservation 18, 1099–1115. https://doi.org/10.1007/s10531-008-9519-9

Siebert, F., Eckhardt, H.C. & Siebert, S.J., 2010, ‘The vegetation and floristics of the Letaba enclosures, Kruger National Park’, Koedoe 52, Art. #777, 1–12. https://doi.org/10.4102/koedoe.v52i1.777

Soil Classification Working Group, 1991, ‘Soil classification: A taxonomic system for South Africa’, in Memoirs on the Agricultural Natural Resources of South Africa, vol. 15, pp. 1–257, Department of Agricultural Development, Pretoria.

Siebert, F., Eckhardt, H.C. & Siebert, S.J., 2010, ‘The vegetation and floristics of the Letaba enclosures, Kruger National Park’, Koedoe 52, Art. #777, 1–12. https://doi.org/10.4102/koedoe.v52i1.777

Soil Classification Working Group, 1991, ‘Soil classification: A taxonomic system for South Africa’, in Memoirs on the Agricultural Natural Resources of South Africa, vol. 15, pp. 1–257, Department of Agricultural Development, Pretoria.

Stirling, G. & Wilsey, B., 2001, ‘Empirical relationships between species richness, evenness, and proportional diversity’, American Naturalist 158, 286–299. https://doi.org/10.1086/321317

Tratalos, J., Fuller, R.A., Warren, P.H., Davies, R.G. & Gaston, K.J., 2007, ‘Urban form, biodiversity potential and ecosystem services’, Landscape and Urban Planning 83, 308–317. https://doi.org/10.1016/j.landurbplan.2007.05.003

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, J. & James, P., 2007, ‘Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review’, Landscape and Urban Planning 81, 167–178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Van der Maarel, E., 2005, Vegetation ecology, Blackwell Publishing, Oxford.

Van der Walt, L., Cilliers, S.S., Du Toit, M.J. & Kellner, K., 2015, ‘Conservation of fragmented grasslands as part of the urban green infrastructure: How important are species diversity, functional diversity and landscape functionality?’, Urban Ecosystems 18, 87–113. https://doi.org/10.1007/s11252-014-0393-9

Whitford, V., Ennos, A.R. & Handley, J.F., 2001, ‘City form and natural process – Indicators for the ecological performance of urban areas and their application to Merseyside, UK’, Landscape and Urban Planning 57, 91–103. https://doi.org/10.1016/S0169-2046(01)00192-X

Wilsey, B. & Stirling, G., 2007, ‘Species richness and evenness respond in a different manner to propagule density in developing prairie microcosm communities’, Plant Ecology 190, 259–273. https://doi.org/10.1007/s11258-006-9206-4

http://www.abcjournal.org

Open Access
# APPENDIX 1

## TABLE 1-A1: Synoptic table of the natural vegetation of Bloemfontein, Free State, South Africa.

| Vegetation units | 1 | 2 | 3 | 4 | 5 |
|------------------|---|---|---|---|---|
| **Number of relevés** | 3 | 3 | 7 | 2 | 2 |
| **SPECIES GROUP A:** Diagnostic species of Oenothera rosea — Bromus catharticus Wetland vegetation |
| Oenothera rosea | II | . | III V | . | II V , IV |
| Bromus catharticus | . | I | III V | . | II V , + |
| Gomphocarpus fruticosus | . | I III | . | I | II |
| **SPECIES GROUP B:** Diagnostic species of Rumex lanceolatus — Cyperus longus Streambed vegetation |
| Persicaria lapathifolia | V V | . | III | . | II |
| Cyperus longus | . | V | V III | V III | I |
| Paspalum dilatatum | . | IV | III | V | II |
| Rumex lanceolatus | . | II | V III | V | . |
| **SPECIES GROUP C:** Asparagus loricatus |
| Asparagus coorepi | . | . | V | V IV | . |
| Bidens bipinnata | . | . | V | V V | V H I | III | III | III | I | . |
| Ziopham mucronata | . | . | V | IV | IV | III | III | III | I | . |
| Asparagus sauveolens | . | . | III II IV V | II IV II III V III V IV | I V |
| Solanum retroflexum | . | . | V | II V | III | II | I | . |
| Setaria verticillata | . | . | III | IV V | III | II | I |
| Opuntia vulgaris | . | + | . | II IV III II I III III | I |
| Ehtharta erecta | . | . | II | III IV | . | III |
| Searsia lancea | . | I | V V | + | . |
| **SPECIES GROUP D:** Diagnostic species of Vachellia karroo — Asparagus loricatus Streambank vegetation |
| Vachellia karroo | . | V V V V V V | I |
| Tagetes minuta | . | I | V V V | V IV | . |
| Atriplex semibaccata | . | IV | III V V | . | . |
| Lepidium africanum | . | I | II II II | II | + | I |
| Cynodon dactylon | . | V | III III V IV II | . | II |
| Achyranthes aspera | . | V | II IV IV III |
| Melica decumbens | . | II | IV V IV | I |
| Osalis corniculata | . | IV | V V V |
| Diospyros lycioides | . | IV | IV | V |
| berhneya pinnatifida | . | IV | V IV IV | I |
| Clematis brachiata | . | V | I | I III |
| Chenopodium album | . | I | . | IV II | I |
| Sphenarece bonariensis | . | III | III | II | III |
| Artemisia afra | . | II | I | III |
| Cynodon incompletus | . | I III V |
| Setaria sphacelata | . | II IV I | I | I |
| Sonchus oleraceus | . | I | III I |
| Lycium hirsutum | . | V | I | I |
| Salvia repens | . | . | I | IV |
| **SPECIES GROUP E:** |
| Cheilanthes echlianna | . | . | . | IV IV IV | V III | III |
| Cotyledon orbiculata | . | I | . | . | III IV |
| Commelina africana | . | I | III II | I | . | I |
| Cirus radicans | . | . | III I I IV I V | IV |
| Melinis repens | . | I | II IV III III | II V |
| Aloe grandidentata | . | I | III I IV IV V I | II |
| Chascanum pinnatifidum | . | I | II I I V V | III |
| **SPECIES GROUP F:** |
| Eustachys pascaloides | . | . | V V IV IV IV V V III | III |
| Lantana rugosa | . | . | . | IV IV V V | V II |
| Searsia ciliata | . | IV | III V III V V |
| Felicia filifolia | . | I | II I | V V II |
| Pelosia columnelanos | . | . | . | . | I |

Table 1-A1 continues on the page →
### TABLE 1-A1 (Continues...): Synoptic table of the natural vegetation of Bloemfontein, Free State, South Africa.

| Vegetation units | 1.1 | 1.2 | 3.1 | 3.2 | 4 | 5 |
|------------------|-----|-----|-----|-----|---|---|
| Number of relevés | 3 3 7 2 2 2 10 5 3 3 7 11 12 6 10 3 9 6 5 9 4 3 7 3 5 3 5 4 3 4 5 3 4 5 3 4 5 3 4 |

| Species                  | 1.1  | 1.2  | 3.1  | 3.2  | 4  | 5  |
|--------------------------|------|------|------|------|----|----|
| Enneapogon scoparius      | I    | I    | I    | I    | I  | I  |
| Hyparrhenia hirta         | I    | I    | I    | I    | I  | I  |
| Selago albida             | II   | III  | I    | I    | I  | I  |
| Stapelia grandiflora      | III  | I    | IV   | IV   | II | III|
| Kalanchoe paniculata      | I    | I    | II   | III  | I  | I  |
| Pollichia campastris       | III  | III  | III  | II   | III| I  |
| Hermannia cuneifolia      | III  | I    | I    | I    | III| I  |
| Chrysocoma ciliata        | II   | I    | IV   | IV   | III| V  |

**SPECIES GROUP G**: Diagnostic species of *Olea europaea* – *Buddleja saligna* Shrubland

| Species                  | 1.1  | 1.2  | 3.1  | 3.2  | 4  | 5  |
|--------------------------|------|------|------|------|----|----|
| Olea europaea             | I    | I    | II   | II   | III| IV |
| Buddleja saligna          | V    | V    | V    | V    | V  | V  |
| Grewia occidentalis       | I    | V    | V    | V    | V  | V  |
| Searsia burchellii        | IV   | IV   | V    | V    | V  | V  |
| Pavonia burchellii        | II   | V    | III  | IV   | IV | V  |
| Euclia crispa subsp. crispa |   |     |     |     |    |    |
| Cheilanthes hirta         | II   | V    | V    | V    | I  | IV |
| Gymnosporia polycanthica  | III  | III  | III  | III  | IV  | IV |
| Cussania paniculata       | III  | III  | IV   | III  | I  | I  |
| Solanum tomentosum var. coccineum | II  | I    | I    | IV   | III| V  |
| Erietre rigida            | II   | I    | I    | I    | IV  | V  |
| Diospyros australiana     | III  | III  | III  | I    | I  | I  |
| Searsia erosa             | I    | III  | I    | II   | I  | I  |
| Viscum rotundifolium      | I    | I    | II   | IV   | III| I  |
| Crassula lancifolia       | I    | III  | IV   | II   | V  | V  |
| Asplenium cordatum        | IV   | IV   | V    | I    | I  | I  |
| Tarchonanthus camporhatus  | I    | III  | I    | I    | I  | I  |

**SPECIES GROUP H**: Diagnostic species of *Aristida diffusa* subsp. burkei – *Crassula nudicaulis* Succulent Grassland

| Species                  | 1.1  | 1.2  | 3.1  | 3.2  | 4  | 5  |
|--------------------------|------|------|------|------|----|----|
| Crassula nudicaulis      | I    | III  | I    | I    | III| IV |
| Euryops emetripolius      | II   | I    | I    | I    | I  | I  |
| Phyllanthus parvulus      | II   | III  | III  | II   | IV | IV |
| Aristida diffusa subsp. Burkei |   |     |     |     |    |    |
| Albuca setosa            | I    | I    | IV   | II   | II | II |
| Cynanchum viminale subsp. viminale | II  | I    | V    | IV   | V  | V  |
| Euphorbia montanaica     | II   | I    | IV   | III  | IV | IV |
| Heliotheca carnea         | I    | III  | IV   | IV   | IV | IV |

**SPECIES GROUP I**: Diagnostic species of *Delosperma pottsii* – *Cotyledon orbiculata* Grassland

| Species                  | 1.1  | 1.2  | 3.1  | 3.2  | 4  | 5  |
|--------------------------|------|------|------|------|----|----|
| Delosperma pottsii       | III  | I    | II   | V    | I  | I  |
| Cymbopogon caesius        | II   | II   | V    | V    | V  | V  |
| Euclia crispa subsp. ovata |   |     |     |     |    |    |
| Wahlenbergia albens       | IV   | II   | I    | I    | I  | I  |
| Jamesbritenia atropurpurea |   |     |     |     |    |    |
| Lantania laxa             |     |     | III  | I    | I  | I  |

**SPECIES GROUP J**: Diagnostic species of *Oropropetum capense* – *Eragrostis nindensis* Grassland

| Species                  | 1.1  | 1.2  | 3.1  | 3.2  | 4  | 5  |
|--------------------------|------|------|------|------|----|----|
| Oropropetum capense      |     |     | V    | I    | V  | I  |
| Eragrostis nindensis     |     |     | V    | I    | IV | V  |
| Ledebouria luteola        |     |     | I    | I    | IV | V  |
| Crassula dependens       |     |     | II   | II   | II | V  |
| Stomantum mustellinum    |     |     | V    | III  | I  | I  |
| Euryops multifidus       |     |     | I    | I    | I  | I  |
| Geigeria ornata          |     |     | I    | I    | II | I  |
| Ruschia spicata          |     |     | IV   | V    | V  | V  |
| Eragrostis trichophora    |     |     | IV   | V    | II | V  |

Table 1-A1 continues on the page →
| Vegetation units | 1   | 2   | 3   | 3.1 | 3.2 | 4   | 5   |
|------------------|-----|-----|-----|-----|-----|-----|-----|
| **Number of relevés** | 3 3 7 2 3 10 5 3 12 6 7 10 3 9 6 5 4 6 7 3 5 5 5 7 8 | 1 2 3 4 4 3 5 3 2 2 4 3 3 4 3 2 2 2 2 2 2 2 2 | 1 2 3 4 4 3 5 3 2 2 4 3 3 4 3 2 2 2 2 2 2 2 2 | 1 2 3 4 4 3 5 3 2 2 4 3 3 4 3 2 2 2 2 2 2 2 2 | 1 2 3 4 4 3 5 3 2 2 4 3 3 4 3 2 2 2 2 2 2 2 2 | 1 2 3 4 4 3 5 3 2 2 4 3 3 4 3 2 2 2 2 2 2 2 2 | 1 2 3 4 4 3 5 3 2 2 4 3 3 4 3 2 2 2 2 2 2 2 2 |
| Tragus berteronius | .. | .. | .. | .. | .. | .. | .. |
| Strumaria tenella subsp. orientalis | .. | .. | .. | .. | .. | .. | .. |
| Pelargonium minimum fasciculatum | .. | .. | .. | .. | .. | .. | .. |
| Chlorophytum | .. | .. | .. | .. | .. | .. | .. |
| Lessertia annulata | .. | .. | .. | .. | .. | .. | .. |
| Erioccephalus spinosiss | .. | .. | .. | .. | .. | .. | .. |
| Euphorbia rhombifolia | .. | .. | .. | .. | .. | .. | .. |
| Cyperus indicus | .. | .. | .. | .. | .. | .. | .. |
| Pelargonium aridum | .. | .. | .. | .. | .. | .. | .. |
| **SPECIES GROUP K:** | | | | | | | |
| Pseudognaphalium undulatum | .. | .. | .. | .. | .. | .. | .. |
| Monsonia angustifolia | .. | .. | .. | .. | .. | .. | .. |
| Ruschia hamata | .. | .. | .. | .. | .. | .. | .. |
| **SPECIES GROUP L:** | | | | | | | |
| Osteospermum scariosum | .. | .. | .. | .. | .. | .. | .. |
| Chloris virgata | .. | .. | .. | .. | .. | .. | .. |
| Argemone ochroleuca subsp. ochroleuca | .. | .. | .. | .. | .. | .. | .. |
| Conyza padocephala | .. | .. | .. | .. | .. | .. | .. |
| **SPECIES GROUP M:** Diagnostic species of Helichrysum dregenorum — Themeda triandra Grassland | | | | | | | |
| Helichrysum | .. | .. | .. | .. | .. | .. | .. |
| Hermannnia comosa | .. | .. | .. | .. | .. | .. | .. |
| Moraea pallida | .. | .. | .. | .. | .. | .. | .. |
| **SPECIES GROUP N:** Diagnostic species of Felicia mucirata — Themeda triandra Grassland | | | | | | | |
| Panicum coloratum | .. | .. | .. | .. | .. | .. | .. |
| Pentzia globosa | .. | .. | .. | .. | .. | .. | .. |
| Lycium cinerereum | .. | .. | .. | .. | .. | .. | .. |
| Enneapogon cenchroides | .. | .. | .. | .. | .. | .. | .. |
| **SPECIES GROUP O:** Companion species | | | | | | | |
| Eragrostis curvula | .. | .. | .. | .. | .. | .. | .. |
| Conyza bonariensis | .. | .. | .. | .. | .. | .. | .. |
| Chaenostoma caeruleum | .. | .. | .. | .. | .. | .. | .. |
| Themeda triandra | .. | .. | .. | .. | .. | .. | .. |
| Eragrostis | .. | .. | .. | .. | .. | .. | .. |
| Lehmanniana | .. | .. | .. | .. | .. | .. | .. |
| Oenothera depressa | .. | .. | .. | .. | .. | .. | .. |
| Aristida congesta | .. | .. | .. | .. | .. | .. | .. |
| Digitaria eriantha | .. | .. | .. | .. | .. | .. | .. |
| Hibiscus pusillus | .. | .. | .. | .. | .. | .. | .. |
| Sporobolus fimbristyla | .. | .. | .. | .. | .. | .. | .. |
| Felicia mucirata | .. | .. | .. | .. | .. | .. | .. |
| Nidorella resedifolia | .. | .. | .. | .. | .. | .. | .. |
| Schkuhria pinnata | .. | .. | .. | .. | .. | .. | .. |
| Eragrostis obtusa | .. | .. | .. | .. | .. | .. | .. |
| Eragrostis superba | .. | .. | .. | .. | .. | .. | .. |
| Senecio hastatus | .. | .. | .. | .. | .. | .. | .. |
| Nexea microphylla | .. | .. | .. | .. | .. | .. | .. |
| Cymbopogon pospachelli | .. | .. | .. | .. | .. | .. | .. |
| Heteropogon contortus | .. | .. | .. | .. | .. | .. | .. |
| Tragus koelerioides | .. | .. | .. | .. | .. | .. | .. |
| Eragrostis chloromes | .. | .. | .. | .. | .. | .. | .. |
| Senecio burchelli | .. | .. | .. | .. | .. | .. | .. |

Table 1-A1 continues on the page →
### TABLE 1-A1 (Continues...): Synoptic table of the natural vegetation of Bloemfontein, Free State, South Africa.

**Vegetation units**

| Number of relevés | 1   | 2   | 3.1 | 3.2 |
|-------------------|-----|-----|-----|-----|
|                   | 1   | 2   | 3   | 4   | 5   |
|                   | 3   | 7   | 2   | 2   | 3   | 10  | 5   | 3   | 7   | 11  | 12  | 6   | 10  | 9   | 5   | 6   | 9   | 4   | 6   | 7   | 3   | 5   | 3   | 5   | 3   | 4   | 4   | 5   | 9   | 3   | 4   |
| *Anthospermum*    |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| *Aristida adscensionis* |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| *Digiraria argyrogra" |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| *Melobium candidum* |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| *Indigofera alternans* |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| *Selago densiflora* |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| *Cyperus usitatus* |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

**SPECIES GROUP P:** Rare species

| Specie                      | Number of releves |
|-----------------------------|-------------------|
| *Crinum bulbispernum*       | IV                |
| *Juncus exsertus*           | II                |
| *Salix babylonica*          | II                |
| *Alchemilla elongata*       | V                 |
| *Verbena arista*gera*       | II                |
| *Lepidosperma sericea*      | II                |
| *Typha capensis*            | II                |
| *Dicoma anomala*            | II                |
| *Lemma minor*               | II                |
| *Salix macrocarpa*          | V                 |
| *Cyperus marginatus*        | V                 |
| *Pseudoschoenus inanis*     | V                 |
| *Hemantria altissima*       | V                 |
| *Gomphostigma virgatum*     | V                 |
| *Conium chaenopodioides*    | V                 |
| *Phragmites australis*      | IV                |
| *Verbena bonariensis*       | II                |
| *Miscanthus ecklonii*       | IV                |
| *Equisetum ramississimum*   | II                |
| *Ranunculus multifidus*     | II                |
| *Leptochloa fusca*          | I                 |
| *Eragrostis minor*           | II                |
| *Eleochthus limosa*         | III               |
| *Amaranthus species*        | III               |
| *Cyperus demudatus*         | III               |
| *Marsilea macrocarpa*       | I                 |
| *Polygonum aviculare*       | I                 |
| *Gleditsia triacanthos*     | III               |
| *Echinocotia crus-galli*    | I                 |
| *Amaranthus caudatus*       | I                 |
| *Alternanthera sessilis*     | III               |
| *Agrostis lachanitha*       | V                 |
| *Polygagon monspeliensis*   | V                 |
| *Veronica anagallis-aquatica* | V              |
| *Medicago laciniata*        | III               |
| *Cotula microglossa*        | I                 |
| *Senecio othonniflorus*     | III               |
| *Cyperus congestus*         | I                 |
| *Plantago lanceolata*       | III               |
| *Labelia thermalis*         | I                 |
| *Sonchus nanus*             | I                 |
| *Melilotus albus*           | II                |
| *Medicago sativa*           | II                |
| *Cistus laevigatim*         | II                |
| *Lactuca serriola*          | II                |
| *Paspalum distichum*        | II                |
| *Searsia pygoides*          | V                 |

Table 1-A1 continues on the page →
| Vegetation units | 1 | 2 | 3 | 4 | 5 |
|------------------|---|---|---|---|---|
| Pentarrhimum insipidum | | | | | |
| Rubia horrida | | | | | |
| Moraea simulans | | | | | |
| Rosenia humilis | | | | | |
| Urochloa panicoides | | | | | |
| Massonia jasminiflora | | | | | |
| Ammobachus coronae | | | | | |
| Solanum supinum | | | | | |
| Solanum lichensteini | | | | | |
| Antzoza angustifolia | | | | | |
| Ailanthura pungens | | | | | |
| Bulbine abyssinica | | | | | |
| Cuscuta campestris | | | | | |
| Colchicum melanthioides | | | | | |
| Duthiastrum sinnfolium | | | | | |
| Celtis africana | | | | | |
| Carex spartea | | | | | |
| Silene undulata | | | | | |
| Gerbera piloselloides | | | | | |
| Cineraria lobata | | | | | |
| Haemanthus humilis | | | | | |
| Bonatea speciosa | | | | | |
| Clusia pulchella | | | | | |
| Eucomis autumnalis | | | | | |
| Heteromorpha arborescens var. abyssinica | | | | | |
| Ericoperum carinatum | | | | | |
| Kedrostis africana | | | | | |
| Pupalia lappacea | | | | | |
| Pennisetum villosum | | | | | |
| Hermannia bryonifolia | | | | | |
| Aristida diffusa | | | | | |
| Rhigazum obovatum | | | | | |
| Cheilanthus viridis | | | | | |
| Commelina bengalensis | | | | | |
| Oysis lanceolata | | | | | |
| Sisymbrium capense | | | | | |
| Sebora compacta | | | | | |
| Pegoletta retroversa | | | | | |
| Pentzia sphaerocephala | | | | | |
| Ipomoea oblongata | | | | | |
| Senecio | | | | | |
| Cuscuta anguineus | | | | | |
| Panicum maximum | | | | | |
| Cineraria aspera | | | | | |
| Panicum deustum | | | | | |
| Galium capense | | | | | |
| Eragrostis biflora | | | | | |
| Cyperus obtusiflorus | | | | | |
| Dicoma macrocephala | | | | | |
| Menadora africana | | | | | |
| Eionurus muticus | | | | | |
| Raphionacme hisruta | | | | | |
| Kyllinga alba | | | | | |
| Talinum caffrum | | | | | |

Table 1-A1 continues on the page→
TABLE 1-A1 (Continues...): Synoptic table of the natural vegetation of Bloemfontein, Free State, South Africa.

| Vegetation units | 1.1 | 1.2 | 2 | 3 | 3.1 | 3.2 |
|------------------|-----|-----|---|---|-----|-----|
| Number of releves | 3 3 7 2 2 3 10 5 3 7 11 12 6 7 10 9 6 5 9 4 6 7 3 3 3 5 3 4 5 7 4 6 5 3 2 4 4 2 4 4 3 4 4 5 9 3 4 |

- *Schizocarphus nervosus*
- *Hibiscus marlothianus*
- *Kohauta amatymsica*
- *Ipomoea oenotheroides*
- *Euphorbia inaequilatera*
- *Salvia kali*
- *Argyrolobium pauciflorum*
- *Helichrysum zeyheri*
- *Triaenis andreanopodioides*
- *Indigofera filipes*
- *Avonia astulata*
- *Microchloa caffra*
- *Crassula setulosa*
- *Gladiolus permeabilis*
- *Cyphium triphyllum*
- *Opuntia species*
- *Drimia elata*
- *Jamesbrutenia aurantica*
- *Anacamposeros telephiasmum*
- *Crassathornia protecta*
- *Trichodiadema barbatum*
- *Albuca prasina*
- *Chasmaphyllum musculum*
- *OphioGLOSSUM polyphylIum*
- *Jamesbrutenia pulla*
- *Crassula corallina*
- *Pteronia species*
- *Anacamposeros filamentosa*
- *Orbeopsis lutea*
- *Nerine laticoma*
- *Tulbagha acutiloba*
- *Senecio inaequidens*
- *Anisata stipitata*
- *Blepharis integrifolia*
- *Harpagoptygium procumbens*
- *Erio spernum species*
- *Melobium calycinum*
- *Berkerha anoparadixia*
- *Henta pallens*
- *Barleria macrostegia*
- *Trichanura grandiflora*
- *Rhynchosia nervosa*
- *Pogonarthria squarroasa*
- *Anthephora pubescens*
- *Hibiscus trianum*
- *Crotalaria sphaerocarpa*
- *Brunsvigia radulosa*
- *Eragrostis guimmfield*

Table 1-A1 continues on the page →
TABLE 1-A1 (Continues...): Synoptic table of the natural vegetation of Bloemfontein, Free State, South Africa.

| Vegetation units | 1  | 2  | 3  | 4  | 5  |
|------------------|----|----|----|----|----|
| Number of relevés| 3  | 3  | 2  | 2  | 3  |
|                  | 10 | 9  | 6  | 9  | 6  |
|                  | 11 | 12 | 6  | 10 | 3  |
|                  | 3  | 7  | 2  | 2  | 10 |
|                  | 3  | 3  | 7  | 12 | 6  |
|                  | 10 | 9  | 6  | 9  | 6  |
|                  | 1  | 2  | 3  | 4  | 5  |

| Species            | 1  | 2  | 3  | 4  | 5  |
|--------------------|----|----|----|----|----|
| Cyperus rupestris  | III| II | III| II | III|
| Helichrysum        | III| II | III| II | III|
| aureusinens        | III| II | III| II | III|
| Wahlenbergia androsacea | II | II | III| II | III|
| Amaranthus thunbergii | II | II | III| II | III|
| Chenopodium murale | III| II | III| II | III|
| Eleusine coracana  | II | II | III| II | III|
| Hyphaea argentea    | III| II | III| II | III|
| Amaranthus hybridus | III| II | III| II | III|
| Dimorphotheca zeyheri | II | II | III| II | III|
| Eragrostis plana    | II | III| II | III| II | III|
| Vahlia capensis     | III| II | III| II | III|
| Aristida bipartita | III| II | III| II | III|
| Setaria incrassata  | III| II | III| II | III|
| Aristida bakeni     | III| II | III| II | III|
| Nemisia fruticans   | III| II | III| II | III|
| Fingerhuthia africana | II | II | III| II | III|
| Convolvulus arvensis* | II | II | III| II | III|
| Hernanthera coccocarpa | III| II | III| II | III|
| Panicum schinzi    | III| II | III| II | III|
| Bidens pilosa      | III| II | III| II | III|
| Tribulus terrestris| III| II | III| II | III|
| Phyla nodiflora    | III| II | III| II | III|
| Scabiosa columbaria| III| II | III| II | III|
| Salvia verbenaca   | III| II | III| II | III|
| Brachiaria eruciformis | III| II | III| II | III|
| Salsola aphylla    | III| II | III| II | III|

* indicates invasive species (Department of Environmental Affairs 2016).