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Phytosociology of Golden Gate Highlands: A focus on Drakensberg-Amathole Afromontane Fynbos

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Vegetation mapping with details of plant communities plays an important role in managing and conserving the natural environment. Vegetation types mapping by Du Preez, including the current Drakensberg-Amathole Afromontane Fynbos (Gd6) in the Golden Gate Highlands National Park, somewhat differs from that of Mucina and Rutherford. Recent research indicated that the Gd6 vegetation type is very restricted in the park. Apart from these shortcomings, there are also questions about the occurrence of other fynbos components within the grassland biome. Using the Braun-Blanquet cover abundance scale, 108 sample plots were placed in three transects across the mapped and proposed sections of Gd6 to collect vegetation data. A TWINSPAN classification in JUICE suggests the phytosociological classification of two distinct plant communities. These two communities were further confirmed by ordination, which indicated that the communities had different environmental preferences. The combination of different plant families found during the study confirms the composition of fynbos elements within the grassland. Our research findings indicate that Gd6 is present within Golden Gate Highlands National Park and serves as a baseline for plant communities related to this vegetation type. The results further suggest that both mapped and proposed sections should be combined to create a single, more detailed map.

Conservation implications: The analysis of plant species and communities in the proposed and mapped sections of the Drakensberg-Amathole Afromontane Fynbos indicated the presence of this vegetation type within Golden Gate Highlands National Park. The description of these communities helped to define and assist with the criteria for the management and protection of fynbos components in the grassland.

Keywords: grassland biome; vegetation classification; vegetation mapping; plant communities; fynbos components.

Introduction

Vegetation mapping serves as a primary and widely used method for simplifying the geographical patterns and complexity of vegetation cover (Mucina & Rutherford 2006). Mapping at a finer scale is essential to develop management plans for the protection of biodiversity (Dayaram et al. 2021) and the management of nature reserves (Kent 2012; Mucina & Rutherford 2006; Rebelo et al. 2006). Furthermore, vegetation maps provide information about an ecosystem and the environmental variables that govern the distribution of plant species (Brown et al. 2013; Franklin 2013). Vegetation mapping involves categorising vegetation into units that share common characteristics, often according to vegetation surveys (classification) conducted by researchers (Franklin 2013; Kent 2012). It further enables us to understand how vegetation cover changes over time (Pettorelli 2013). To effectively manage an ecosystem, a thorough description and a map of the vegetation are required (Brown et al. 2013; Mucina & Rutherford 2006).

Grassland ecosystems are extensive and occupy around 40% of the Earth's surface (Carbutt, Tau & Escott 2011; Sun et al. 2022; Suttie, Reynolds & Batello 2005; Wang et al. 2022; White, Murray & Rohweder 2000). These grasslands are important for ensuring food security, which benefits human well-being (Huber et al. 2011; O'Mara 2012). There are, however, many other ecosystem services provided by grasslands that include carbon sequestration, storage and purification of water, air purification, production of food and climate control (Boval & Dixon 2012; Cadman et al. 2013; Leys et al. 2018). Besides the ecosystem services that grasslands provide, they are also

Note: Additional supporting information may be found in the online version of this article as Online Appendix 1.

economically important for providing economic values such as food, income, and supporting livestock production (Boval & Dixon 2012; Carbutt & Kirkman 2022; Leys et al. 2018).

The South African Grassland biome is the second largest biome, covering approximately 28% of the country (Brown & Bezuidenhout 2020; Cadman et al. 2013; Prinsloo, Reilly & Myburgh 2021). The biome is found on a wide range of soil types and under various climatic conditions (Prinsloo et al. 2021). Grasslands can be subdivided into a variety of ecosystems that differ in terms of species richness, species composition and habitats; they might also support different animal communities (Boval & Dixon 2012; Stevens 2018; Wright et al. 2006). These ecosystems are divided on the basis of correlating floristic and environmental factors (Mucina & Rutherford 2006). Certain vegetation units within this biome contain remnants of fynbos. This study focuses on comparing the Drakensberg-Amathole Afromontane Fynbos (Gd6) mapped and described by Mucina and Rutherford (2006), which occurs within the Golden Gate Highlands National Park (GGHNP), with a proposed revision of this mapped area.

The Drakensberg-Amathole Afromontane Fynbos (Gd6) occurs in KwaZulu-Natal, the Eastern Cape and the Free State as isolated patches in deeply incised valleys of the Drakensberg (Mucina & Rutherford 2006). This vegetation type is mostly present at 1660 m and then again from 1900 m to 2060 m, with some outliers at 1520 m as well as at 2600 m above sea level (Mucina & Rutherford 2006). Evergreen shrublands with ericoid leaves, ranging in height from 1 m to 3 m, make up most of the vegetation. The most important fynbos elements include genera such as *Passerina, Cliffortia, Erica, Euryops, Helichrysum, Macowania, Protea, Widdringtonia,* and *Ischyrolepis*. Research indicates that there is also a low-altitude, very species-poor, fynbos shrubland dominated by *Passerina montana* on the outskirts of high eastern Free State koppies such as Thaba'Nchu (Roberts 1961) and Korannaberg (Du Preez 1992) as well as on the foot slopes of the Clarens sandstone cliffs of Golden Gate Highlands National Park (Mucina & Rutherford 2006). Research by Brand, Du Preez and Brown (2008, 2009) also found fynbos components in the grassland on Platberg. Mention was also made of fynbos components occurring on Korannaberg by Du Preez (1992). Inselbergs within the Free State have created ideal environments and pathways for the fynbos to move from the Cape Floristic Region (CFR) to the Drakensberg Alpine Centre (DAC) (Brand, Brown & Du Preez 2011), of which Golden Gate forms part (Mucina & Rutherford 2006). The inselbergs have cool temperatures with leached soils, which create ideal environments for fynbos vegetation to grow in.

Fynbos occurs in moist conditions under current temperatures in grasslands at higher elevations (Mucina & Rutherford 2006; Norström et al. 2009). Although fynbos occurs in parts of the Free State's grassland, it seems to be relics and out of place; 'fynbos-like' shrubland has been more extensive during the wetter parts of the Late Pleistocene, as is indicated by research at Elim and Craigrossie (near the Little Caledon River in the vicinity of Clarens; eastern Free State Province) (Scott 1989; Scott et al. 2012, 2013) and Braamhoek (close to the Drakensberg escarpment) (Norström et al. 2009, 2014). Research indicates that the occurrence of fynbos elements was also much more extensive in the past during the Late Quaternary in lower-lying parts where they are currently absent, covered by grasslands or savanna, probably because of lowering of vegetation belts caused by climate change during cool wet periods (Brook et al. 2010; Coetzee 1967; Scott 1982; Scott et al. 2012). This was also found in the pollen record at Tswaing Crater in Gauteng (c. 200 000–150 000 years ago) in some of the organic-rich sections which preserved pollen (Scott 1999a, 1999b). The western parts of the Free State also showed fynbos elements in the form of Ericaceae and Restionaceae present during cooler times at Florisbad (c. 300 000 years ago), although the record was incomplete and discontinuous (Scott 2000; Scott et al. 2019). Another western Free State site, namely Baden-Baden (c. 25 000 years ago), also had fynbos elements in the form of *Stoebe*-type pollen, indicating cooler conditions (Van Aardt et al. 2015). When conditions changed to warmer and drier climates or developed stronger seasonal rainfall patterns, a decline was observed in these families and genera (Ericaceae, *Stoebe*-type and *Anthospermum*) associated with fynbos elements (Norström et al. 2009, 2014; Scott 1982, 1989; Scott et al. 2013, 2019; Van Aardt et al. 2015). The remnants of fynbos found by Brand et al. (2008, 2009) on Platberg could be relics from cooler periods when fynbos was more extensive during the Late Quaternary (Brand et al. 2008, 2009, 2011).

This study aimed to determine the community composition of the Drakensberg-Amathole Afromontane Fynbos within Golden Gate Highlands National Park as mapped by Mucina and Rutherford (2006) and proposed by Du Preez (2017). However, recent mappings by Du Preez (2017) mapped a much larger area. Daemane et al. (2022) indicated that Gd6 was not very prominent in the park, but mentioned that the vegetation occurs in shallow depressions on mid-slopes, leading to drainage lines. We have thus investigated these discrepancies.

Study area

Golden Gate Highlands National Park (hereafter GGHNP) (Figure 1) is in the vicinity of Clarens in the eastern Free State (28°30′05″ S, 28°34′43″ E), near the Lesotho border (SANParks 2020). The GGHNP is situated on the Highveld, which is an inland plateau at the foothills of the Maloti Drakensberg Mountain range, covering an area of 340 km^2 (Botham et al. 2020; Groenewald 1986; SANParks 2020). The GGHNP was established in 1963 with the intention of protecting and conserving the montane, Afro-alpine grassland biome and sandstone formations (SANParks 2020; Taru, Chingombe & Mukwada 2013).

The study area is located within the summer rainfall region, with rainfall restricted from November to April (Daemane et al. 2022; Grab et al. 2011; Groenewald 1986; Moffett 2018) and occurs in the form of thunderstorms (Van Zyl 2003). Late afternoon thunderstorms are mostly accompanied by hail

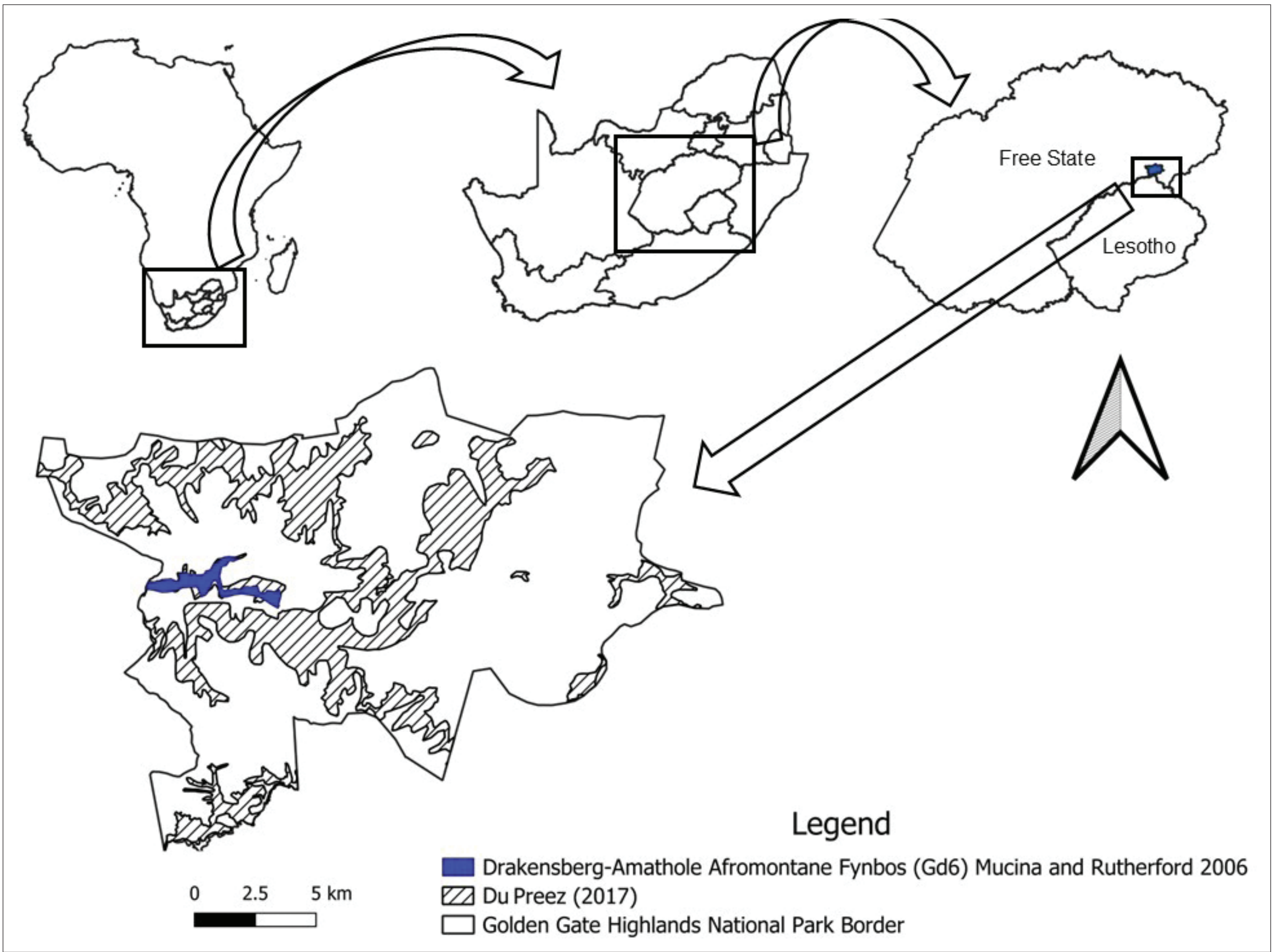


FIGURE 1: Study area map indicating the sections mapped by Mucina and Rutherford (2006) and Du Preez (2017).

and some lightning (Moffett 2018; Van Zyl 2003). The average mean annual rainfall of the area is 800 mm – 1820 mm, with periodic snowfall and frost in winter months on the highest peaks as well as summer mist (Cooks & Pretorius 1987; Groenewald 1986; MacKellar, New & Jack 2014; Moffett 2018). The area mostly experiences warm summers and cold winters (Grab et al. 2011).

The vegetation of GGHNP is dominated by sour grass, occurring in high rainfall areas on leached soils (Mucina & Rutherford 2006). These grasslands are seen as stable because of a dense cover of grasses (Tainton 1999). Vegetation types (Figure 2) found in the Park include the Basotho Montane Shrubland (Gm5), Eastern Free State Sandy Grassland (Gm4), Lesotho Highland Basalt Grassland (Gd8), Northern Drakensberg Highland Grassland (Gd5), and Drakensberg-Amathole Afromontane Fynbos (Gd6) where this study is focused (Figure 2) (Mucina & Rutherford 2006; Mukwada, Chingombe & Taru 2016; SANParks 2020).

The Drakensberg-Amathole Afromontane Fynbos (Gd6) comprises fynbos elements characterised by fine-leaved, evergreen sclerophyllous shrubs whose regeneration is influenced by fire (Mucina & Rutherford 2006). Although the original map by Mucina and Rutherford (2006) only indicated the occurrence of Gd6 in Golden Gate Highlands National Park, it was also found near Harrismith on Platberg (Brand et al. 2008, 2009) and on Korannaberg near Excelsior (Du Preez 1992).

Research methods and design

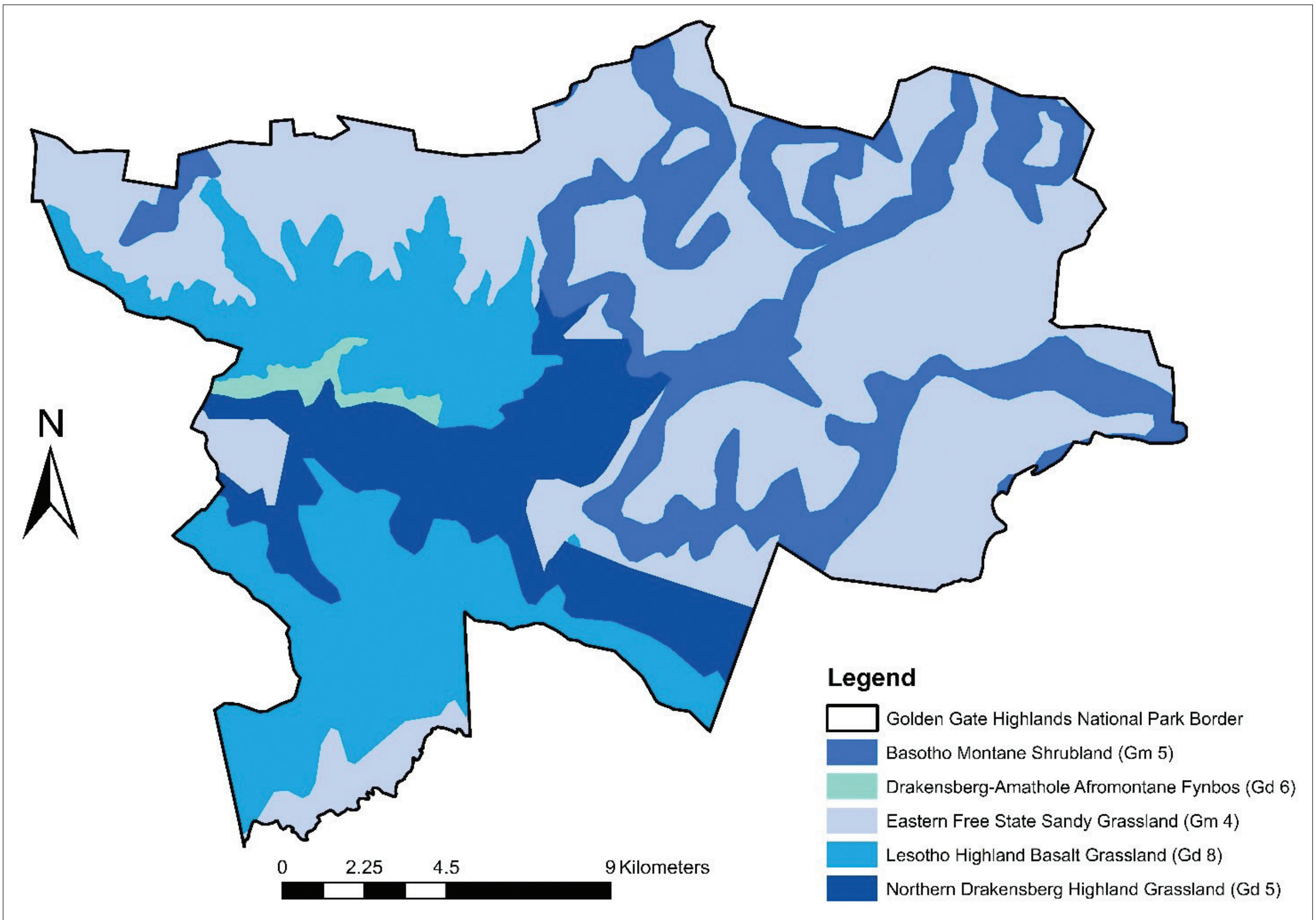
As a tool in nature and wildlife conservation to stratify land into management units, we investigated the vegetation of the study area by mapping it and comparing the results with previous studies. The mappings by Mucina and Rutherford (2006) made use of maps published in various scientific journals in South Africa as well as unpublished reports at provincial and national levels. Their resources also included master's and doctoral theses at different universities across the country. Other than that, they created the first National Vegetation Map (NVM) for South Africa using satellite imagery, aerial photographs and spatial predictive modelling (Mucina & Rutherford 2006). There was limited ground truthing involved in the mappings by Mucina and Rutherford (2006). Furthermore, the descriptions of the different vegetation types were very broad and not conducted at community level. From 2015 until 2019, the late Professor Johann Du Preez from the University of the Free State used his extensive knowledge of the vegetation of the Free State as well as helicopter flights as a mode of reconnaissance to refine the maps of Mucina and Rutherford (2006) (unpublished data Du Preez 2017). His mappings sometimes overlapped with those of Mucina and Rutherford (2006), but with slight deviations. However, in some instances, he expanded the distribution of vegetation types with more polygons. The areas mapped by Du Preez did not include any metadata, but polygons were assigned to the same codes as the 2006 NVM, and we, therefore, assume that his refinements were carried out based on the same descriptions as those of Mucina and Rutherford (2006). These proposed refinements by Du Preez were never ground-truthed, and thus, they also lack detailed information. To date, it could thus not be confirmed whether his mappings should be included in the updated versions of the NVM. This NVM provides the baseline dataset used for ecosystem threat assessment, informing national and provincial conservation strategies, and quantifying conservation targets. The NVM further presents the potential vegetation that can be present in an area in the absence of human intervention.

Data collection

During February 2022 (the growing season), 108 sample plots were placed in three transects across the mapped sections of the Drakensberg-Amathole Afromontane Fynbos by Mucina and Rutherford (2006) and that proposed by Du Preez (2017). The modified Braun-Blanquet cover abundance scale (Table 1) was used to record all vascular plants in the combined mapped sections of Gd6. Plots were 10 m × 10 m (Bredenkamp & Brown 2003; Brown et al. 2013; Du Preez 1992; Grobler, Bredenkamp & Brown 2002) with 10 m between each sampling plot along the transect. Unknown species sampled were stored and identified at the Geo Potts Herbarium (BLFU) at the University of the Free State. Bulbs, succulents and geophytes were photographed instead of sampled if they could not be identified.

Classification

Field data were captured in VegCap, a Macro-enabled Excel spreadsheet developed by Dr Nacelle Collins. Captured data



Source: Mucina, L. & Rutherford, M.C., 2006, *The vegetation of South Africa, Lesotho and Swaziland*, Strelitzia 19, p. 801, South African National Biodiversity Institute, Pretoria

FIGURE 2: Vegetation types of Golden Gate Highlands National Park.

TABLE 1: Modified Braun-Blanquet cover abundance scale used.

Symbol	*r*	+	1	2a	2b	3	4	5
%	≤ 5% (1–3 individuals)	≤ 5% (few individuals)	≤ 5% (numerous individuals)	5% – 12.5%	12.5% – 25%	25% – 50%	50% – 75%	≥ 75%

Source: Adapted from Werger, M.J.A., 1973, 'On the use of association-analysis and principal component analysis in interpreting a Braun-Blanquet phytosociological table of a Dutch grassland', *Plant Ecology* 28, 129–144. https://doi.org/10.1007/BF02389616 were then imported into JUICE (Tichy & Holt 2006), where a modified TWINSPAN (Hill 1979) analysis (two-way-indicator species analysis) was conducted. The Table from JUICE was refined using Braun-Blanquet procedures (Brown et al. 2013). JUICE was also used to calculate and distinguish between dominant and diagnostic species (Brown et al. 2013) using the analysis of the Columns of a Synoptic Table function. Threshold frequencies were set to 75, 60 and 50, respectively, for diagnostic, dominant and constant species (Theron, Van Aardt & Du Preez 2020). This was only carried out for the communities. Species indicated in bold had values higher than the threshold values, while * indicates alien invasive species in the phytosociological table (Online Appendix 1).

Ordination

To conduct correspondence analysis (CA), species data were uploaded into CANOCO (Ter Braak & Smilauer 2002). Biplot scaling was used to focus the analysis on inter-species distance. No transformation of the species data was carried out, and rare species were not down-weighted. To determine the different plots surveyed, basic ordination plots were drawn using CANOCO. Various combinations of the first, second and third axes were used, and diagrams best presenting the vegetation observed in the field are shown in the results and discussion. An environmental gradient of rocky outcrops and deeper soils was used and fitted to the axis as it was observed in the field during data collection.

Ethical considerations

Ethical approval was obtained from the Environmental and Biosafety Ethics Committee at the University of the Free State (UFS-ESD2023/0037/3) on 10 May 2023.

Results and discussion

Vegetation classification

The classification results below indicate communities, sub-communities and variants of the Gd6 vegetation of the mapped sections by Mucina and Rutherford (2006) and the proposed section by Du Preez (2017). Additionally, some figures under the categories of diagnostic, dominant and constant species indicate the prevalence of those species in a community. Table 1-A1 represents the phytosociological classification of the vegetation of the two sections. Two communities with a total of four sub-communities and four variants were identified, and they are as follows:

1. *Erica woodii–Passerina montana* Community
    - 1.1 *Erica woodii–Passerina montana–Digitaria monodactyla* Sub-community
        - 1.1.1 *Crassula dependens* Variant
        - 1.1.2 *Afroaster perfoliatus* Variant
    - 1.2 *Erica woodii–Passerina montana–Aristida junciformis* Sub-community
2. *Cymbopogon pospischilii–Cotula hispida* Community
    - 2.1 *Cymbopogon pospischilii–Cotula hispida–Lotononis lotononoides* Sub-community
    - 2.2 *Cymbopogon pospischilii–Cotula hispida–Helichrysum auriceps* Sub-community
        - 2.2.1 *Selago densiflora* Variant
        - 2.2.2 *Eragrostis racemosa* Variant

Description of plant communities

1. *Erica woodii–Passerina montana* Community

Diagnostic species: None
Dominant species: *Aristida junciformis* 2, *Diospyros whyteana* 2, *Erica algida* 7, *Erica woodii* 11, *Monocymbium ceresiiforme* 2, *Themeda triandra* 2, *Tristachya leucothrix* 11
Constant species: *Passerina montana* 64, *Erica woodii* 73, *Helichrysum auronitens* 64, *Tristachya leucothrix* 82

The *Erica woodii–Passerina montana* plant community is located on the mid-slope of a mountain where there is full sun exposure. The slope is gentle to steep with some rocky outcrops on the edges of the community. The plant community consists of a mixture of ferns, herbs and shrubs characterised by *Erica woodii, Passerina montana* and *Erica algida* shrubs from Species Group A (Table 1-A1). *Passerina montana* shrubs can be used to distinguish this community from the rest of the communities in Table 1-A1 (Figure 3). The presence of *Erica* species such as *E. woodii* and *E. algida* throughout this community serves as evidence that this community is part of Gd6 because these species form part of the characteristic species described by Mucina and Rutherford (2006) for this vegetation type.

Brand et al. (2008) found an *Eragrostis curvula–Eragrostis racemosa* community where *P. montana* was a variant. In this variant, *Heteropogon contortus* and *T. leucothrix* are some of the species that had significant cover abundance values. The results of our study and those of Brand et al. (2008) are comparable because the species that were identified as characteristic in their study are the same as the species in our study. Du Preez (1992) found *Passerina montana–Cymbopogon dieterlenii* to be a major community. However, the community identified by Du Preez (1992) differs from the community identified in our study in terms of the species

Note: Photograph taken by the lead author Jubilant Vongani Sithole.
FIGURE 3: *Erica woodii – Passerina montana* community.

found within each of the communities. In Du Preez's (1992) study, *Passerina montana* was a dominating species, whereas in our study, it occurs with high cover abundance. Mucina and Rutherford (2006) regard *Passerina montana* as an important species in the Gd6 vegetation type. Brand et al. (2011) indicate that the presence of *P. montana* confirms the presence of Gd6 as a vegetation type. Furthermore, Brand et al. (2011) indicate that *Passerina montana* is sclerophyllous and characterises some of the communities they found on Platberg. The occurrence of *P. montana* in our research is thus a clear indication that this community represents the vegetation of Gd6.

1.1 *Erica woodii–Passerina montana–Digitaria monodactyla* Sub-community

This sub-community is located on a rocky outcrop of a mid-slope with shallow soils that are well drained. As a result of heavy rainfall in summer, water tends to collect on the rocks, creating rockpools. The sub-community is defined by grasses and herbs from Species Group B (Table 1-A1), including *Digitaria monodactyla*, *Wahlenbergia krebsii*, *Stiburus alopecuroides* and *Aristida congesta.* These species occur with high cover abundance in this sub-community and with little or no cover abundance in other sub-communities. Brand et al. (2008) described a community called *Helichrysum dasycephalum–Digitaria monodactyla* community where *Digitaria monodactyla* is one of the dominating species. The community described by Brand et al. (2008) is located on a flat rocky ridge on the steep and exposed mid-slopes where the soils are well drained. The community described by Brand et al. (2008) is like the sub-community described in our study in terms of location and species found. This sub-community can be divided into two variants.

1.1.1 *Crassula dependens* Variant

This variant occurs on a steep south-facing mid-slope, on the sandstones of the Clarens Formation. The soil collecting on the rocky outcrops is approximately 8 cm – 10 cm deep. Soil and nutrients from runoff are collected in the rocks and create an ideal environment for *Crassula dependens* (Species Group C; Table 1-A1) to grow. This environment is ideal for these species to grow because the soil contains abundant moisture during the rainy season. The vegetation is dominated by *Aristida junciformis* (Species Group E), *Erica woodii* (Species Group A), *Tristachya leucothrix* (Species Group L) and *Crassula dependens* (Species Group C), having high cover abundance values (Table 1-A1). Most of the species occurring in Species Group C are absent or occur with low cover abundance in other communities and sub-communities. Although this variant was not described in any of the available literature by Du Preez (1992) and Brand et al. (2008, 2009), the species that are found within the variant are similar to the species found by these researchers, for example, *Crassula dependens* and *Oxalis depressa* from Species Group C.

1.1.2 *Afroaster perfoliatus* Variant

This variant is located on a mid-slope with rocky outcrops and is defined by species from Species Group D (Table 1-A1), which includes *Afroaster perfoliatus, Senecio othonniflorus, Senecio harveianus, Melinis repens, Hypoxis costata, Chrysocoma ciliata, Hypoxis hemerocallidea, Ficinia stolonifera, Satyrium longicauda, and Ledebouria cooperi.* These species have little or no cover abundance in the rest of the communities. This variant is dominated by *Afroaster perfoliatus* from Species Group D in Table 1-A1. Neither Du Preez (1992) nor Brand et al. (2008, 2009) found similar associations in their studies.

1.2 *Erica woodii–Passerina montana–Aristida junciformis* Sub-community

This sub-community is located on a mid-slope and is dominated by grasses, herbs and shrubs from Species Group E (Table 1-A1). Vegetation in this sub-community is exposed to strong sunlight and the soils are well drained, although there are signs of wetness because of water damming on the rocks after heavy rainfall during summer. The strong presence of *Aristida junciformis* and *Erica alopecuroides* distinguishes this sub-community from the other sub-communities. *Aristida junciformis* is considered an important indicator species by Mucina and Rutherford (2006) within the Gd6 vegetation type.

2. *Cymbopogon pospischilii–Cotula hispida* Community

Diagnostic species: None
Dominant species: *Cymbopogon pospischilii* 6, *Themeda triandra* 23
Constant species: *Cymbopogon pospischilii* 77, *Selago flanaganii* 81, *Themeda triandra* 90, *Tristachya leucothrix* 62

The *Cymbopogon pospischilii–Cotula hispida* Community is located on a mountain in a mid-slope position where there is deep soil with some stones. The community receives strong sunlight but retains moisture well after heavy rainfall. This is a grassland community dominated by *C. pospischilii* (Species Group F) and *T. triandra* (Species Group J) (Table 1-A1). The species that distinguish this community from community 1 are *Cymbopogon pospischilii* and *Cotula hispida* (Species Group F), which occur with low cover abundance values in the other communities. This can be a new community or a community that indicates disturbance as it was not previously found in research about Gd6. In literature, *C. hispida* is indicative of disturbance and therefore, its presence in this community indicates a disturbance (Fish et al. 2015). However, species that occur in this community but are not characteristic were found by previous research to be present in Gd6. These species are indicated in blue on the phytosociological table (Table 1-A1) and include *Lotononis lotononoides, Andropogon appendiculatus* (Species Group H), *Eragrostis chloromelas, Eragrostis curvula, Crassula lanceolata, Cheilanthes eckloniana* (Species Group I), and *Vernonia hirsuta* (Species Group J) (Brand et al. 2008, 2009; Du Preez 1992; Mucina & Rutherford 2006).

2.1 *Cymbopogon pospischilii–Cotula hispida–Lotononis lotononoides* Sub-community

The sub-community is located on a steep mid-slope with isolated patches of rocks with shallow soils. *Cymbopogon pospischilii* (Species Group F) and *Themeda triandra* (Species Group J) dominate this community, with *Lotononis lotononoides* and *Pelargonium sidoides* (Species Group G) having high cover abundance values (Table 1-A1) and dominating this sub-community. The other species such as *Crassula natalensis, Panicum natalense, Diascia integerrima, Andropogon appendiculatus, Scabiosa columbaria, Moraea brevistyla, Helichrysum tenax, Nemesia fruticans,* and *Cynoglossum hispidum* (Species Group G) are also characteristic of this sub-community and have little cover abundance in the other communities. There are also species that correspond to what Du Preez (1992) and Brand et al. (2008, 2009) found during their studies, including *Andropogon appendiculatus* and *L. lotononoides* (Species Group G).

2.2 *Cymbopogon pospischilii–Cotula hispida–Helichrysum auriceps* Sub-community

This sub-community is located on the mid-slope of the Clarens and Drakensberg Formation where there are about 10% rocky outcrops. The soils found were black (which might be indicative of high organic matter content) and damp. Species such as *Cymbopogon pospischilii* and *Themeda triandra* (Species Group H) dominate this sub-community with high cover abundance values (Table 1-A1). Brand et al. (2009) described an *Asparagus ramosissimus–Leucosidea sericea–Fraxinus angustifolia* Sub-community, which was located on sandstones of the Clarens Formation. The soils in the sub-community described by Brand et al. (2009) were deep, black and damp. The sub-community in our study is similar to that described by Brand et al. (2009) in terms of the location as well as the high cover abundance of *Leucosidea sericea* (Species Group H):

2.2.1 *Selago densiflora* Variant

This variant is located on a mid-slope that receives full sun exposure with well-drained soils. It is characterised by species from Species Group I (Table 1-A1), which are mostly grasses, shrubs and herbs. This variant is distinguished from variant 2.2.2 because of the absence or low cover abundance values of species from Species Group I (Table 1-A1). The dominating species in this variant include *Cymbopogon pospischilii* (Species Group F) and *Themeda triandra* (Species Group J). The variant consists of four species from Species Group I, highlighted in blue, which include *Eragrostis chloromelas, Eragrostis curvula, Crassula lanceolata,* and *Cheilanthes ecklonіana*, which were also found by researchers (Brand et al. 2008, 2009; Du Preez 1992; Mucina & Rutherford 2006) working on Gd6-related vegetation.

2.2.2 *Eragrostis racemosa* Variant

This variant is characterised by species from Species Group J, with *Vernonia hirsuta* (Species Group J) (Table 1-A1) also found by Brand et al. (2008, 2009) in their description of Gd6 vegetation. These species have a strong presence in this variant, with little or no cover abundance in the other communities. The variant is dominated by the grass *Eragrostis racemosa*.

Ordination

The CA resulted in a clear grouping of two different communities (Figure 4), similar to the phytosociological classification, consisting of the grassland community (*Cymbopogon pospischilii–Cotula hispida*) and the fynbos community (*Erica woodii–Passerina montana*) occurring on rocky outcrops. There are, however, some plots in the communities that are common to both communities. Given that transects were sampled across the proposed and mapped sections, these overlapping plots might be indicative of ecotonal areas.

Family comparison of Fynbos and Grassland

Families found in the study area that had more than four species are all included in Figure 5. Asteraceae and Poaceae are the most prominent families found in the study area. Fabaceae, Cyperaceae and Schrophulariaceae also have a high number of individuals occurring within the study area.

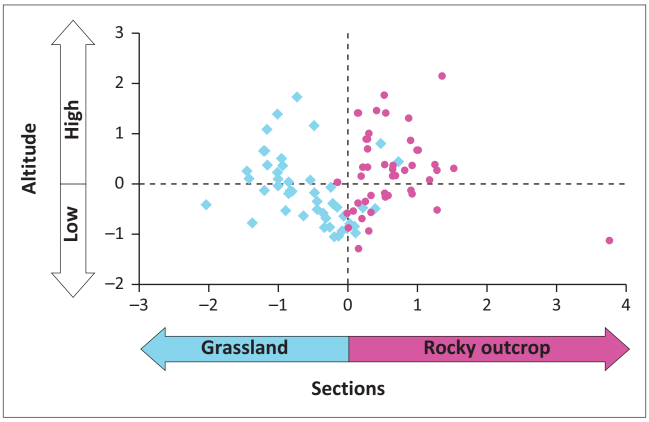
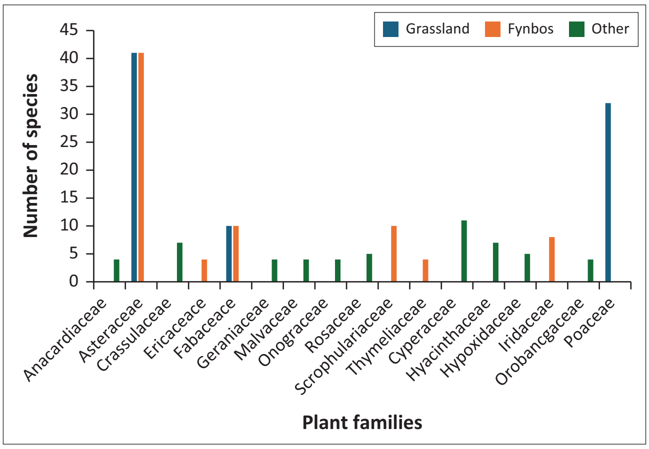


FIGURE 4: Graph of the correspondence analysis of the two mapped sections of Gd6 indicating grassland (blue squares) areas (*Cymbopogon pospschilii–Cotula hispida* community), and those that prefer rocky outcrops (pink circles) (*Erica woodii–Passerina montana* community).



Note: The green legend represents all the families that are not characteristic of the Fynbos or the Grassland. The orange indicates the families that are characteristic of the Fynbos, while the blue indicates the families that are characteristic of the Grassland. Families such as Asteraceae and Fabaceae occur as characteristic families in both the Fynbos and Grassland Biomes (according to Mucina & Rutherford 2006) and are therefore indicated in blue and orange.

FIGURE 5: Graph indicating the number of species found within each family during the study.

Fynbos is mostly dominated by ericoid shrubs that are fine-leaved, which include Ericaceae, Asteraceae, Rhamnaceae, Thymelaeaceae, Rutaceae, Restionaceae, and Proteaceae (Mucina & Rutherford 2006). Important families in the Cape Fynbos include Fabaceae, Iridaceae, Aizoaceae, Ericaceae, and Schrophulariaceae (Goldblatt & Manning 2000). However, when the families are ranked, the top 10 families include: Asteraceae, Fabaceae, Iridaceae, Ericaceae, Aizoaceae, Schrophulariaceae, Restionaceae, Proteaceae, Rutaceae, and Orchidaceae. Poaceae is ranked 11th among the families present in the fynbos (Manning & Goldblatt 2012). In Figure 5, the families in the orange legend represent those from the fynbos found in the study area.

Grasslands, however, are structurally simpler and mostly dominated by Poaceae. The three largest families in the Grassland Biome are Asteraceae, Poaceae and Fabaceae (Retief & Meyer 2017). In Figure 5, the families coloured in blue represent those from the grassland found in the study area.

Asteraceae and Poaceae are regarded as the two largest plant families on Platberg and are also common in the DAC (Carbutt & Edwards 2001). These two families are the most prominent within the study area. Although Poaceae and Cyperaceae dominate the grasslands, when it comes to the Fynbos biome, this environmental and floristic position is filled by Restionaceae. The dominance of Poaceae and Cyperaceae is also evident in our study. We can therefore say that the combination of families found in this study is a further indication that there are fynbos elements within the grassland.

Conclusion

The study aimed to determine the community composition of the Drakensberg-Amathole Afromontane Fynbos within Golden Gate Highland National Park (GGHNP) as mapped by Mucina and Rutherford (2006) and proposed by Du Preez (2017). Two different communities were found. One community preferred rocky outcrops with cracks and crevices, while the other community was restricted to the grassland with most likely deeper soils. In this study, there were no differences found between the communities in the polygons of Mucina and Rutherford (2006) and those of Du Preez (2017). We can, therefore, say that there is no discrepancy between the mappings of these two researchers and suggest that their polygons be combined to extend the current area of Gd6 to include both in the study area. Although Daemane et al. (2022) indicated that Gd6 was not very prominent in the park GGHNP, we found it extensively in the study area. Our findings are supported by the presence of characteristic species indicated in the phytosociological table (Table 1-A1) as well as the presence of various families from both the Fynbos and Grassland Biomes. We are also of the opinion that the communities found represent a more natural expression of the vegetation type because they are in a national park with less anthropogenic influence compared to instances of the vegetation type outside GGHNP. Therefore, the information from this study can be used as baseline data for a more detailed description of Gd6 in the national classification system, which seeks to describe our best approximation of an unmodified form of each type. Future research on this vegetation type should focus more on the effects of environmental factors on the vegetation. These descriptors of a type are essential to build our understanding of functional models of ecosystem types as described by the International Union for Conservation of Nature (IUCN) Global Ecosystem Typology (eds. Keith et al. 2020), to which South Africa is subscribed. Researchers can look at the plant-soil interactions as well as the effect of above- and below-average rainfall. The effects of fire on the vegetation can also be investigated.

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Competing interests

The first author, J.V.S. received the Joan Wrench Scholarship from SANBI to work on vegetation related to Fynbos, which in this case was the Drakensberg-Amathole Afromontane Fynbos. This Scholarship was to complete her Masters at the University of the Free State. They have disclosed those interests fully and have in place an approved plan for managing any potential conflicts arising from that involvement.

Authors' contributions

J.V.S. was responsible for conducting fieldwork, data collection and analysis of the data. A.C.v.A. (partly) contributed to the analysis of the data. A.C.v.A. assisted in the choice of methodology and study area. A.D. contributed to the improvement of the maps by Du Preez and Mucina and Rutherford. All authors contributed equally to the writing of the manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author, A.C.v.A. upon reasonable request.

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