Plant endemism in Griqualand West, South Africa

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Highlights

- Twenty-two species have their distribution ranges restricted to the Griqualand West region, representing 1.4% of the region's flora.
- The presence of the hypothesized Griqualand West Centre of plant endemism is confirmed.
- Many GWC endemics show indications of holo-endemism owing to their preference for the Ca-rich substrates of the Ghaap Plateau.
- This study proposes the concept of ‘core area’ which highlights the area with the highest endemic plant density.

Abstract

Griqualand West, a region in the semi-arid Northern Cape and North-West provinces of South Africa, has been variously suggested to contain a number of range-restricted plant species, and was proposed to be a local centre of plant endemism. The Griqualand West Centre (GWC), hitherto demarcated by geological features and limited floristic data, is hereby investigated to determine the true levels of endemism and its extent of occurrence. Findings suggest that at least 23 plant species have their natural distribution ranges restricted to the Griqualand West region. These endemics represent 1.4% of the region’s flora. Although this is a lower than the predicted level of endemism, it matches the trends of endemicity found in other centres in semi-arid savanna of southern Africa. Many of the GWC endemics show indications of holo-endemism owing to their apparent preference for the Ca- and Mg-rich substrates of the Ghaap Plateau. When the total distributions of all GWC endemic species are considered, then the resulting boundary of the GWC is more extensive than the substantial area already proposed previously (>40 000 km^2). This study therefore proposes the concept of 'core area' in which distant outlier populations of endemic species (>100 km outside the main distribution range with no suitable habitat in between) are discarded during the demarcation of the centre's boundary. It is proposed that this concept is best applied when assessing extensive areas with few endemic species. A more refined GWC core area will allow for more effective conservation and future research efforts by focussing attention on those areas where high numbers of endemic plant species co-occur. Within the GWC core area, specific regions, such as the increasingly densely populated Kimberley region, the banded ironstone hill ranges, and the unique environment that is the Ghaap Plateau, are highlighted as areas of conservation importance.

Keywords: centre of endemism; dolomite; endemic; Ghaap; ironstone; limestone; near-endemic.

1. Introduction

Worldwide, many vascular land plants exhibit total distributions that are restricted to small geographic regions (White, 1983; Van Wyk and Smith, 2001). In many cases, it has been noted that many restricted-range (endemic) plant species share a common geographical range (Jansson, 2003). Such regions are often referred to as local or regional "centres of plant endemism" (Van Wyk and Smith, 2001). Centres of endemism are of interest for a wide number of reasons, including, among others, directing conservation efforts (e.g. Anderson, 2002), understanding plant gene-flow and speciation (Ellstrand 1992; Anderson et al., 2001), and assessing the potential impacts of climate change on endemic plant diversity (Loarie et al., 2008; Dirnböck et al., 2011). In the diverse botanical region of southern Africa, various centres of plant endemism have been identified or proposed (e.g. Van Wyk, 1996; Siebert et al., 2002; Clark et al., 2009; Williamson and Balkwill, 2015; Hahn, 2017). Most of these are associated with the Great Escarpment of southern Africa (Clark et al., 2011).

One region of semi-arid savanna in north-central South Africa not associated with the escarpment, known as Griqualand West, has been noted as botanically diverse and rich in endemic plants (Wilman, 1946; Acocks, 1988). Despite these reports, the patterns of floristic diversity in Griqualand West are poorly known because of a sparsity of plant collections. Van Wyk and Smith (2001) tentatively proposed that the region may be a local centre of plant endemism, namely the Griqualand West Centre (GWC). This proposal was made in light of the apparent presence of 40 range-restricted plant species in the region, representing approximately 2.2% of the region's flora (Van Wyk and Smith, 2001). Another factor that lead to the proposal was Griqualand West's diverse geology – a factor often known to be associated with higher levels of plant endemism around the world (Kruckeberg and Rabinowitz, 1985) and specifically in southern Africa (Wild, 1965; Siebert et al., 2001; Williamson and Balkwill, 2015). However, as no phytogeographic study had been conducted on the plants of Griqualand West, the possible presence of a centre of plant endemism in the region has remained questionable. To address this shortcoming, this study attempted to collate the known plant collections from the Griqualand West region to test the validity of the proposed centre of endemism by analysing endemic plant distributions, the GWC's proposed borders and levels of floristic endemism. Such a study is crucial for the region from a conservation perspective, as it is inadequately conserved, and under great pressure from widespread mining activities which focus primarily on limestone, manganese ore and ironstone deposits.

2. Materials and method

2.1 Study area

Griqualand West covers an area of around 40 000 km^2, and is located in north-central South Africa, primarily in the Northern Cape, but also extending into parts of North-West. Griqualand West was inhabited by the Khoesaan from at least the Late Iron Age (Coon and Hunt, 1965). The region is named after a Khoekhoe people inhabiting this area, namely the Griqua (Van Wyk and Smith, 2001). The Griqua were semi-nomadic tribes with a diverse heritage including Dutch, Tswana, Khoekoe and San people (Penn, 2005).

The topography of Griqualand West is made up of undulating landscapes with higher and lower-lying areas. The eastern-central part of Griqualand West is an extensive flat plateau approximately 130 km wide and 280 km long, known as the Ghaap Plateau (± 1 450 m a.s.l.). It comprises primarily of dolomite and associated Ca-rich sediments. The western-central section of the Griqualand West has a number of low mountain ranges and hills cutting through the region from north to south, most prominent of which are the quarzitic Langberg (± 1 800 m a.s.l.) and the banded ironstone of the Kuruman (± 1 835 m a.s.l.) and Asbestos Hills (± 1 200 m a.s.l). The longest of these ranges is the Langberg stretching some 130 km (Raper et al., 2014). Large intermontane valleys are filled with aeolian Kalahari sands.

Table 1.

Selected climate variables illustrating the gradient from east to west and north to south in Griqualand West.

Region	Geographic regions	Mean annual precipitation (mm)	Mean annual temperature (°C)	Mean annual frost days (< 0°C)	Mean annual soil moisture stress (%)
Ghaap Plateau	Eastern	411	17.1	42	83
Ironstone Hills	Central	370	17.1	38	84
Langberg	Western	292	17	35	84
Above combined	Southern	358	17	38	84
Kalahari sands	Northern	262	18.4	27	86

Griqualand West is classified as a semi-arid region (Fischer and Turner, 1978), with an average annual rainfall ranging from 262 to 411 mm from west to east, most of which falls in the summer months (Table 1). The low and erratic rainfall means that Griqualand West has few perennial rivers. The most prominent is the Orange River, which originates in higher rainfall areas to the southeast and forms the southern and south-western boundary of Griqualand West. Many smaller rivers and tributaries in the region remain dry for many months, or in extreme droughts, years at a time. The mean annual temperature of Griqualand West is around 17–18 °C (Table 1). However, mean maximum and minimum temperatures of higher lying areas and mountain ranges are cooler than surrounding lower-lying Kalahari sands in both summer and in winter (Mucina and Rutherford, 2006). Thus, the mountain ranges and, most prominently the elevated Ghaap Plateau, have a cooler climate.

The vegetation of Griqualand West can be broadly described as Savanna, specifically forming part of the Eastern Kalahari Bushveld Bioregion (Mucina and Rutherford, 2006). The Savanna Biome is characterized by an herbaceous ground layer dominated by forbs and grasses, and a scattered upper layer comprising of woody vegetation. Some of the important grass species in Griqualand West include *Aristida canescens* Henrard, *A. congesta* Roem. & Schult., *Brachiaria nigropedata* (Ficalho & Hiern) Stapf, *B. serrata* (Thunb.) Stapf, *Cymbopogon pospischilli* (K.Schum.) C.E.Hubb., *Digitaria eriantha* Steud., *Enneapogon cenchroides* (Licht. ex Roem. & Schult.) C.E.Hubb., *Eragrostis cylindriflora* Hochst., *E. superba* Peyr., *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult., *Melinis repens* (Willd.) Zizka and *Themeda triandra* Forssk. (Mucina and Rutherford, 2006). Important forb species include *Barleria macrostegia* Nees, *Dicoma capensis* Less., *Harpagophytum procumbens* (Burch.) DC. ex Meisn., *Helichrysum cerastioides* DC., *Hermannia tomentosa* (Turcz.) Schinz ex Engl., *Hermbstaedtia odorata* (Burch. ex Moq.) T.Cooke, *Hibiscus* *marlothianus* K.Schum. and *Jamesbrittenia aurantiaca* (Burch.) Hilliard (Mucina and Rutherford, 2006). Important woody species include *Boscia albitrunca* (Burch.) Gilg & & Benedict, *Dichrostachys cinerea* (L.) Wight & Arn., *Ehretia rigida* (Thunb.) Druce, *Euclea crispa* (Thunb.) Guerke, *Grewia flava* DC., *Gymnosporia buxifolia* (L.) Szyszyl., *Olea europaea* L., *Searsia lancea* (L.f.) F.A.Barkley, *Senegalia caffra* (Thunb.) P.J.H. Hurter & Mabb., *S. mellifera* (Benth.) Seigler & Ebinger, *Tarchonanthus camphoratus* L., *Vachellia erioloba* (E.Mey.) P.J.H. Hurter, *V. karroo* (Hayne) Banfi & Galasso, *V. tortilis* (Forssk.) Banfi & Galasso and *Ziziphus mucronata* Willd. (Mucina and Rutherford, 2006).

2.2 Assessment of endemicity

A list of plant taxa potentially endemic or near-endemic to the Griqualand West region was compiled from various sources (Supplementary Table 1), including Wilman (1946), Acocks (1988), Van Wyk and Smith (2001), Germishuizen and Meyer (2003), and Mucina and Rutherford (2006). Additionally, all published volumes of the Flora of southern Africa (e.g. Codd, 1985) were consulted to identify plant taxa with distributions centred in the Griqualand West region. The resulting list comprised 85 taxa considered as potentially endemic to the Griqualand West region. Distribution data of these species were supplemented with specimen data housed in herbaria with substantial collections from the Griqualand West region, namely A.P. Goossens Herbarium (PUC), Geo Potts Herbarium (BLFU), McGregor Museum Herbarium (KMG), National Museum Herbarium (NMB), Pretoria National Herbarium (PRE) and the South African National Parks Herbarium (KSAN). Fuzzy Gazetteer (Kohlschuetter, 2003) was used to clarify descriptive locality records. Information regarding the substrate and geology on which specimens were collected was recorded from herbarium sheets.

Once all available locality data were collected for each of the potential endemic taxa, the distribution of each species was mapped with ArcGIS (ESRI, 2011). GPS records were limited and therefore the quarter-degree-grid (QDG: ca. 675 km^2) system was often applied for mapping purposes.

Assessing the resulting distribution maps and identifying taxa endemic to the Griqualand West region was based on "Intuitive discernment" (Rosen, 1988). Species were regarded as endemic if their distributions were centered (Fig. 1a) over the GWC boundaries proposed by Van Wyk and Smith (2001). These boundaries were based on underlying geology and used as a reference point for the position of the GWC. Distributions beyond these boundaries in Griqualand-West did not disqualify endemicity. A near-endemic was defined as a taxon with a distribution centered over the GWC boundaries proposed by Van Wyk and Smith (2001), but with a population or populations disjunct in other centres of endemism (Fig. 1b). Floristic elements were regarded as taxa with a high density of locality records in the Griqualand West region, but with sparse distributions elsewhere in southern Africa (Fig. 1c).

All taxa with distributions adjudged to not belong to one of the three afore-mentioned categories were discarded (Fig. 1d).

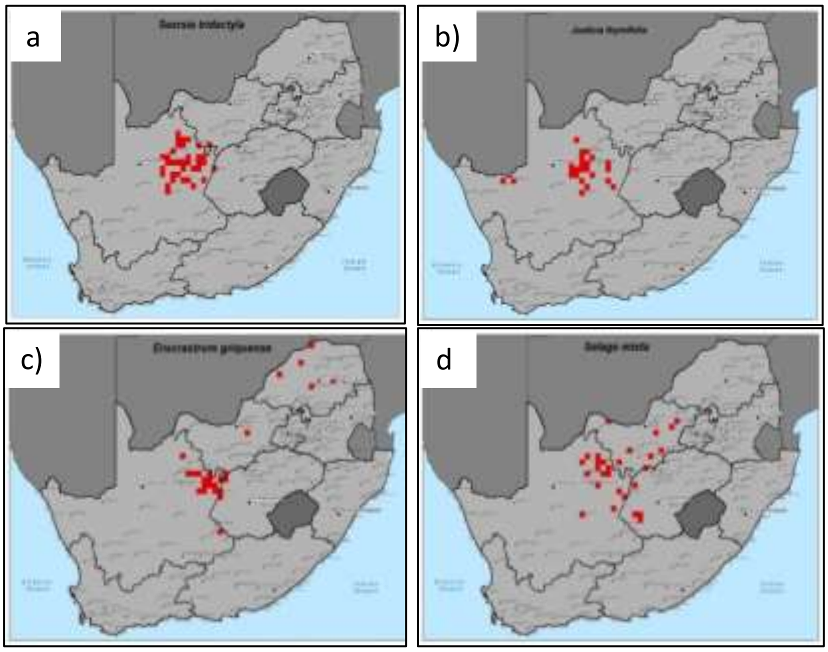

Figure 1: Mapping criteria. a) Endemic: centered and restricted distribution in Griqualand West; b) Near-endemic: distribution shared between Griqualand West and another recognized centre of endemism (Gariep Centre in this case); c) Floristic element: widespread with a clear clustering in Griqualand West, but sparse occurrences beyond its boundaries, and d) Widespread and not endemic.

2.3 Mapping the GWC

The distributions of the endemic and near endemic taxa identified in section 2.2 were overlaid using ArcGIS (ESRI, 2011) to create a quarter-degree-grid distribution map. All grids containing at least one of the 21 endemic species were incorporated into the definition of the GWC's extent of occurrence. The outermost grids in all cardinal directions in which an endemic occurs were taken as the border of the GWC. This border was smoothed to follow the geology of the area and to reflect a more likely natural distribution of endemic species.

2.4 Comparison with other centres

Species lists were obtained for the quarter-degree grids (QDGs) in which the GWC is located from BODATSA (Ranwashe, 2015). These lists were supplemented with herbarium records obtained in section 2.2. The ratio between number of endemic taxa and total number of species occurring in the GWC QDG's was calculated to determine the level of endemism for the centre. The relationship between total number of species comprising its flora, and the number of endemic species was tested using R statistical software (R Core Team, 2016) for all 18 southern African centres, by utilizing Spearman's rank correlation coefficient. As there was a large correlation, it was possible to do a weighted regressions also using R statistical software (R Core Team, 2016) for all 18 centres by comparing the total number of species against the number of endemics. This was done for both the untransformed and the natural log (ln) transformed data.

2.5 Core area concept

The GWC borders were further refined by excluding grids in which there were less than three records of endemic species. Cross checks confirmed that where two or less endemics were present in a grid that they occurred in areas bordering outlying geological features of the GWC and that the majority of the grid would not harbor appropriate habitat. This exclusion of grids allowed for more accurate demarcation of the core area of the GWC in which the density of endemic taxa was the highest. Outer grids of the refined area were again taken as the outer border of the GWC.

3. Results and Discussion

3.1 Floristic elements

The distributions of the identified floristic elements indicated links to both the Nama-Karoo and Savanna Biomes. Eight taxa extend from GWC to the Nama Karoo Biome and are as follows: *Aizoon asbestinum* Schltr. (succulent forb), *Digitaria polyphylla* Henrard (grass), *Eragrostis macrochlamys* Pilg. var. *wilmaniae* (C.E.Hubb. & Schweick.) De Winter (grass), *Euphorbia wilmaniae* Marloth (succulent forb), *Indigofera damarana* Merxm. & A.Schreib. (forb), *Pharnaceum viride* Adamson (forb), *Stachys burchelliana* Launert (forb) and *Titanopsis calcarea* (Marloth) Schwantes (succulent forb). The strongest link seems to lie in the Poaceae and succulent forb species. This link may be explained by the relatively arid climate of the Nama Karoo and the adaptability shown by these drought tolerant grasses and succulents to such conditions in GWC (Blake and Jordan, 1993).

Sixteen floristic elements have shared distributions extending from GWC to the broader Savanna Biome and are as follows: *Carex burchelliana* Boeck. (forb), *Corchorus pinnatipartitus* Wild (forb), *Crotalaria griquensis* Bolus (forb), *Ebracteola wilmaniae* (L.Bolus) Glen (forb), *Erucastrum griquense* (N.E.Br.) O.E.Schulz (forb), *Euphorbia bergii* A.C.White, R.A.Dyer & B.Sloane (succulent forb), *Euphorbia duseimata* R.A.Dyer (succulent forb), *Helichrysum spiciforme* DC. (forb), *Ipomoea suffruticosa* Burch. (forb), *Jamesbrittenia albiflora* (Verd.) Hilliard (forb), *Lotononis crumanina* Benth. (forb), *Pentzia oppositifolia* Magee (forb), *Selago mixta* Hilliard (forb), *Sesbania notialis* J.B.Gillett (forb), *Sutera griquensis* Hiern (forb) and *Triaspis hypericoides* Burch. (forb). The floristic link is forb dominated by members of the Fabaceae and Scrophulariaceae, and to a lesser extent by the Asteraceae and Euphorbiaceae. The dominance of the Fabaceae is largely expected for areas containing ironstone (Gibson et al., 2010) and it is also the most dominant family in the Savanna Biome within which the GWC lies. The observed link with the Scophulariaceae may potentially be a result of the complex geology of the region and the observed occurrence of members of this family occurring as endemics in geologically defined centres (Allison and Stevens, 2001; Siebert et al., 2001).

3.2 Endemic and near-endemic taxa

Of the 86 taxa that were potentially endemic to the GWC (Supplementary Table 1), 36 were discarded due to unfitting distributions, nomenclatural changes or a lack of data, and 26 taxa were found to be floristic elements of the GWC. Twenty-two taxa were found to be endemic to the GWC, and two near-endemic. The distributions of the 22 endemics and two near-endemics (Fig. 1, suppl. data) were roughly centered in the GWC boundaries of Van Wyk and Smith (2001). These GWC endemics are as follows (arranged alphabetically by family, then by species):

Acanthaceae

- ***Barleria media*** C.B.Clarke in Fl. Cap. 5(1): 51 (1901). Type: South Africa, Kalahari region, Bechuanaland [Griqualand West], on the rocks at Chue Vley, Oct 1812, *Burchell 2386* (K, holo.). Perennial forb (0.05-0.1 m) assessed as Vulnerable (Raimondo et al., 2009) and found on the Ghaap Plateau, Kuruman Hills and in river valleys in the Northern Cape and North-West (Obermeyer, 1933).
- ***Blepharis marginata*** (Nees) C.B.Clarke in Fl. Cap. 5(1): 29 (1901); *Acanthodium marginatum* Nees in Prodr. 11: 275 (1847). Type: South Africa, Hay division, Griqualand West, Griqua Town [Griquatown], *Burchell 1902* (G-DC, holo; K, PRE, iso.). Dwarf shrub (0.05-0.1 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and in river valleys in the Northern Cape (Vollesen, 2000).
- ***Glossochilus burchellii*** Nees., in Prodr. 11: 83 (1847). Type: Griqualand West, Hay Division, plains between Griqua Town [Griquatown] and Witte Water, *Burchell 1976.* Bechuanaland [Griqualand West]; near Kuruman, near the source of Kuruman river, *Burchell 2471* (K, syn.). Perennial forb (0.05-0.2 m) found on the Ghaap Plateau, Kuruman Hills and Asbestos Hills in the Northern Cape (Clarke, 1901).
- ***Justicia puberula*** Immelman, FSA 30 (3:1): 33 (1995); *Justicia parvibracteata* Immelman, Bothalia 16(1): 39 (1986). Type: South Africa, Cape Province [Northern Cape], 11 miles NNW of Olifantshoek, in Toto Mountains, kloof, in rock crevices and under shrubs, *Tölken & Schlieben 1176* (PRE, holo.). Dwarf shrub (0.15-0.5 m) found

on the Ghaap Plateau, Kuruman Hills, Langberg and in river valleys in the Northern Cape (Immelman, 1995).

- ***Justicia thymifolia*** (Nees) C.B.Clarke in Fl. Cap. 5(1): 64 (1901); *Adhatoda thymifolia* Nees in Prodr. 11: 392 (1847). Type: South Africa, Kalahari region, Hay division, Griqualand West, between Griquatown and Spuigslang, *Burchell 1702* (K, lecto. designated by Immelman (1995); PRE photo). Shrub (0.35-1.75 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and in river valleys in the Northern Cape (Immelman, 1995).

Aizoaceae

- ***Antimima lawsonii*** (L.Bolus) H.E.K.Hartmann, Bothalia 28(1): 74 (1998); *Mesembryanthemum lawsonii* L.Bolus, Ann. Bolus Herb. 4: 85 (1927). *Ruschia lawsonii* (L.Bolus) L.Bolus, Notes Mesembryanthemum: 219 (1950). Type: South Africa, Hay district, Papkuil, Aug 1912, *Lawson 18551* (BOL, holo.). Perennial succulent forb (0.1-0.25 m) found on the Asbestos Hills, Ghaap Plateau and Kuruman Hills in the Northern Cape (Hartmann, 1998).
- ***Hereroa wilmaniae*** L.Bolus, Notes Mesembryanthemum 2: 82 (1929). Type: South Africa, Griqualand West, near Dunmury, Oct 1922, *Wilman 17264* (BOL, lect. designated by Hartmann 2001). *Prepodesma uncipetalum* N.E.Br. in Gard. Chron. 3(89): 389 (1931); *H. uncipetala* (N.E.Br.) L.Bolus, Notes Mesembryanthemum 3: 135 (1938). Type: South Africa, Griekwaland West, Campbell, *Pole Evans 6891* (K, holo.). *H. wilmaniae* L.Bolus var. *langebergenesis* L.Bolus, Notes Mesembryanthemum 2: 82 (1929a). Type: South Africa, Langeberg [Langberg], Mar 1923, *Wilman 17352* (BOL, holo.). Perennial succulent forb (0.05-0.1 m) assessed as Rare (Raimondo et al., 2009) and found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and river valleys in the Northern Cape (Hartmann, 2001).
- ***Lithops aucampiae*** L.Bolus **subsp. *euniceae*** (de Boer) D.T.Cole, Lithops: Flowering Stones: 220 (1988). *L. aucampiae* L.Bolus var. *euniceae* de Boer in Succulenta 45(4): 491 (1966).Type: South Africa. Northern Cape, 13 km north of Hopetown, *Cole 48* (PRE, holo.). *L. aucampiae* L.Bolus var. *fluminalis* D.T.Cole, Natl. Cact. Succ. J., 25: 8 (1970); *L. aucampiae* L.Bolus ssp. *euniceae* (de Boer) D.T.Cole var. *fluminalis* D.T.Cole, Lithops: Flowering Stones: 220 (1988).Type: South Africa, Hopetown, 21 July 1968, *Cole 54* (PRE, iso.). Perennial succulent forb (0.02 m) assessed as Vulnerable (Raimondo et al., 2009) and found on the Asbestos Hills and river valleys in the Northern Cape. (Hartmann, 2001).

- ***Lithops bromfieldii*** L.Bolus, Notes Mesembryanthemum 2: 452 (1934). Type: South Africa, Gordonia division, Upington, *Bromfield 2286/33* (BOL, holo.). *L. glaudinae* de Boer, Succulenta: 129 (1960); *L. bromfieldii* L.Bolus var. *glaudinae* (de Boer) D.T.Cole, Excelsa 3: 50 (1973). Type: South Africa, Glen Lyon, Matsap, *Cole 116* (PRE). *L. insularis* L.Bolus, Notes Mesembryanthemum 3: 75 (1937); *L. bromfieldii* L.Bolus var. *insularis* (L.Bolus) B.Fearn, Cact. Succ. J. 42: 92 (1970). Type: South Africa, Kamies, 5 miles N of Orange River Bank, 23 miles SW of Upington Station, *Wilmot 1353/34* (BOL, holo.). *L. mennellii* L.Bolus, Notes Mesembryanthemum 3: 75 (1937); *L. bromfieldii* L.Bolus var. *mennellii* (L.Bolus) B.Fearn, Cact. Succ. J. 42:92 (1970). Type: South Africa, Gordonia division [Griqualand West], *Mennell 645/34* (BOL, holo.). Perennial succulent forb (0.03 m) found in the Langberg region in the Northern Cape (Hartmann, 2001).
- ***Lithops lesliei*** (N.E.Br.) N.E.Br. **subsp. *burchellii*** D.T.Cole, Lithops: Flowering Stones: 217 (1988). Type: South Africa, Cape Province, Postmasburg, NE of Douglas, in calcrete, *Cole 302* (PRE, holo., iso.). Perennial succulent forb (0.01 m) assessed as Near Threatened (Raimondo et al., 2009) and found on the Asbestos Hills and Ghaap Plateau of the Northern Cape (Hartmann, 2001).
- ***Prepodesma orpenii*** (N.E.Br.) N.E.Br. in Gard. Chron. 3(89): 389 (1931). *Mesembryanthemum orpenii* N.E.Br. Gard. Chron. 3(70): 303 (1921); *Aloinopsis orpenii* (N.E.Br.) L.Bolus in S. African Gard. 19: 288 (1929); *Nananthus orpenii* (N.E.Br.) L.Bolus, Notes Mesembryanthemum 3: 133 (1938). Type: South Africa, Griqualand West, discovered by Mr Redmond Orpen at Campbell, *Pole Evans 6910* (K, holo.). *Rabiea tersa* N.E.Br., Gard. Chron. 3(89): 54 (1931); *Nananthus tarsus* (N.E.Br.) G.D.Rowley, Natl. Cact. Succ. J., 33(1): 6 (1978). Type: South Africa, Northern Cape Province, Kuruman, *Pole Evans 7623* (K, holo). Perennial succulent forb (0.05 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills and Langberg in the Northern Cape (Hartmann, 2001).

Anacardiaceae

- ***Searsia tridactyla*** (Burch.) Moffett in Bothalia, 37(2): 173 (2007); *Rhus tridactyla* Burch., Trav. S. Africa, 1: 340 (1822). Type: South Africa, Northern Cape, Asbestos Mountains, 27 Sep 1811, *Burchell 1667* (K, holo.; BOL, iso.). Large shrub (0.5-4 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and in river valleys in the Northern Cape (Moffett, 1993).

Asteraceae

- ***Amphiglossa tecta*** (Brusse) Koek. in Bothalia 29(1): 72 (1999); *Pterothrix tecta* Brusse in Bothalia 20(1): 67 (1990). Type: South Africa, Northern Cape, Hay district, Witsand [Witsand Nature Reserve], some 70 km SW of Postmasburg, farm Witsand 250, approximately 2 km W of Doornaar homestead, 26 Nov 1989, *Brusse 5629* (PRE, holo.; AD, B, BAF, BH, BM, BOL, BR, BRI, C, CAN, CANB, COI, E, EA, G, GH, GRA, HBG, J, K, L, LD, LG, LISU, LMA, M, MEL, MO, NBG, NH, NSW, NU, O, P, R, S, SRGH, U, UC, UPS, US, W, WAG, WIND, Z, iso.). Dwarf shrub (0.3-0.6 m) assessed as Critically Rare (Raimondo et al., 2009), found along the Asbestos Hills, Langberg and Ghaap Plateau in the Northern Cape (Koekemoer, 1999).
- ***Cineraria exilis*** DC. in Prodr. 6: 305 (1838) Type: South Africa, Vryburg division, at the source of the Moshaweng River near Takun, 27 Sept 1812, *Burchell 2274* (G-DC, holo.; K, iso.). Perennial forb (0.15 m) found on the Ghaap Plateau and Kuruman Hills in the Northern Cape and North-West (Cron et al., 2006).
- ***Dicoma kurumanii*** S.Ortiz & Netnou in Bot. J. Linn. Soc. 147(4), 510 (2005). Type: South Africa, Northwest Province, Kuruman District, top of Ga Mhana Peak, 11 Feb 1886, *Marloth 1103* (NBG, holo.; K, PRE, iso.). Dwarf shrub (0.5 m) found on the Ghaap Plateau and Kuruman Hills in the Northern Cape (Ortiz and Netnou, 2005)
- ***Eriocephalus ericoides*** (L.f.) Druce **subsp. *griquensis*** M.A.N.Müll. in FSA 33(4:1): 49 (2001). Type: South Africa, Northern Cape, Herbert district, farm Eureka*, Acocks 8753* (BOL, holo.; PRE, iso.). *Kapokbos* is a dwarf shrub (0.3-1 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and in river valleys in the Northern Cape (Müller et al., 2001).
- ***Gnaphalium englerianum*** (O.Hoffm.) Hilliard & B.L.Burtt in Bot. J. Linn. Soc. 82(3): 193 (1981); *Amphidoxa engleriana* O.Hoffm. in Bot. Jahrb. Syst. 10: 274 (1889). Type: South Africa, Betschuanaland [Griqualand West], Kachun near Kuruman, 1200m, Feb 1886, *Marloth 1004* (BOL, PRE, SAM, iso.). Perennial semi-decumbent forb (0.1 m) found on the Ghaap Plateau, Kuruman Hills and in river valleys in the Northern Cape (Hilliard and Burt, 1981; Hilliard, 1983).
- ***Pentzia stellata*** (P.P.J.Herman) Magee in Bot. J. Linn. Soc. 178(4): 644 (2015)*; Rennera stellata* P.P.J.Herman in Bot. J. Linn. Soc. 129(4): 368 (1999). Type: South Africa, Northern Cape, Koopmansfontein Agricultural Research Station, 5 Mar 1998, *Herman 1482* (PRE, holo.; B, BM, C, E, J, G, K, KMG, M, MO, NBG, NMB, P, PRU, S, UPS, WAG, WIND, Z, iso.). Perennial forb (0.5 m) assessed as Near Threatened (Raimondo et al., 2009) and found on the Ghaap Plateau, primarily next to unweathered calcrete pans in the Northern Cape and North-West (Herman, 1999).

- ***Tarchonanthus obovatus*** DC., Prodr. 5: 431 (1836). Type: South Africa, Bechuanaland division [Griqualand West], Klipfontein, 19 Jun 1812, *Burchell 2155* (G-DC, holo.; GH, K, M, P, iso.). The Gordonia Camphor-Bush is a shrub (2 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and in river valleys in the Northern Cape (Herman, 2002).

Celastraceae

- ***Maytenus ilicina*** (Burch.) Loes., in Nat. Pflanzenfam., 2nd ed., 20b: 140 (1942); *Celastrus ilicinus*, Burch. Trav. S. Africa 1: 340 (1822); *Gymnosporia ilicina* (Burch.) Davidson in Bothalia 2: 296 (1927). Type: South Africa, Griekwaland West [Griqualand West], Asbestos mountains, *Burchell 1663* (K, holo.). The Gordonia Koko-Tree is a large shrub (3 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills and Langberg in the Northern Cape (Coates Palgrave, 2002).
- ***Putterlickia saxatilis*** (Burch.) Jordaan, in SAJB 64(6): 328 (1998); *Celastrus saxatalis* Burch., Trav. S. Africa, 2: 264 (1824); *Gymnosporia saxatalis* Davidson in Bothalia 2: 303 (1927). Type: South Africa, Asbestos mountains, Griqua Town [Griquatown], *Burchell 1671* (K, holo.). The Gordonia False-spikethorn is a shrub (1.5-2 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and valleys in the Northern Cape (Jordaan and Van Wyk, 1998).

Fabaceae

- ***Calobota cuspidosa*** (Burch.) Boatwr. & B.-E.Van Wyk, in SAJB 75(3): 553 (2009); *Spartium cuspidosum* Burch., Trav. S. Africa 1: 348 (1822). Type: South Africa, Northern Cape, between ‘Gatikamma’ and ‘Klaarwater’ [Griquatown], *Burchell 1697* (K, holo.). *Lebeckia macrantha* Harv. in Fl. Cap. 2: 83–84 (1862). Type: South Africa, without precise locality, ‘Zooloo country’, *Miss Owen s.n*. (TCD, photo.). The Griqualand Porcupine Bush is a shrub (1.5-4 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills, Langberg and valleys in the Northern Cape (Boatwright et al., 2018).

Poaceae

- ***Brachiaria dura*** Stapf. **var. *pilosa*** J.G.Anderson in Kirkia I: 104 (1960–1961). Type: South Africa, Hay division, Witsand [Witsand Nature Reserve], at foot of dunes, Apr 1940, *Esterhuysen 2269* (PRE, holo.; K, iso.). Perennial grass (0.5-1.3 m) found in the Langberg region in the Northern Cape (Fish et al. 2015).

Stilbaceae

- ***Nuxia gracilis*** Engl., in Bot. Jahrb. Syst. 10: 243 (1888); *Lachnopylis gracilis* (Engl.) C.A.Smith, Bull. Misc. Inform. Kew 1930(1): 17 (1930). Type: South Africa, Hay division, Klein Boetsap, Feb 1886, *Marloth 980* (PRE, lecto. designated by Leeuwenberg (1975); K, PRE iso.). The Sticky Nuxia is a shrub (1.5-4 m) found on the Asbestos Hills, Ghaap Plateau, Kuruman Hills and valleys in the Northern Cape (Leeuwenberg, 1975).

3.2 Phytogeographic patterns and geographical affinities of GWC endemics

Some of the GWC endemics are very rare, known from only a small region or a few localities such as the forbs *Amphiglossa tecta*, *Dicoma kurumanii* and *Gnaphalium englerianum*, and the cryptic succulents *Lithops aucampiae* subsp. *euniceae* and *Lithops lesiei* subsp. *burchellii* (Fig. 1, suppl. data). There are also a number of GWC endemics that are widely distributed throughout most of the centre. These specifically include the shrubs *Calobota cuspidosa*, *Putterlickia saxatilis*, *Searsia tridactyla* and *Tarchonanthus obovatus*. The two near-endemics, *Justicia thymifolia* and *Nuxia gracilis*, indicate links with two other centrs of endemism, namely Gariep (Jürgens, 1991, Van Wyk and Smith, 2001) and Sekhukhuneland (Siebert et al., 2002) respectively. In the GWC, the Asteraceae (seven species) and Aizoaceae (six species) contributed the most endemics, with the Acanthaceae (five species) also making a contribution with these three families contributing 18 of the 24 endemic and near-endemic taxa. The Asteraceae is diverse in southern Africa (McKenzie and Barker, 2008) and one of the most dominant families in the GWC, possibly explaining the high number of endemics associated with it. Dolomitic areas are often characterized by endemics in the Asteraceae (Allison and Stevens, 2001). The large number of endemics in the Aizoaceae may be partially explained by the arid nature of the centre and the succulence of the endemics involved (Valente et al., 2013).

Only one of the 21 GWC endemics had a distribution that was restricted to the Nama-Karoo Biome in the southern extremity of the centre (Prieska region), namely *Lithops aucampiae* subsp. *euniceae* (Fig. 1, suppl. data). All the other endemics preferred the savanna areas which covers more than 95% of the GWC. However, as this region in the Nama-Karoo Biome was also host to numerous other GWC endemics, it was not excluded from the spatial definition of the centre. Floristically it fits with the southern part of the Ghaap Plateau (Frisby, 2016).

In three other centres of endemism in the Savanna Biome of South Africa, the two largest families with endemics were the Asphodelaceae and Asteraceae (Soutpansberg Centre; Hahn, 2017), the Araceae and Vitaceae (Sekhukhuneland Centre; Siebert et al., 2001), and the Asteraceae and Fabaceae (Barberton Centre; Williamson and Balkwill, 2015) respectively. The Asteraceae is one of the largest endemic-bearing families in three of the four Savanna centres of endemism, a trend that may be explained by the diversified nature of the Asteraceae in both southern Africa and the world. However the other largest endemic bearing families in four centres of endemism in the Savanna Biome are all different, indicating differing selective pressures along different phylogenetic lineages (Kessler, 2002).

The GWC can broadly be subdivided into four floristic regions based on geology, topography and the associated climatic variations (Frisby, 2016), namely the Ghaap Plateau (GP), Ironstone Hills (IH; Kuruman and Asbestos Hills), the Langberg (LB), and the low lying northern areas filled with Kalahari sands (KS). The substrate in the GWC which supports the most endemic and near-endemic species is the soils derived from calcrete, dolomite and limestone rocks of the GP. High biodiversity and endemism is globally well known for these types of habitats (Clements et al., 2006). Thus, the flora of the GWC appears to be strongly influenced by Ca- or Mg-rich substrates. This is evident when considering not only the presence of GWC endemics, but also that several known calcicoles (species adapted to grow on calcium-rich substrates) that are widespread in the arid regions of southern Africa, have abundant distributions in the GWC, namely *Bergia anagaloides*, *Eragrostis macrochlamys* var. *wilmaniae*, *Erucrastrum griquense*, *Justicia puberula*, *Lotononis crumaniana* and *Salvia namaensis* (Van Wyk and Smith, 2001). Of the 24 endemic and near-endemic species, nine show a specific preference to soils rich in calcium. Of these, *Nuxia gracilis* and *Pentzia stellata* appear to be edaphic specialists, having only been recorded occurring on Ca-rich soils. The former is a near-endemic known also from the Roossenekal-Steelpoort region in Sekhukhuneland Centre of Endemism. This is a widely disjunct distribution (± 700 km) between the two centers (Fig. 1, suppl. data), likely because of the presence of Ca-rich substrates and arid conditions in both (Van Wyk and Smith, 2001). The taxonomic status of the plants from Sekhukhuneland and the GWC, however, deserves closer scrutiny (see further on). *Pentzia stellata* occurs solely next to weathered calcrete pans. Twelve other GWC endemics also have part of their distributions occurring within the GP, suggesting that 20 of the 24 endemic/near-endemic taxa prefer the cooler and more mesic conditions of the plateau.

Twenty-one of the 24 endemics were recorded from the IH adjacent to the GP. Such patterns of endemism is well known for ironstone formations globally (Jacobi et al., 2007). Kuruman Hills hosts 18 of the GWC endemics, as the climate is similarly to GP more favorable than the rest of the GWC. Ironstone formations are also known for their specific plant-soil associations (Gibson et al., 2010). *Lithops aucampiae* subsp. *euniceae* is currently only known from the slightly drier Asbestos Hills in the southern part of the IH. Two GWC endemics have distributions restricted to the LB, namely *Lithops bromfieldii* and *Brachiaria dura* var. *pilosa*. Thirteen GWC endemics have at least part of their distributions within the LB. No GWC endemics have distributions restricted to the KS. Thirteen GWC endemics do have at least part of their distributions within the KS, although at low frequencies, probably as unfavorable arid conditions prevail here compared to the other regions.

The large numbers of GWC endemics that are restricted to or show distributional preference for the Ca-rich substrates of the GP indicate high levels of holo-endemism. However, it is likely that some of the GWC endemics are also either paleoendemics or neoendemics. The GWC near-endemic *Nuxia gracilis* is likely a paleoendemic. However, closer inspection of type specimens of this species may result in taxonomic differentiation between the two populations due to the large distance in between. The other GWC near-endemic, *Justicia thymifolia* is likely to be a paleoendemic due to the close proximity of the two populations.

The endemic shrubs tend to be distributed throughout the defined GWC, but succulents tend to be range restricted (Table 2). However, Van Wyk and Smith (2001) proposed that many plant taxa in the GWC may remain undescribed, largely due to the severe lack of botanical collections that have been made in the region, emphasising the need to further investigate the botanical diversity in Griqualand West to better understand the endemic flora.

Table 2.

Breakdown of endemism per region according to total, restricted range and growth forms of GWC endemics. The ironstone hills are subdivided into the northern Kuruman and southern Asbestos ranges.

Region	Number of GWC endemics	Restricted GWC endemics	Forbs (5)	Succulents (6)	Dwarf shrubs (5)	Shrubs (7)
Ghaap Plateau	21	1 forb	5	4	5	7
Ironstone Hills:	21	1 succulent	4	5	5	7
Kuruman hills	17	0	4	3	4	7
Asbestos hills	15	1 succulent	1	5	3	7
Kalahari sands	14	0	2	2	4	6
Langberg	14	1 succulent; 1 grass	1	3	4	6

3.3 Mapping the GWC boundary

Following the identification of the GWC endemic and near-endemic species, and overlaying all their distributions, new borders for the GWC are proposed (Fig. 2) by fitting boundaries to the outer grids in which GWC endemics were present. The resultant boundaries of the GWC based on the endemic distributions differ from that of Van Wyk and Smith (2001). The borders generated by the current study are significantly larger, having been extended most noticeably south, south-west and east towards Kimberley (Fig. 2), as the proposed endemics have a wider distribution than previously thought. The northern and eastern borders predicted by Van Wyk and Smith (2001) largely coincide with those of this study. This proposed region represents a noticeable transition from more elevated rocks of various sedimentary origins, to lower-lying patches of deep aoelian sand based on the habitat preferences of the GWC endemics. The expanded borders of the GWC proposed in this study are not clearly linked to any ecological regions which differ from the regions included in the GWC of Van Wyk and Smith (2001), barring the inclusion of some pockets of Nama-Karroo in the southern regions.

3.4 Comparison with other centres

The large size and lower than predicted level of endemism (1.4% versus 2.2% of Van Wyk and Smith (2001)) prompted a comparison between the total number of species and total number of endemic species identified from the new GWC borders with that of other recognized centres of plant endemism in southern Africa. As would be expected, a correlation (greater than 0.5) was found for the variables total number of species and total number of endemic species. The residual value for the GWC for the untransformed data (Fig. 3a) was not larger than 2 and is therefore not an outlier value for number of endemic taxa expected per total number of species on a 95% confidence interval. The residual value for the GWC for the natural log transformed data (Fig. 3b) remained below 2 and therefore shows the GWC to not be an outlier value for number of endemic taxa per total number of species on a 95% confidence interval. This result suggests that despite the large size and limited numbers of endemic species, the GWC suggested by this study falls within the current norms for

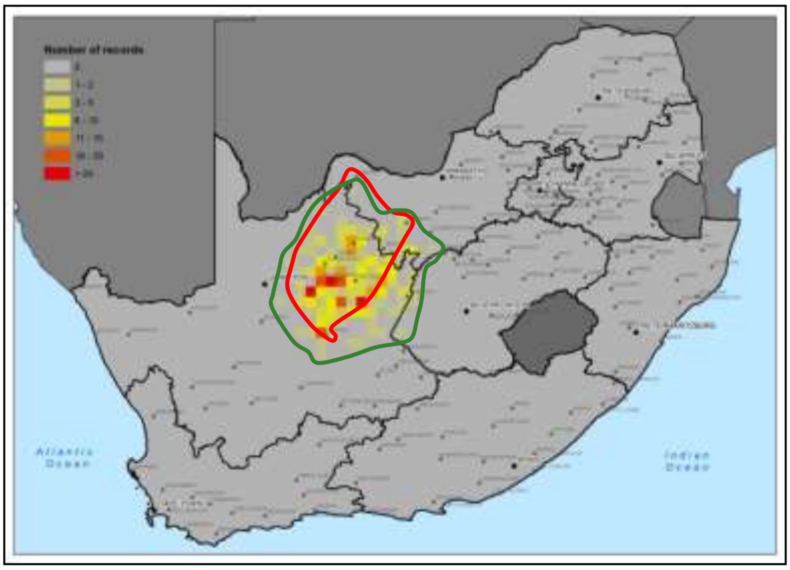

Figure 2: Combined distribution of GWC endemic and near-endemic species (24 taxa). The green polygon demarcates the total distribution of the endemic species. The red polygon represents the boundaries of the GWC as proposed by Van Wyk & Smith (2001).

recognizing centres of plant endemism based on its total species pool. Indeed similar trends were identified by Cowling and Hilton Taylor (1997) which showed a correlation between the size of an areas species pool and endemism levels in southern Africa. This seems to be often the case for centres of endemism in semi-arid savanna regions where endemism levels are dependent on the size of the species pool and not the area.

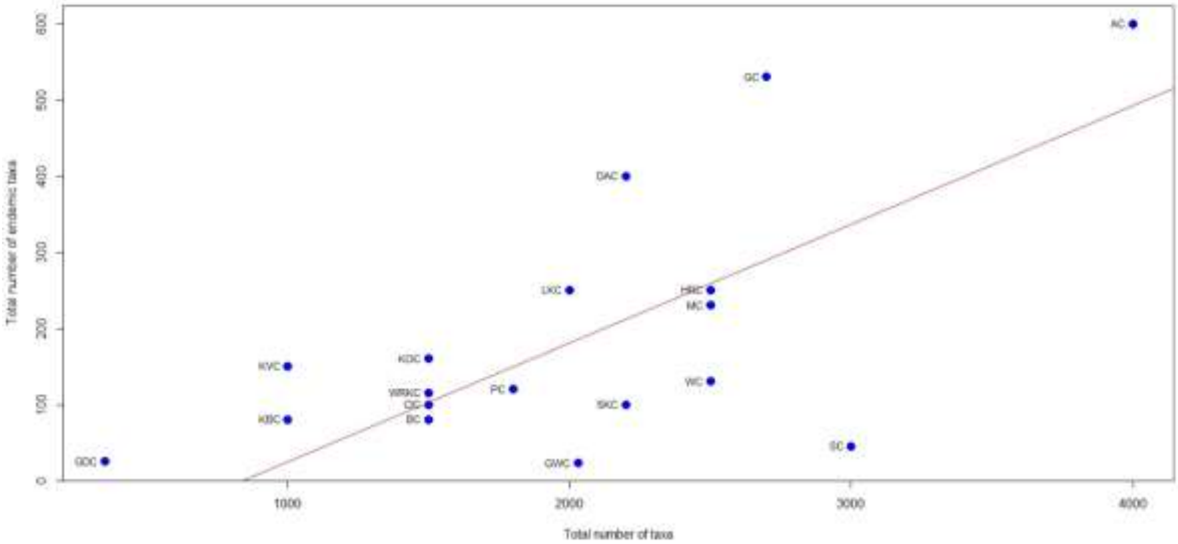

Figure 3a: Weighted regression of endemism and flora for 18 centres of endemism (Van Wyk & Smith, 2001). Albany Centre (AC); Barberton Centre (BC); Chimanimani-Nyanga Centre (CIC); Drakensberg Alpine Centre (DAC); Gariep Centre (GC); Great Dyke Centre (GDC); Griqualand West Centre (GWC); Hantam-Roggeveld Centre (HRC); Kamiesberg Centre (KBC); Kaokoveld Centre (KOC); Knersvlakte Centre (KVC); Little Karoo Centre (LKC); Maputaland Centre (MC); Pondoland Centre (PC); Soutpansberg Centre (SC); Sekhukhuneland Centre (SKC); Wolkberg Centre (WC); Worcester-Robertson Karoo Centre (WRKC).

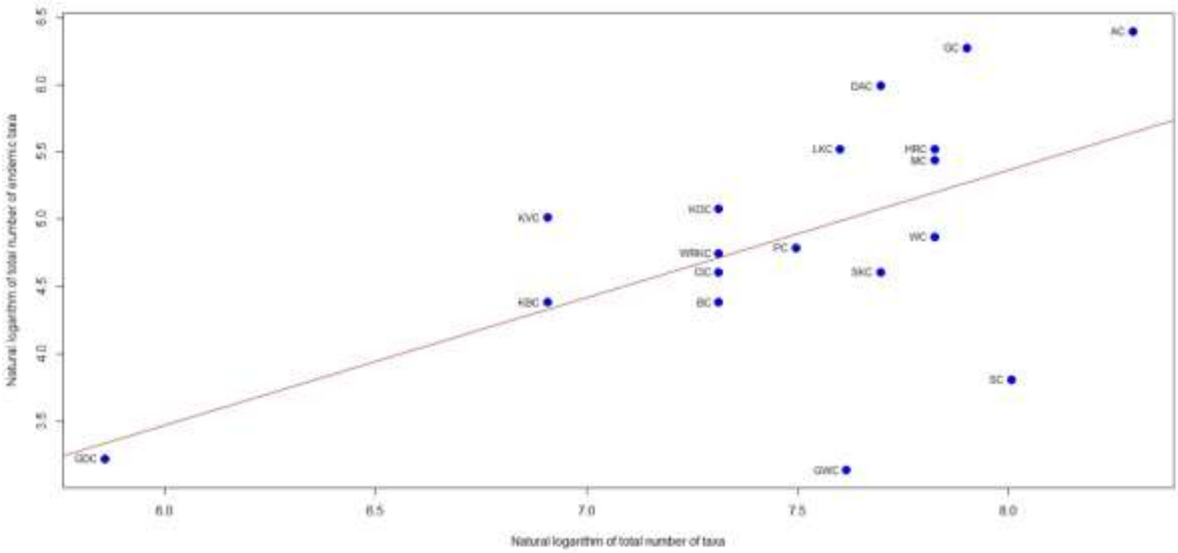

Figure 3b: Weighted regression of endemism and flora for 18 centres of endemism (Van Wyk & Smith, 2001) after natural log (ln) transformation. Albany Centre (AC); Barberton Centre (BC); Chimanimani-Nyanga Centre (CIC); Drakensberg Alpine Centre (DAC); Gariep Centre (GC); Great Dyke Centre (GDC); Griqualand West Centre (GWC); Hantam-Roggeveld Centre (HRC); Kamiesberg Centre (KBC); Kaokoveld Centre (KOC); Knersvlakte Centre (KVC); Little Karoo Centre (LKC); Maputaland Centre (MC); Pondoland Centre (PC); Soutpansberg Centre (SC); Sekhukhuneland Centre (SKC); Wolkberg Centre (WC); Worcester-Robertson Karoo Centre (WRKC).

3.5 Core area of the GWC

The newly proposed borders of the GWC (Fig. 2) was found to cover a very extensive area – larger than the borders proposed by Van Wyk and Smith (2001), and also harboring comparatively less endemics. As there was a clear increase of endemics per grid from the periphery to the core of the centre, it was decided to further explore the mapping of GWC to highlight those areas richest in endemics. No endemics with restricted range distribution occurred in the peripheral areas and were not excluded. The new GWC borders were therefore refined further by excluding grids harboring low levels of endemism (Fig. 4). The concept of 'core area' proposed by this study may be of use when working with large centres with few endemic species. The 'core area' of the GWC is based on high frequencies of records for the 22 endemic species. The core area coincides with the three most prominent geologies of the region, including the banded ironstone hills, quartzitic outcrops and the dolomitic Ghaap Plateau.

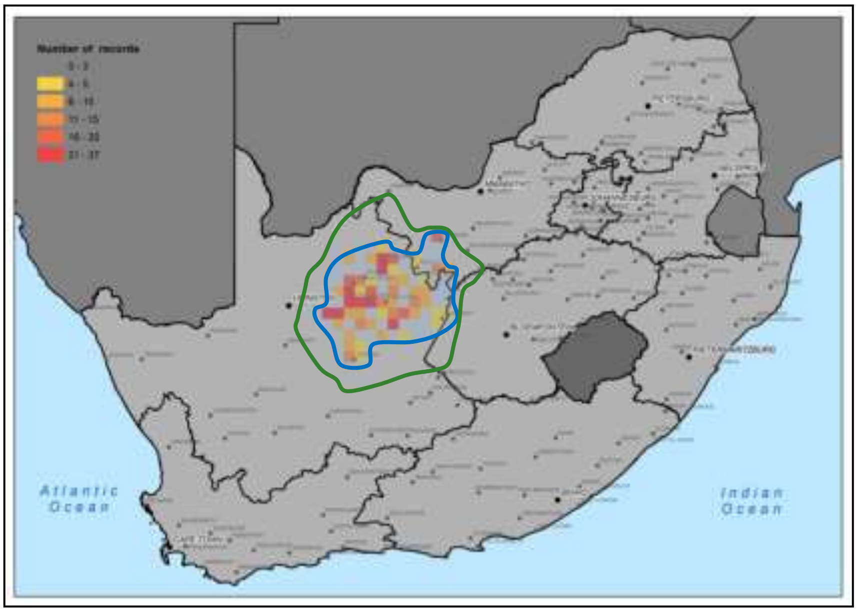

Figure 4: Core area of the GWC (blue-shaded polygon) based on the occurrence of endemic species. Core area grids have more than three records of endemic species. Green polygon represents the GWC boundaries based on the occurrence of at least one GWC endemic plant species per quarter-degree-grid.

4. Conclusion and future prospects

This study addressed the lack of knowledge regarding plant endemism in the Griqualand West region, and provides support for the recognition of endemic plants from this region. The endemic and near-endemic species accounted for 1.4% of the flora and their restricted distributions demarcated the GWC beyond current definitions. The level of endemism matches the trend found in other local centres of floristic endemism in southern

Africa. Thus, the GWC can justifiably be recognised as a centre of endemism. Many of the GWC endemics show preference for Ca-rich substrates. As the GWC borders identified in this study are extensive, covering a large geographical area, the more refined GWC core area was demarcated to aid focussed conservation and future research efforts. This study proposes the concept of 'core area' to identify an area that contains all the endemics and the highest frequencies thereof. This will allow for focused conservation planning. Within the GWC core area, the ranges of banded ironstone and the Ca-rich substrates of the Ghaap Plateau account for >90% of the endemics. Future studies should identify the abiotic variables that influence the flora of the GWC and thus the distribution of its endemics, especially plant-soil associations (Gibson et al., 2010). This may provide insight into the finer-scale distributions of the endemic plants, potentially allowing the identification of GWC sub-centres of endemism, further directing conservation and research efforts which is much needed in these unique ecosystems (Clements et al., 2006; Jacobi et al., 2007).

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Appendix. Supplementary data.

Distribution data

Supplementary Table 1

Taxa considered during the screening process for GWC endemics and near-endemics. Justifications are based on herbarium records as were available on 30 January 2017.

Species	Family	Classification	Justification
Agrostis griquensis Stapf	Poaceae	Floristic element	Distribution extends as far east as Bloemfontein; centred in GWC.
Aizoon asbestinum Schltr.	Aizoaceae	Discarded	Wide distribution extending from GWC to southern Namibia.
Amphiglossa tecta (Brusse) Koekemoer Syn.: *Pterothrix tecta* Brusse	Asteraceae	GWC endemic	One locality at Witsand in western GWC.
Antimima lawsonii (L.Bolus) H.E.K.Hartmann Syn.: *Ruschia lawsonii* (L.Bolus)	Aizoaceae	GWC endemic	Restricted to GWC, south and north of Lime Acres.
Barleria media C.B.Clarke	Acanthaceae	GWC endemic	Restricted to GWC between Kuruman and Pomfret.
Bergia anagaloides E.Mey. ex Fenzl Syn.: *Bergia alsinoides* Friedr.-Holzh.	Elatinaceae	Discarded	Widespread in South Africa and Namibia.
Blepharis marginata (Nees) C.B.Clarke Syn.: *Acanthodium marginatum* Nees	Acanthaceae	GWC endemic	Restricted to central GWC between Sishen, Kimberley and south of Postmasburg.
Boscia foetida Schinz subsp*. foetida* Syn.: *Boscia rautanenii* Schinz	Capparaceae	Discarded	Widespread in Gariep region and Namibia.
Brachiaria dura Stapf var. *pilosa* J.G.Anderson	Poaceae	GWC endemic	Restricted to GWC south of Postmasburg.
Brachystelma canum R.A.Dyer	Apocynaceae	Discarded	Occurs too far east of GWC; south of Mafikeng.
Brachystelma dimorphum R.A.Dyer subsp*. dimorphum*	Apocynaceae	Discarded	Occurs too far east of GWC in Free State near Bloemfontein.
Calobota cuspidosa (Burch.) Boatwr. & B.-E.Van Wyk Syn.: *Lebeckia macrantha* Harv.	Fabaceae	GWC endemic	Restricted to GWC, but widespread within it.
Calobota psiloloba (E.Mey.) Boatwr. & B.-E.Van Wyk Syn.: *Lebeckia psiloloba* (E.Mey.) Walp.	Fabaceae	Discarded	Not present in GWC, occurring in Eastern Cape.

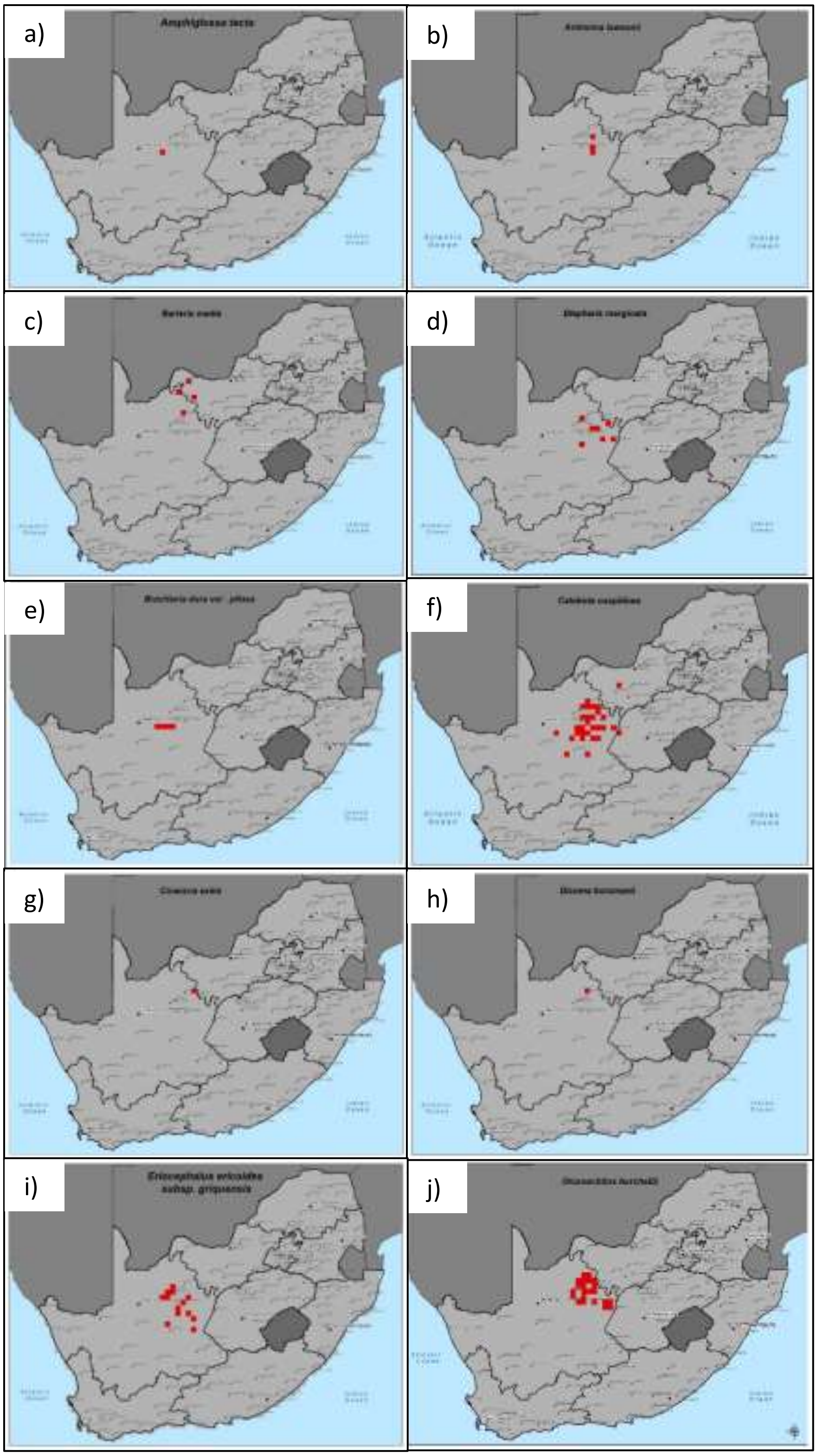
Carex burchelliana Boeckeler	Cyperaceae	Floristic element	Occurs as far east as Klerksdorp. Centred in GWC.
Cineraria exilis DC.	Asteraceae	GWC endemic	Restricted to GWC; known only from type specimen found east of Kuruman.
Convolvulus boedeckerianus Peter	Convolvulaceae	Discarded	Widespread in central South Africa.
Corchorus pinnatipartitus Wild	Malvaceae	Floristic element	Also occurs in southern Botswana; centred in GWC.
Crotalaria griquensis L.Bolus	Fabaceae	Floristic element	Wide distribution in central South Africa.
Dicoma kurumanii S.Ortiz & Netnou	Asteraceae	GWC endemic	Restricted to GWC around Kuruman.
Digitaria polyphylla Henrard	Poaceae	Floristic element	Distribution extends west as far as Hoopstad; centred in GWC.
Ebracteola wilmaniae (L.Bolus) Glen Syn.: *Ruschia wilmaniae* (L.Bolus) L.Bolus *var. wilmaniae*	Aizoaceae	Floristic element	Distribution extends east to just north of Bloemhof; centred in GWC.
Eragrostis macrochlamys Pilg. var. *wilmaniae* (C.E.Hubb. & Schweick.) De Winter Syn.: *Eragrostis macrochlamys* Pilg. p.p.	Poaceae	Floristic element	Also present in central Namibia and western Botswana; centred in GWC.
Eriocephalus ericoides (L.f.) Druce subsp. *griquensis* M.A.N.Müll. Syn.: *Eriocephalus ericoides* (L.f.) Druce p.p.	Asteraceae	GWC endemic	Restricted to GWC, but widespread within it.
Erucastrum griquense (N.E.Br.) O.E.Schulz Syn.: *Diplotaxis griquensis* (N.E.Br.) Sprague	Brassicaceae	Floristic element	Widespread in central and north-western South Africa, extending as far as Zimbabwean border; centred in GWC.
Euphorbia bergii A.C.White, R.A.Dyer & B.Sloane	Euphorbiaceae	Floristic element	Extends too far into Free State to south of Koffiefontein; centred in GWC.
Euphorbia duseimata R.A.Dyer	Euphorbiaceae	Floristic element	Also in Namibia; centred in GWC.
Euphorbia inornata N.E.Br. Syn. of *Euphorbia crassipes* Marloth	Euphorbiaceae	Discarded	Sunken into *E. crassipes* Marloth.
Euphorbia planiceps A.C.White, R.A.Dyer & B.Sloane Syn.: *Euphorbia wilmaniae* Marloth	Euphorbiaceae	Discarded	Sunken into *E. wilmaniae* Marloth.

Euphorbia rectirama N.E.Br. Syn.: *Euphorbia spartaria* N.E.Br.	Euphorbiaceae	Discarded	Sunken into *E. spartaria* N.E.Br.
Euphorbia wilmaniae Marloth Syn.: *Euphorbia planiceps* A.C.White, R.A.Dyer & B.Sloane	Euphorbiaceae	Floristic element	Wide distribution in South Africa; centred in GWC.
Galenia portulacacea Fenzl	Aizoaceae	Discarded	Wide distribution in South Africa.
Glossochilus burchellii Nees	Acanthaceae	GWC endemic	Restricted to GWC, but widespread within it.
Gnaphalium englerianum (O.Hoffm.) Hilliard & B.L.Burtt Syn.: *Amphidoxa engleriana* O.Hoffm.	Asteraceae	GWC endemic	Restricted to GWC around Reivilo.
Halopeplis amplexicaulis (Vahl) Ung.-Sternb. ex Ces., Pass. & Gibelli	Chenopodiaceae	Discarded	Cosmopolitan species.
Helichrysum spiciforme DC.	Asteraceae	Floristic element	Also present in southern Namibia; centred in GWC.
Hereroa wilmaniae L.Bolus Syn.: *Hereroa uncipetala* (N.E.Br.) L.Bolus	Aizoaceae	GWC endemic	Restricted to GWC, but widespread within it.
Indigofera damarana Merxm. & A.Schreib. Syn.: *Indigofera wilmaniae* Baker f. ex J.B.Gillett	Fabaceae	Floristic element	Also occurs in Namibia; centred in GWC.
Ipomoea suffruticosa Burch. Syn.: *Turbina suffruticosa* (Burch.) A.Meeuse	Convolvulaceae	Floristic element	Widely distributed in southern Africa; centred in GWC.
Jamesbrittenia albiflora (I.Verd.) Hilliard Syn.: *Sutera albiflora* I.Verd.	Scrophulariaceae	Floristic element	Distribution extends too far east and south into Free State; partially centred in GWC.
Justicia puberula (Immelman) Immelman Syn.: *Justicia parvibracteata* Immelman	Acanthaceae	GWC endemic	Restricted to GWC, but widespread within it.
Justicia thymifolia (Nees) C.B.Clarke Syn.: *Adhatoda thymifolia* Nees	Acanthaceae	GWC near-endemic	Main population restricted to GWC and widespread within it; marginally present in Gariep Centre.
Listia minima (B.-E.van Wyk) B.-E.van Wyk & Boatwr.	Fabaceae	Discarded	Unresolved taxon.
Listia subulata (B.-E.van Wyk) B.-E.van Wyk & Boatwr.	Fabaceae	Floristic element	Distribution extends too far east into Free State; partially centred in GWC.
Lithops aucampiae subsp*. aucampiae* var. *aucampiae* (de Boer) D.T.Cole	Aizoaceae	Discarded	Variety no longer recognised.

Lithops aucampiae subsp*. aucampiae* var*. koelemanii* (de Boer) D.T.Cole	Aizoaceae	Discarded	Variety no longer recognised.
Lithops aucampiae L.Bolus subsp. *euniceae* (de Boer) D.T.Cole	Aizoaceae	GWC endemic	Restricted to GWC between Hopetown and Douglas.
Lithops bromfieldi L.Bolus Syn.: *Lithops bromfieldii* L.Bolus var. *glaudinae* (de Boer) D.T.Cole	Aizoaceae	GWC endemic	Restricted to GWC south-west of Postmasburg.
Lithops lesliei (N.E.Br.) N.E.Br. subsp. *burchellii* D.T.Cole Syn.: *Lithops lesliei* (N.E.Br.) N.E.Br. p.p.	Aizoaceae	GWC endemic	Restricted to GWC between Griquatown and Campbell.
Lotononis burchellii Benth.	Fabaceae	Floristic element	Widespread; centred in GWC.
Lotononis crumanina Burch. ex Benth.	Fabaceae	Floristic element	Wide distribution in central South Africa; centred in GWC.
Lotononis linearifolia B.-E.van Wyk	Fabaceae	Discarded	Distribution in Namibia unknown; should be investigated further as a potential near-endemic taxon.
Maytenus ilicina (Burch.) Loes. Syn.: *Gymnosporia ilicina* (Burch.) Davison	Celastraceae	GWC endemic	Restricted to GWC, but widespread within it.
Melhania transvaalensis Szyszyl.	Malvaceae	Discarded	Marginally present in GWC, centred in Limpopo Province.
Mestoklema copiosum N.E.Br. ex Glen	Aizoaceae	Floristic element	Present in Eastern Cape, Northern Cape and Free State provinces; centred in GWC.
Monechma districhotrichum (Lindau) P.G.Mey. Syn.: *Justicia distichotrichum* Lindau	Acanthaceae	Discarded	Present in southern Namibia.
Nananthus aloides (Haw.) Schwantes Syn.: *Aloinopsis aloides* (Haw.) Schwantes	Aizoaceae	Discarded	Widespread in central South Africa.
Nerine frithii L.Bolus	Amaryllidaceae	Discarded	Centred in North-West Province; marginally present in GWC.
Nerine hesseoides L.Bolus	Amaryllidaceae	Discarded	Present too far west of GWC near Kroonstad.
Nolletia annetjieae P.P.J.Herman	Asteraceae	Discarded	Present in central and eastern Namibia and southern Botswana.

Nuxia gracilis Engl. Syn.: *Lachnopylis gracilis* (Engl.) C.A.Sm.	Buddlejaceae	GWC near-endemic	Present in GWC between Vryburg and Douglas with a disjunct population in Sekhukhuneland Centre.
Pentzia stellata (P.P.J.Herman) Magee	Asteraceae	GWC endemic	Restricted to GWC between Vryburg and south of Danielskuil.
Pentzia oppositifolia Magee	Asteraceae	Floristic element	Present too far east of GWC as far as Boshof; centred in GWC.
Petalidium parvifolium C.B.Clarke ex Schinz Syn.: *Petalidium wilmaniae* Oberm.	Acanthaceae	Discarded	Mainly in Gariep region including southern Namibia.
Pharnaceum viride Adamson	Molluginaceae	Floristic element	Also present in Soutpansperg (Limpopo), Western Cape and Gariep region; centred in GWC.
Phyllobolus amabilis Gerbaulet & Struck	Aizoaceae	Discarded	Sunken into *Mesembryanthemum amabile* (Gerbaulet & Struck) Klak which also occurs in the Western Cape.
Prepodesma orpenii (N.E.Br.) N.E.Br. Syn.: *Nananthus orpenii* N.E.Br.	Aizoaceae	GWC endemic	Restricted to GWC, but widespread within it.
Putterlickia pyracantha (L.) Szyszyl. Syn.: *Catha campestris* (Eckl. & Zeyh.) C.Presl	Celastraceae	Discarded	Widespread in southern Africa.
Putterlickia saxatilis (Burch.) M.Jordaan Syn.: *Gymnosporia saxatilis* (Burch.) Davison	Celastraceae	GWC endemic	Restricted to GWC, but widespread within it.
Ruschia griquensis (L.Bolus) Schwantes Syn.: *Mesembryanthemum griquense* L.Bolus	Aizoaceae	Discarded	Widespread in South Africa.
Salsola atrata Botsch. Syn.: *Salsola globulifera* Fenzl	Amaranthaceae	Discarded	Sunken into more widely distributed *Caroxylon atratum* Botsch.
Salsola humifusa A.Brückn.	Chenopodiaceae	Floristic element	Distribution extends south and east, as far south as De Aar; centred in GWC.
Salvia namaensis Schinz Syn.: *Salvia burchellii* N.E.Br.	Lamiaceae	Discarded	Widespread in central South Africa and Western Cape, and southern Namibia.

Searsia tridactyla (Burch.) Moffett Syn.: *Rhus tridactyla* Burch.	Anacardiaceae	GWC endemic	Restricted to GWC, but widespread within it.
Selago mixta Hilliard Syn.: *Walafrida paniculata* (Thunb.) Rolfe	Scrophulariaceae	Floristic element	Distribution extends too far into North-West Province, as far east as Rustenburg; centred in GWC.
Septulina ovalis (E.Mey. ex Harv.) Tiegh. Syn.: *Loranthus ovalis* E.Mey. ex Harv.	Loranthaceae	Discarded	Not present in GWC; only in Gariep Centre.
Sesbania notialis J.B.Gillett	Fabaceae	Floristic element	Distribution extends too far to the east, as far as Bothaville; centred in GWC.
Stachys burchelliana Launert Syn.: *Stachys burchellii* Benth.	Lamiaceae	Floristic element	Present in southern Namibia (outside of Gariep Centre); centred in GWC.
Stapelia hursita L. var. *gariepensis* (Pillans) Bruyns Syn.: *Stapelia gariepensis* Pillans	Apocynaceae	Discarded	Only present in Gariep region.
Stapelia rubiginosa Nel	Apocynaceae	Discarded	Not present in GWC, only in Gariep Centre.
Stapelia similis N.E.Br. Syn.: *Stapelia juttae* Dinter	Apocynaceae	Discarded	Not present in GWC.
Sutera griquensis Hiern Syn.: *Sutera burchellii* Hiern	Scrophulariaceae	Floristic element	Also present in central Free-State and central North-West Provinces; centred in GWC.
Tarchonanthus obovatus DC.	Asteraceae	GWC endemic	Restricted to GWC, but widespread within it.
Thesium dumale N.E.Br.	Santalaceae	Discarded	Sunken into widely distribued *T. resedoides* A.W.Hill
Titanopsis calcarea (Marloth) Schwantes Syn.: *Titanopsis fulleri* Tischer	Aizoaceae	Floristic element	Widely distributed in central GWC.
Trachyandra burkei (Baker) Oberm. Syn.: *Anthericum burkei* Baker	Asphodelaceae	Discarded	Also present in southern Botswana.
Triaspis hypericoides (DC.) Burch. subsp. *hypericoides*	Malpighiaceae	Floristic element	Also present in Limpopo, Gauteng and Mpumalanga; centred in GWC.


a)
Amphiglossa tecta
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Eriocephalus ericoides subsp. griquensis
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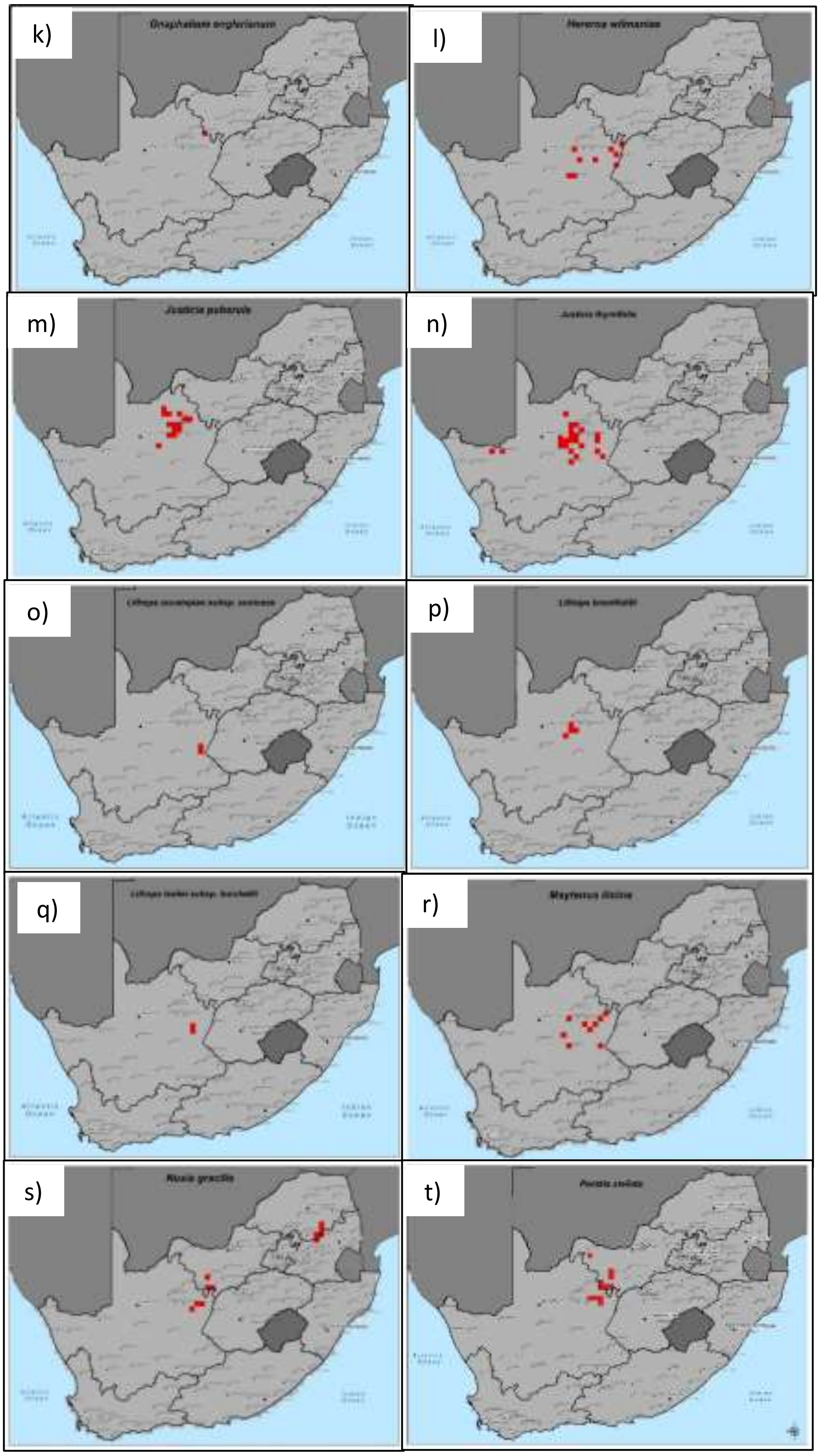
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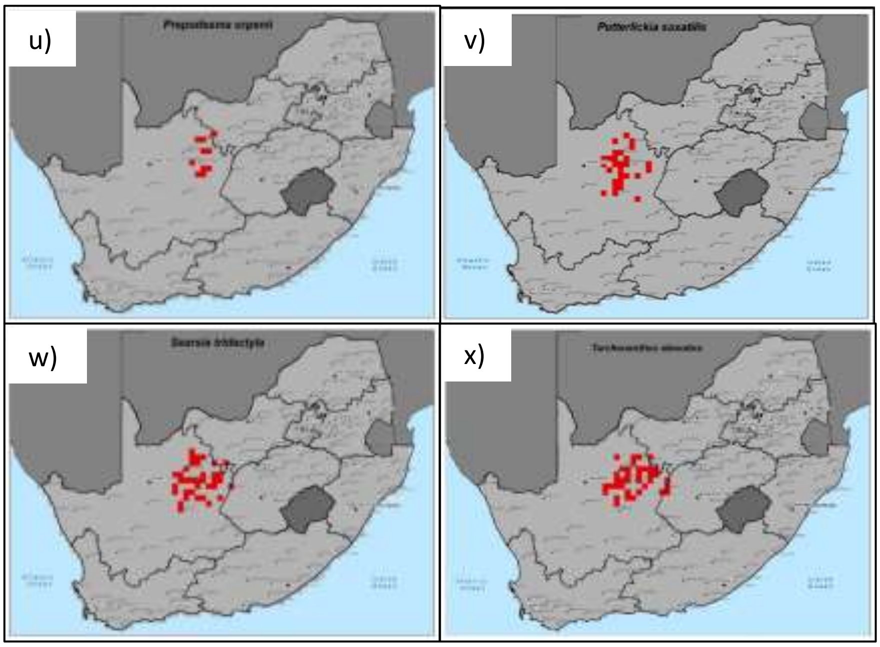

Figure 1: Global distribution of a) *Amphiglossa tecta*; b) *Antimima lawsonii*; c) *Barleria media*; d) *Blepharis marginata*; e) *Brachiaria dura* var. *pilosa*; f) *Calobota cuspidosa*; g) *Cineraria exilis*; h) *Dicoma kurumanii*; i) *Eriocephalus ericoides* subsp. *griquensis*; j) *Glossochilus burchelli*; k) *Gnaphalium englerianum*; l) *Hereroa wilmaniae*; m) *Justicia puberula* (near endemic); n) *Justicia thymifolia*; o) *Lithops aucampiae* subsp. *euniceae*; p) *Lithops bromfieldii*; q) *Lithops lesliei* subsp. *burchellii*; r) *Maytenus ilicina*; s) *Nuxia gracilis* (near endemic); t) *Pentzia stellata*; u) *Prepodesma orpenii*; v) *Putterlickia saxatilis*; w) *Searsia tridactyla*; and x) *Tarchonanthus obovatus*.