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Revision of the North West province, South Africa, vegetation map

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Background: The vegetation type boundaries in the North West province as they appear in the 2018 National Vegetation Map, for the most part, are derived from agricultural land types that were mapped in the 1980s.

Aim & objectives: Given (1) the importance the National Vegetation Map plays in conservation assessment and planning, as well as environmental planning and decision making; and (2) the map boundary errors reported by users, an update of the provincial vegetation map was considered necessary.

Methods: A vegetation identification key using high-level environmental parameters (in order of importance: flooding, bioregion, terrain, geology and soil) was developed. This key was used to manually interpret high-resolution colour aerial imagery, together with existing environmental spatial datasets (land types as a proxy for soils, simplified geology and terrain/land form). The existing vegetation type concepts are sound and are mostly retained in this map.

Results & conclusion: Changes to the map include: (1) all vegetation boundaries in the province are remapped; (2) Olea Sclerophyllous Forest is proposed as a sub type/community related to the Northern Afrotemperate Forest vegetation type; (3) two existing vegetation types currently not mapped as occurring in the province are brought into the province, namely, Subtropical Alluvial Vegetation and Waterberg Mountain Bushveld; and (4) three vegetation units recognised in previous vegetation studies and which are not indicated in the current National Vegetation Map are included here as new vegetation types, namely, Vryburg Thornveld, Morokweng Thornveld and Central Sandy Mountain Bushveld. The descriptions of all terrestrial vegetation types occurring in the province are also updated and an updated annotated global plant species list for the province is provided. Changes reflected in this vegetation map have been incorporated into the National Vegetation Map Version 2024 beta.

Keywords: North West, vegetation map, classification, ecosystem type, revision.

Introduction

The South African vegetation map is a national scale map of the terrestrial ecosystems found within the country. The current National Vegetation Map, first published in 2006 (Mucina & Rutherford 2006) and updated in 2018 (Dayaram et

al. 2019), includes 459 unique vegetation types of which 35 terrestrial and six azonal types occur in the North West province (NW). A beta release of the next version was released in 2024 (SANBI 2006–2024), which now incorporates revisions from work in this paper.

The purpose of the National Vegetation Map is to: a) provide a coarse-filter spatial surrogate that broadly represents biodiversity patterns across the whole country; b) provide ecologically relevant environmental management units; and c) provide ecologically meaningful units that can be used in environmental planning and management (Dayaram et al. 2021). Consequently, it is generally regarded as the national map of terrestrial ecosystems for the country. While itself not formally mandated by law, in practice the National Vegetation Map is regarded as one of South Africa's foundational biodiversity datasets that has an important legislative function, as it informs a number of government environmental and biodiversity planning and management tools, such as maps of Critical Biodiversity Areas and Ecological Support Areas; protected area expansion strategies; and forms a basis for environmental impact assessment. Thus, poorly delineated vegetation types can lead to poor outcomes for conservation planning, land management and planning decisions, and ultimately the loss of biodiversity.

Each vegetation type delineates and describes the parts of the landscape that share similar plant communities that are influenced or determined by shared environmental drivers (Mucina & Rutherford 2006). These maps are essentially models of the natural variation observable in any landscape. They reduce the complexity and continuity of natural landscapes to a set of discrete categories. Irrespective of the methods used to classify landscapes there are invariably mapping errors, especially where the transition between ecosystems is a continuum rather than being marked by a clear boundary and where landscapes have been significantly modified. The National Vegetation Map aims to map the original or historical extent of ecosystems before contemporary settlements, croplands and mining modified landscapes. This is defined as the ecosystems present prior to the advent of permanent European settlement in South Africa circa 350 years ago (Mucina & Rutherford 2006). This is a pragmatic, albeit problematic, threshold as it does not consider the impact of precolonial populations on vegetation as significant, whereas it is highly likely that these populations did have extensive and significant impacts on ecosystems (e.g., Sadr 2022). As such, ecosystem classification and mapping can be particularly problematic in highly modified landscapes. In these instances, understanding the key environmental determinants of ecosystems is very important for mapping the original extent of vegetation.

Given the central role that the South African vegetation map plays in land and environmental management and biodiversity conservation, there is an imperative to maintain and update this map to reflect the best available data and emerging knowledge of historical vegetation. In the NW, concerns were raised during the preparation of the North West Biodiversity Sector Plan (NW READ 2015) that the current provincial vegetation map, which is based on the National Vegetation Map published in Mucina and Rutherford (2006), did not accurately reflect observed vegetation patterns. Three important accuracy issues were identified with respect to the 2006 vegetation map:

1. Inaccurate delineation of vegetation type boundaries.
2. Incorrect assignment of areas to a vegetation type class that did not reflect the characteristics of communities observed on the ground.
3. Redundant vegetation type descriptions and the existence of new or undescribed vegetation types.

Therefore, the purpose of this project was to resolve these issues in the NW vegetation map using currently available datasets, and to publish the revised vegetation map while aligning to SANBI's guidelines for revisions (Dayaram et al. 2021). Once published, the NW vegetation map can be reviewed for incorporation into the National Vegetation Map.

Whilst the current NW portion of the National Vegetation Map was published in 2006, the origin of the vegetation type boundaries as they currently appear in the map can be traced back to the agricultural land type maps prepared by the Department of Agriculture (Mucina et al. 2006). Land types were originally designed to serve the agricultural industry, and these would be areas with generally uniform climate, terrain and soil patterns (MacVicar et al. 1974).

The vegetation type boundaries as mapped in the 2006 National Vegetation Map are based on a vegetation map for the NW prepared by Bredenkamp and Brown (2003a). Unfortunately, all metadata relating to the development of this map was lost other than a hard-copy version of this map that was subsequently digitised[1]. The boundaries in this map, however, appear to be based predominately on the agricultural land type maps for NW. This assumption is supported by a comparison of the boundaries between the Bredenkamp and Brown (2003a) and the land type maps that indicates there is an 80% spatial coincidence of boundaries between the two maps (Figure 1). There has been significant development and refinement in the vegetation type concepts since Acocks (1953, 1975, 1988), but there has been comparatively little refinement of the vegetation type boundaries in the NW. Essentially, the majority of vegetation type boundaries as they appear in the 2006 vegetation map,

[1]Leslie Brown and Ray Schaller pers. comm.

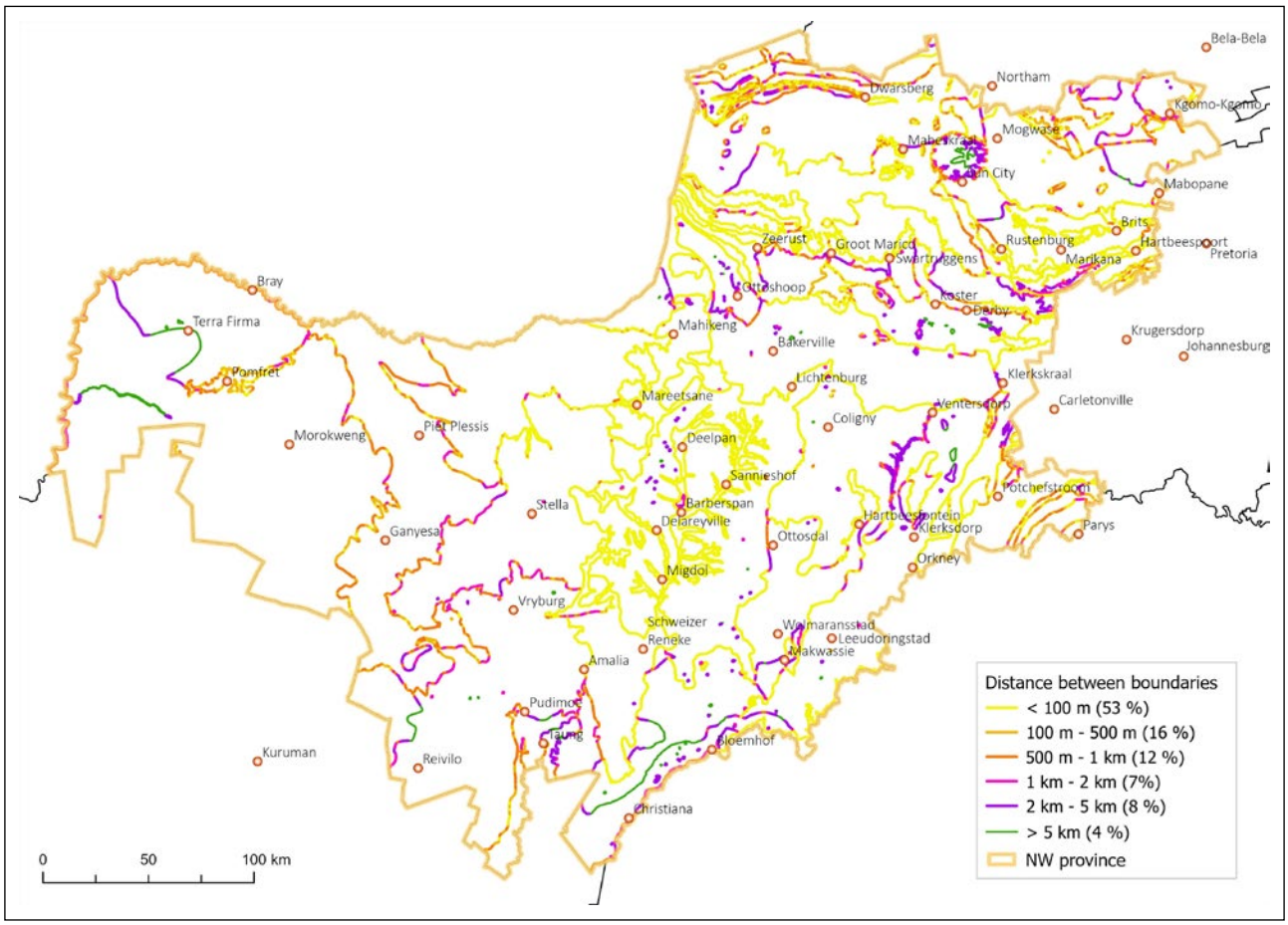

Figure 1. The spatial relationship between the vegetation type boundaries mapped in Bredenkamp and Brown (2003a) versus agricultural land types.

and subsequent 2018 map, were first mapped sometime in the 1980s. With the current availability of high-resolution aerial imagery, the emergence of desktop Geographic Information System (GIS) mapping technology, as well as the increased importance and use of the vegetation map for site-based environmental management, these have exposed the boundary errors inherent in the 2006 map and have highlighted the need to update the boundary mapping in this map.

The vegetation concepts and descriptions in the NW vegetation map draw on concepts in previous vegetation maps of South Africa (Acocks 1988; Low & Rebelo 1996), as well as the Bredenkamp and Brown (2003a) vegetation map. There are at least 93 published studies or reports relating directly to the vegetation of the NW. This body of literature, however, discusses almost exclusively vegetation concepts at the plant community scale. There are few quantitative studies that explicitly explore the floristic and environmental relationships between phytosociological units at the scale of the vegetation type, and none that attempt to define vegetation types using phytosociological approaches or discuss relationships between phytosociological units and vegetation types.

This is not unexpected as the bulk of the relevant vegetation science literature predates the current vegetation type concepts published in 2006. Post-2006 there has been very little phytosociological research published that covers the northwest region of South Africa. The absence of research directly exploring the relationships between phytosociological units and vegetation types, whilst not unexpected, highlights a very important vegetation science research gap. There is a clear need for more quantitative vegetation science research to develop and refine the current vegetation type concepts at the spatial scale at which they are conceived, as this provides the scientific justification for the concepts which is necessary to affirm the application of vegetation types in legislative and legal processes.

Bredenkamp and Brown (2003b) used a phytosociological approach to define higher-order vegetation association concepts for the Bankenveld in the Highveld region that are at a similar conceptual scale to vegetation types. Similarly, Winterbach (1998) and Winterbach et al. (2000) defined higher-order vegetation association concepts in the Arid Sweet Bushveld region of the NW to derive units that approach vegetation types. Van der Meulen and Westfall (1979) used agricultural land types as the basis to define and delineate vegetation units. In all these studies the same basic set of environmental elements are associated with these higher-order units,

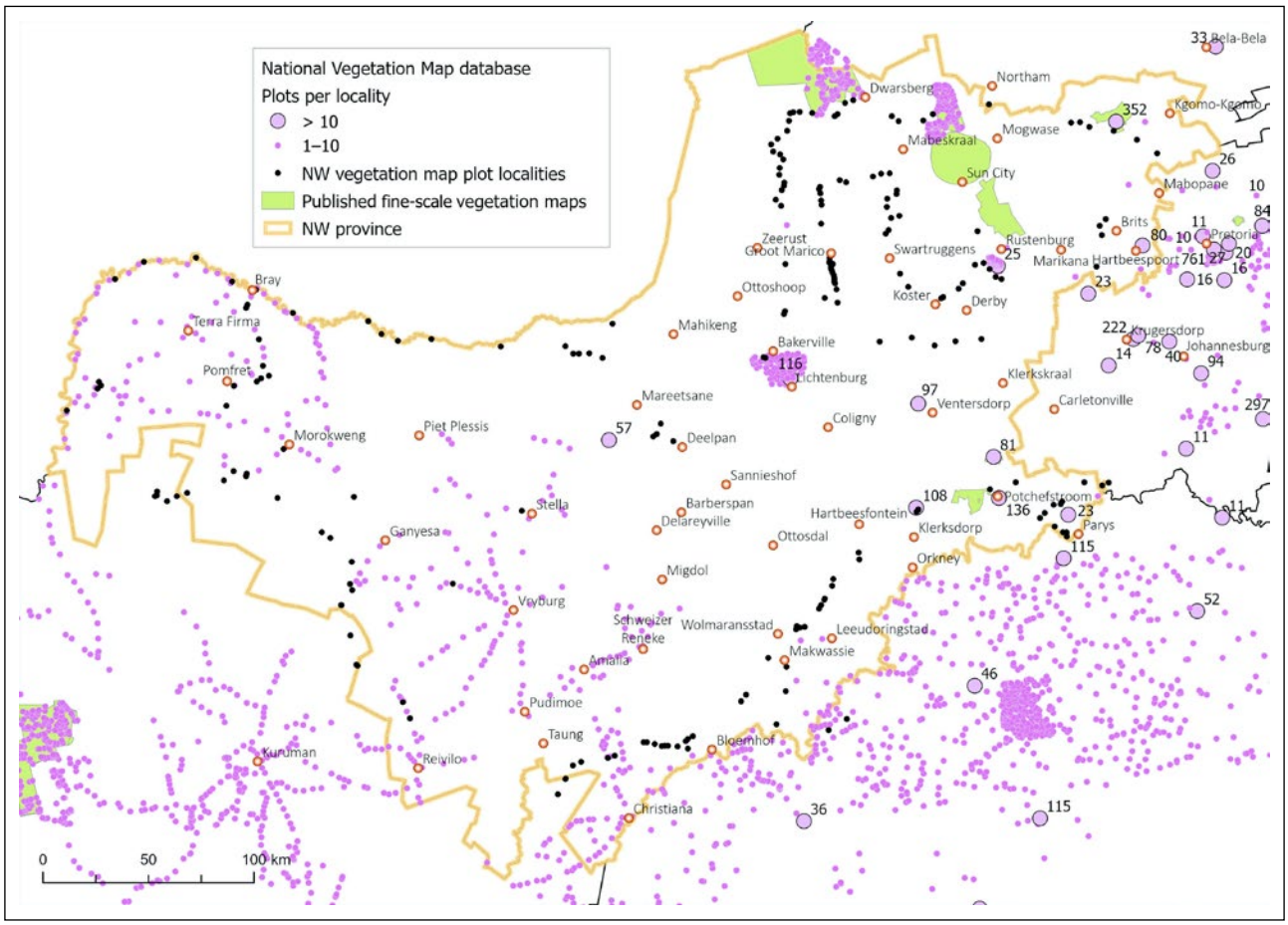

Figure 2. The extent of published fine-scale vegetation maps and available relevé data in and around the North West province (NW).

namely, soil (clay vs sandy soils on plains), terrain (plains vs mountains) and geology (quartzite vs igneous).

The spatial extent of individual vegetation studies relevant to the NW varies considerably. Some studies accept the agricultural land types as acceptable vegetation mapping units and conduct phytosociological analyses within these units (Bezuidenhout et al. 1993; Bezuidenhout et al. 1994a, 1994b) or across these units (Van der Meulen & Westfall 1979; Smit 2000). Other studies are conducted at a broader general geographic area (Morris 1976; Bredenkamp et al. 1989; Bezuidenhout & Bredenkamp 1990; Du Preez & Venter 1990a, 1990b; Bezuidenhout et al. 1994c, 1994d), or geological area (Bezuidenhout et al. 1988; Bezuidenhout et al. 1994b), or protected area (Van Zyl 1965; Coetzee 1975; Bredenkamp & Bezuidenhout 1990; Bredenkamp et al. 1994; Stalmans & De Wet 2003), or even part of a protected area (Brown & Bredenkamp 1994; Brown et al. 1995, 1996).

There are at least 29 published papers or reports that include fine-scale vegetation maps for their respective study areas that are relevant to the NW (Figure 2). Excluded from this list are phytosociological studies that used agricultural land types as the mapping unit rather than generating their own vegetation maps (e.g. Bezuidenhout et al. 1993; Bezuidenhout et al. 1994a, 1994b; Smit 2000; Van der Meulen & Westfall 1979). Collectively, these fine-scale maps cover 260 000 ha or 2.5% of the province. Despite there being a reasonable wealth of vegetation studies relevant to the region, there is a relative paucity in the extent of published vegetation maps. Added to this is the lack of curation of this information with none of the vegetation maps having spatial data in an accessible data archive.

Whilst the vegetation type concept has been accepted and used in South Africa at least since Acocks (1953), it was only in the 2006 version of the vegetation map that the current vegetation type concept was clearly articulated and defined (Mucina et al. 2006). Despite this major advance in the vegetation map, at least for the vegetation types occurring in the NW, it is not clear in the current delineation and description of the vegetation types what are the environmental variables or factors and species or communities that differentiate one vegetation type from another. These variables are implicit in the 'verbal models' used to define and delineate vegetation types (Mucina et al. 2006). However, a clear functional understanding or description of the differentiating factors between vegetation types is absent in the current descriptions of vegetation types. This is often cited by users of the NW vegetation map as being a limitation to using and interpreting the current map at the site level.

The National Vegetation Map is mapped at a broad spatial scale of a whole region or landscape. At the site level there will inevitably be boundary errors when using the vegetation map due to the difference between the scale of map production and scale of use. Therefore, users invariably have to interpret on-the-ground observations of vegetation patterns to 'fine scale' the vegetation map and determine the appropriate vegetation type or types occurring at a site. For users of the vegetation map to be able to make this interpretation at the site level, an understanding of the relationship between underlying environmental variables and the delineation of vegetation types is necessary. Having a clear understanding or model for where and why vegetation types occur is essential for the consistent and defensible mapping of vegetation boundaries, and ultimately the integrity of the vegetation type concept. Whilst this thinking is implicit in the current delineation of vegetation types, it is not, however, always made explicit or clear in the current vegetation type descriptions.

Given these observations and limitations of the current National Vegetation Map in the NW, the objectives of this project were to:

1. Draw on the existing vegetation type classification and descriptions to develop an identification key to vegetation types in the NW based on broad environmental variables.
2. Review existing studies, expert inputs and field observations to determine if there are redundant vegetation types (i.e., two vegetation types that can be merged) or undescribed vegetation types that need to be added to the map and, where possible, support proposed changes with numerical data, and use this information to update the current vegetation type descriptions.
3. Using the identification key in conjunction with available environmental spatial data and current high-resolution aerial imagery, remap vegetation type boundaries at a higher spatial resolution.

Study area

The NW is located on the African Plateau in central southern Africa on the border between South Africa and southern Botswana. The province is 104 881 km^2 and measures roughly 550 km (east–west) by 380 km (north–south). It straddles three major physiographic regions: in the west, parts of the Kalahari region, in the northeast, the Bushveld region and in the southeast, the Highveld region. These broad geographic regions are associated with three major drainage systems, namely the Molopo catchment in the Kalahari, Vaal catchment in the Highveld and Limpopo catchment in the Bushveld. The Molopo and Vaal systems drain towards the west into the Orange River and ultimately the Atlantic Ocean, whereas the Limpopo system drains to the northeast into the Indian Ocean (Figure 3A).

The median elevation of the NW is 1 271 m (mean 1 263 m, minimum 904 m, maximum 1 817 m). It is a relatively flat to gently undulating landscape punctuated with few and scattered regions of hills or mountains (Figure 3A). The major mountain ranges of the province are to be found in the Northern Bankenveld entailing the Dwarsberg and Rant van Tweedepoort, the Southern Bankenveld entailing the Magaliesberg, Witwatersberg, Enzelsberg and Swartruggens (Partridge et al. 2010), the Pilanesberg, the hilly landscape spanning between Wolmaransstad to Hartbeesfontein known as the Maquassi Hills, the predominantly east-facing low cliffs of the Ghaap Plateau forming a west dipping cuesta on the border between the NW and Northern Cape, and the Vredefort Dome in the southeast bordering Gauteng and Free State provinces. For all these mountain ranges the elevational range between the surrounding plains, valleys and summits rarely exceeds 300 m. The largest altitudinal gradient is located in the western Magaliesberg and Pilanesberg, where the maximum elevational range is approximately 600 m.

The climate of the NW is humid to semi-arid subtropical in character. Rainfall ranges from near 800 mm per annum in the Highveld on the eastern border with Gauteng and decreases to 250 mm in the extreme west of the province. There is a single summer-rainfall season from October through to April. Temperatures are coolest with higher incidence of frost on the Highveld, while the northern savannas are warmest. The Kalahari region has the warmest summer temperatures and the Bushveld region the mildest winters (Figure 4 and 5). Mucina and Rutherford (2006) described the climate of each vegetation type in more detail.

The geology of the region is varied (Figure 6); however, a singular dominant factor influencing vegetation patterns across the province is the widespread presence of Tertiary aeolian Kalahari sand. Outside of the Kalahari region, relic pockets of these sands can be encountered throughout most of the province. In terms of the underlying geology, important rock types with strong influences on vegetation are quartzite-rich sedimentary rocks giving rise to dystrophic sandy soils contrasted with mafic and ultramafic rocks giving rise to base-rich clay soils.

The flora of the NW is discussed in some detail by Hahn (2013). The flora is characterised by comprising mostly widespread species with very low levels of endemism. There are at least 2 786 species (2 387 indigenous and 399 not indigenous) recorded in the NW (see Supplementary Material 1) with 16 species (0.6%) known to be endemic or near-endemic to the province (Hahn 2013). Five species (44%) within this group of endemic species are associated with dystrophic quartzite geology of the Magaliesberg and Swartruggens regions, which is assigned to the Gold Reef Mountain Bushveld vegetation type (Table 1).

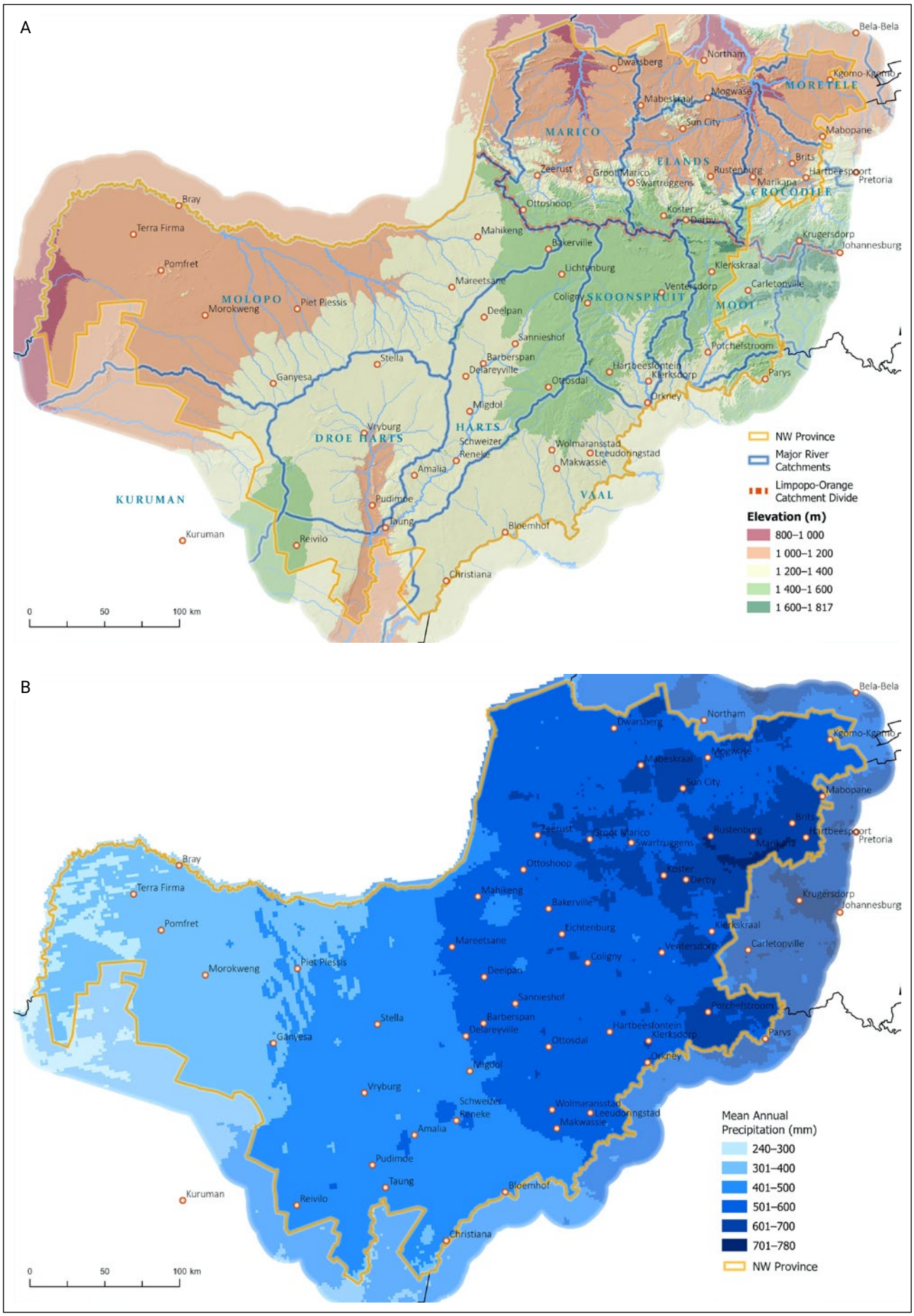

Figure 3. A, elevation and hydrology; B, mean annual precipitation in the North West province.

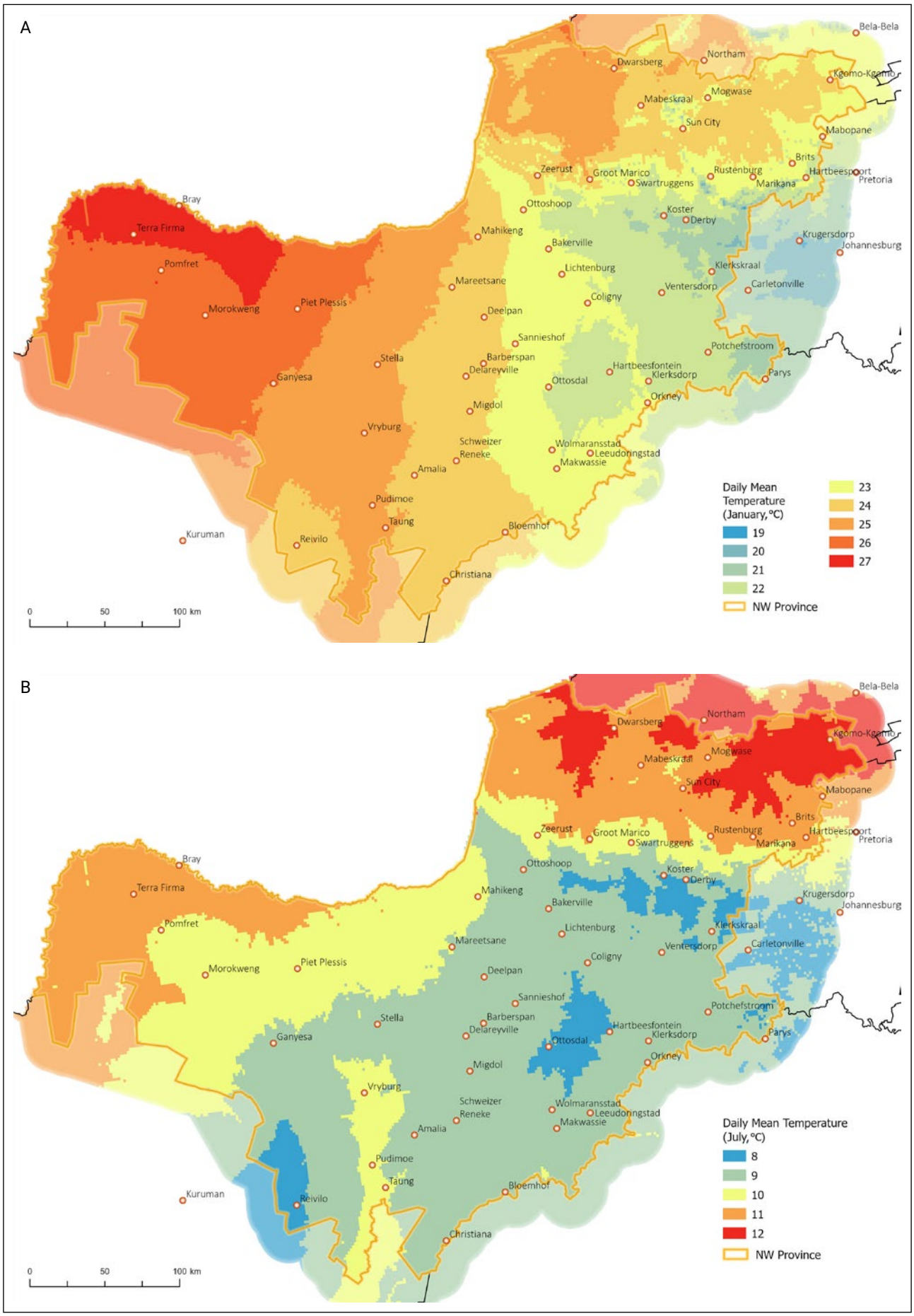

Figure 4. A, daily mean temperature for warmest; and B, coldest months in the North West province.

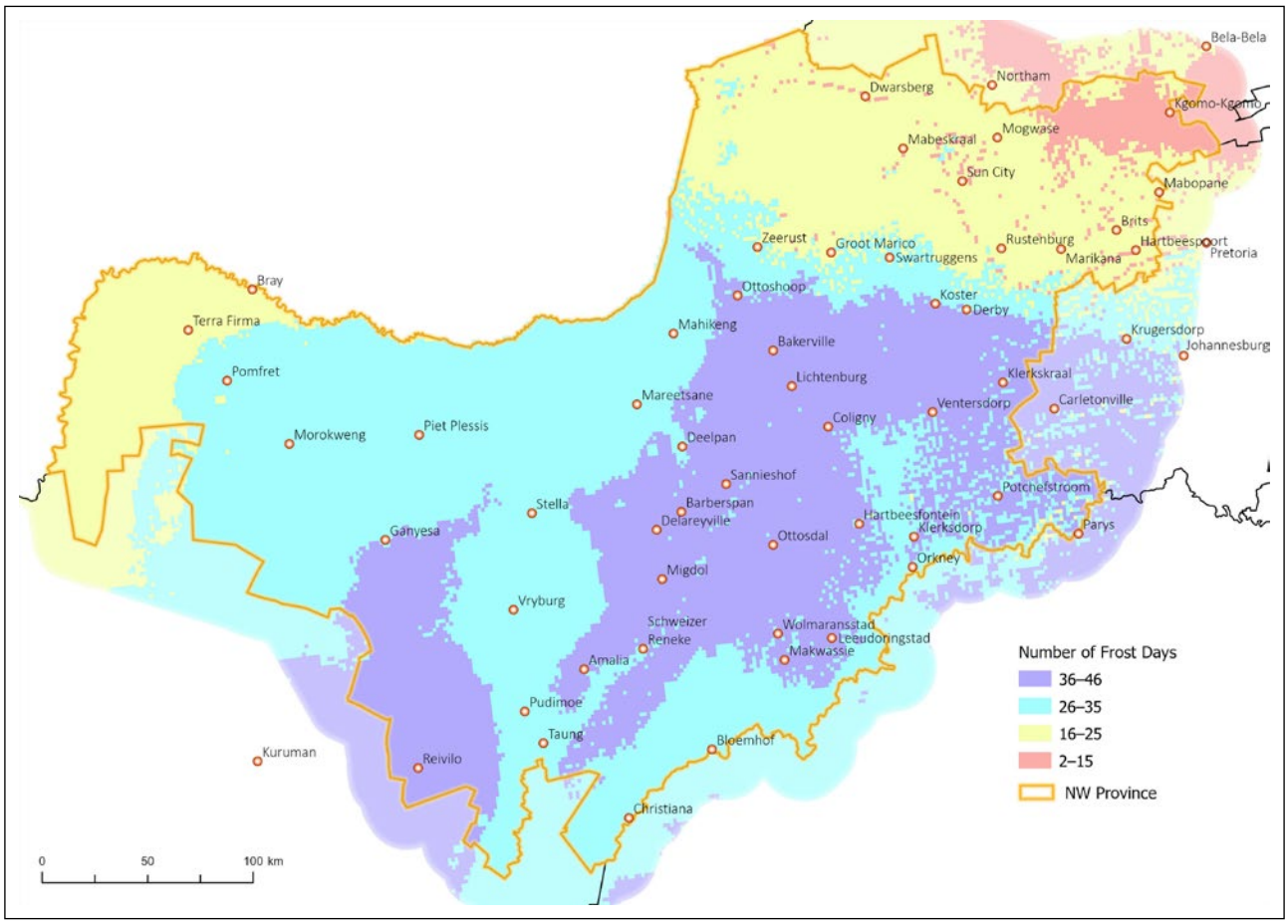

Figure 5. The number of frost days in the North West province.

Table 1. Known endemic (E) and near-endemic (nE) species to the North West province after Hahn (2013). Q = species endemic to the quartzite geology of the Gold Reef Mountain Bushveld vegetation type. R = Rare according to the national Red List categories

ID	Species name	Endemicity	Quartzite endemic
1	*Aloe peglerae*	nE	Q
2	*Blepharis angusta*	E	
3	*Brachystelma canum*	E, R	
4	*Brachystelma gracillimum*	E, R	Q
5	*Ceropegia insignis*	nE	
6	*Euphorbia knobelii*	E	Q
7	*Frithia pulchra*	nE	Q
8	*Gladiolus filiformis*	nE	
9	*Indigofera commixta*	E	
10	*Ledebouria atrobrunnea*	nE	
11	*Miraglossum laeve*	nE	
12	*Nuxia glomerulata*	nE	
13	*Pentzia stellata*	nE	
14	*Senecio holubii*	E, R	Q

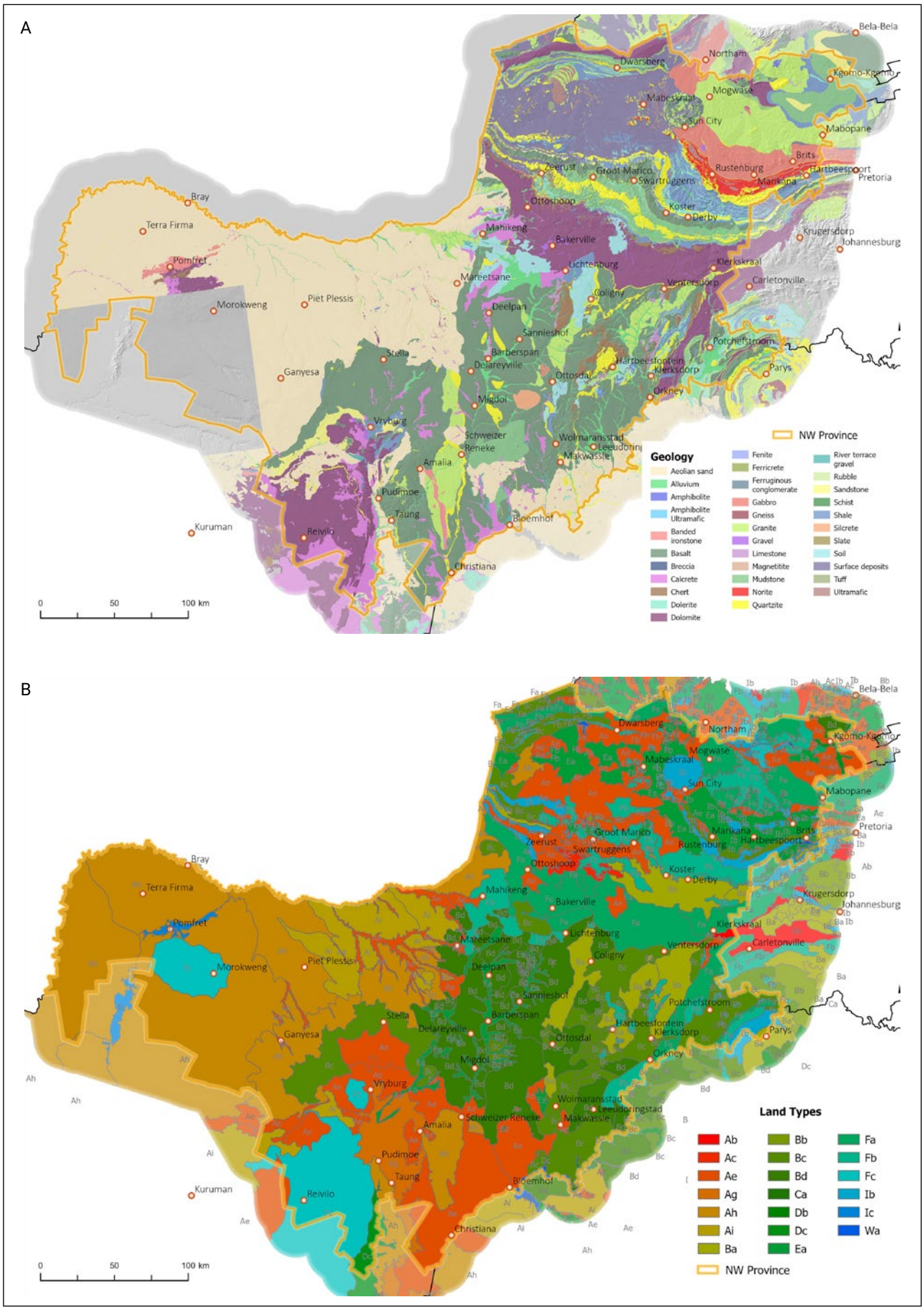

Figure 6. Spatial datasets used to inform the revision of the North West province vegetation map: A, simplified geology based on the 1:250 000 Geology of South Africa dataset; B, agricultural land types.

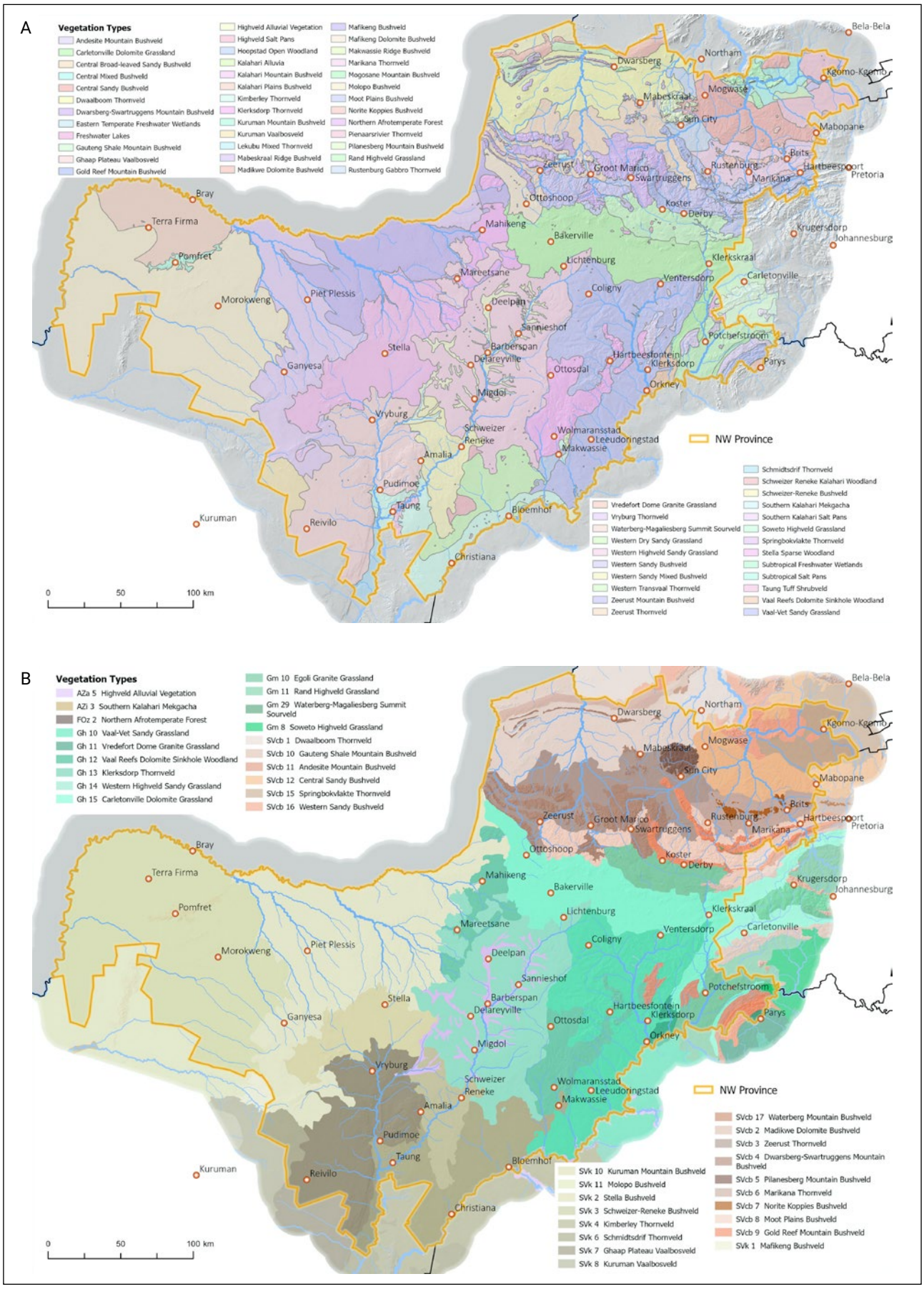

Figure 7. Spatial datasets used to inform the revision of the North West province vegetation map: A, Bredenkamp and Brown (2003a) vegetation map of the North West province; and B, the current 2018 National Vegetation Map (NVM) of South African vegetation types for the North West province (Dayaram et al. 2019).

Methods

Vegetation mapping

Vegetation type polygons were manually mapped using a heads-up digitising technique (Kennedy 2009). The vegetation types were delineated by interpreting patterns observed in colour aerial imagery overlayed with data layers representing the environmental variables used in the identification key to define vegetation types, namely: (1) land types as a proxy for soils, (2) simplified geology, and (3) terrain. In total 24 spatial datasets were used to inform the mapping process (Table 2).

In addition to the vegetation type identification key that provides a regional-scale framework for interpreting and mapping vegetation types, field observations and published descriptions of landform-vegetation relationships were also used to interpret patterns in aerial imagery at the local scale. Examples of landform–vegetation relationships include catena vegetation sequences or agricultural landtype map descriptions of landform–soil relationships. Different vegetation communities are associated with different landforms, and the landform–vegetation patterns tend to differ between vegetation types.

Vegetation identification key

To map vegetation in a logical and defensible manner it is necessary to have a framework for how vegetation types are classified and related to one another based on vegetation and floristic patterns and underlying environmental variables or determinants of vegetation types. Mucina et al. (2006) describe such a classification framework for how vegetation types in South Africa are circumscribed that forms the basis for how vegetation types are defined and mapped in the current National Vegetation Map. As described in the introduction, in the NW it is often not clear from the existing verbal models describing vegetation types what the defining features are of a vegetation type and what separates one vegetation type from another. Therefore, before any remapping of vegetation type boundaries could be attempted it was necessary to distil from existing vegetation type descriptions, expert inputs, published vegetation studies and field observations what the key environmental determinants are for each vegetation type, and use this information to develop an identification key to the vegetation types being mapped.

Vegetation type mapping is generally not concerned with mapping plant assemblage boundaries, but rather mapping higher-order spatial scale environmental discontinuities such as aspect, slope, elevation, soil, geology and landform. These are the same variables used to define land types, hence the close historic association between land types and vegetation types. The identification key developed here uses only broad environmental variables to define vegetation units stratified by bioregions or biomes, which represent the major climatic gradients present in the province.

As the first step in remapping the vegetation type boundaries of the NW, a basic identification key to the vegetation types of the province based on mappable environmental variables was developed. This key provided the quantitative framework within which input environmental and imagery datasets could be interpreted and vegetation boundaries mapped in the GIS. The key was based primarily on environmental attributes, but to increase utility for vegetation type identification in the field, broad vegetation structural attribute data was also included in the key. Vegetation structural characteristics are a function of underlying environmental attributes but are not always observable in single observation colour aerial imagery and therefore are not necessarily a reliable variable to use for mapping vegetation.

Species data

Plant species information was collated from existing data sources, as well as from data collected by this project. Data sources include:

1. Herbarium record data from SANBI's POSA database (SANBI 2016).
2. Published vegetation surveys that have been collated and archived in SANBI's National Vegetation Map Database (NVD).
3. Rapid vegetation survey plots and species observations conducted by this project and added to iNaturalist.

A current global species list for the province was created from herbarium record data. The purpose of the global species list was to provide a total flora context for the vegetation survey plot data and also provide a master species list against which to compare and correct plot species data. Data from SANBI's POSA database was obtained via a direct data request. The NW includes all or part of 229 unique quarter degree squares (QDS).

Vegetation survey plot data from most of the phytosociological studies that have been undertaken in the province have been collated and archived in the NVD. This is a national database that strives to archive all published vegetation survey data in South Africa. The database currently hosts data for about 58 000 plots. Plots from in and around the NW were extracted from this database for analysis. The purpose of this data was to: (1) inform the important species information in the vegetation type descriptions; and (2) to conduct an ordination analysis to compare the numerical

Table 2. Summary of the input datasets informing the mapping process

Original data source		Derived data layer name	Data format	Source
Digital Elevation Model (DEM)	1	Elevation (JAXA 30m DEM) (Figure 3A)	Raster	Japan Aerospace Exploration Agency (JAXA)
	2	Slope	Raster	This project using ArcGIS and Whitebox terrain analysis tools
	3	Aspect	Raster	
	4	Topographic position	Raster	
Geology	5	1:250 000 Geology of South Africa simplified to basic geological types (Figure 6A). Lithostratigraphic nomenclature of geological types are dispensed with in favour of simplified geological descriptions that link more closely with geology general physical and chemical properties.	Vector poly	Council for GeoScience Simplified types – this project
Modelled hydrology from DEM	6	Streamlines	Vector line	This project using Whitebox hydrological tools
	7	Catchments	Vector poly	
	8	Flow accumulation (indication of catena position)	Raster	
Hydrology	9	DWA Quinary Catchments	Vector poly	Department of Water and Sanitation (DWS)
	10	1:50 000 topographical map streamlines	Vector line	National Geo-spatial Information (NGI)
Wetland maps	11	National Wetland Atlas Map 6 Beta	Vector poly	South African National Biodiversity Institute (SANBI)
	12	Modelled depression wetlands of the Vaal subcatchment	Vector poly	SANBI
High-Resolution Aerial Imagery	13	ArcGIS Pro Online World Imagery	Raster	Environmental Systems Research Institute, Inc. (ESRI)
	14	Google Earth	Raster	Google Earth
	15	NGI RSA 2012 25 cm colour aerial	Raster	NGI
Vegetation maps	19	NW Bredenkamp and Brown 2003a (Figure 7A)	Vector poly	North West Department of Economic Development, Environment, Conservation and Tourism (NW DEDECT)
	20	National Vegetation Map 2018 (Figure 7B)	Vector poly	SANBI
	21	Agricultural land types (Figure 6B)	Vector poly	Department of Agriculture, Land Reform and Rural Development Agriculture Geographic Information System (AGIS)
Species data	22	National Vegetation Database of existing relevés (Figure 2)	Point	SANBI
	23	POSA quarter degree square (QDS) herbarium records	Polygon	SANBI
	24	Field survey plots and observations (iNat)	Point	This project

classification plot data versus the current classification of vegetation types.

The purpose of the rapid vegetation survey was to gather species and vegetation type (plant community and dominant species) observation data and photographs of vegetation types over as wide an area as possible in a limited time period. Field work was carried out over two growth seasons (2021/22 and 2022/23). The sampling method relied on noting discernible changes in the vegetation type along a catenal sequence then filling in a prescribed data sheet. A mobile version of the vegetation map was available on the CarryMap application for use in the field. This included both the 2018 version of the national map, as well as an unpublished NW vegetation map created by P. Desmet (NW READ 2015). This mobile app allowed for the live tracking of an individual as they move through the landscape and the identification of the existing mapped vegetation type present at a sampling location. Dominant species for a vegetation type were identified and noted and species with ethnobotanical importance, limited distribution or threatened and protected species were photographed and lodged on the iNaturalist App (https://www.inaturalist.org). Representative photographs of the vegetation type at each site were also uploaded with each species observation, and these were linked to the South African Vegetation Map project in iNaturalist.

Additional vegetation observation data from two previous field campaigns conducted by the authors in 2015 and 2018 were also collated and added to the observation database.

Expert data

Vegetation experts with experience of either mapping or using the provincial vegetation map were also engaged to canvas their opinion on what needed to be changed or updated in the revised map. Input from experts comprised either (1) verbal inputs, (2) relevé datasets that were not currently in the NVD or, (3) relevant documents or spatial data such as unpublished reports or GIS shapefiles that were not considered in Mucina and Rutherford (2006).

Results

Species data

In total 2 985 plots were extracted from the NVD that fall in or within 20 km of the NW (Figure 2). Of this 1 608 (54%) have no accurate georeference, i.e., locality information comprising a description only with no sample point latitude/longitude. For these plots, a geolocation was added based on the nearest town or area

Table 3. The most abundant species in North West province per growth form in the NVD plot data. Occurrence is expressed as percentage (%) presence in 2 985 plots analysed. Species names are abbreviated to species level only with no subspecific taxa considered in the analysis

Rank	Grass (Poaceae) species	%	Woody species	Family	%	Forb species	Family	%
1	*Aristida congesta*	54.3	*Grewia flava*	Malvaceae	27.0	*Felicia muricata*	Asteraceae	17.6
2	*Themeda triandra*	48.2	*Ziziphus mucronata*	Rhamnaceae	24.6	*Commelina africana*	Commelinaceae	15.1
3	*Heteropogon contortus*	33.0	*Dichrostachys cinerea*	Fabaceae	18.9	*Senecio venosus*	Asteraceae	14.1
4	*Digitaria eriantha*	32.1	*Vachellia karroo*	Fabaceae	18.2	*Dicoma anomala*	Asteraceae	13.7
5	*Brachiaria serrata*	28.3	*Vachellia tortilis*	Fabaceae	17.6	*Anthospermum rigidum*	Rubiaceae	13.3
6	*Eragrostis curvula*	27.9	*Diospyros lycioides*	Ebenaceae	13.4	*Hilliardiella oligocephala*	Asteraceae	13.2
7	*Eragrostis lehmanniana*	26.8	*Elephantorrhiza elephantina*	Fabaceae	13.0	*Schkuhria pinnata*	Asteraceae	12.8
8	*Elionurus muticus*	26.5	*Ehretia rigida*	Boraginaceae	11.2	*Barleria macrostegia*	Acanthaceae	12.6
9	*Setaria sphacelata*	26.0	*Senegalia caffra*	Fabaceae	10.9	*Asparagus laricinus*	Asparagaceae	11.8
10	*Melinis repens*	24.0	*Vachellia erioloba*	Fabaceae	10.9	*Pollichia campestris*	Caryophyllaceae	11.5

Table 3. The most abundant species in North West province per growth form in the NVD plot data. Occurrence is expressed as percentage (%) presence in 2 985 plots analysed. Species names are abbreviated to species level only with no subspecific taxa considered in the analysis (continued)

Rank	Grass (Poaceae) species	%	Woody species	Family	%	Forb species	Family	%
11	*Cynodon dactylon*	23.4	*Searsia leptodictya*	Anacardiaceae	10.8	*Asparagus suaveolens*	Asparagaceae	11.4
12	*Cymbopogon pospischilii*	23.1	*Gymnosporia heterophylla*	Celastraceae	10.8	*Crabbea angustifolia*	Acanthaceae	11.2
13	*Diheteropogon amplectens*	21.9	*Senegalia mellifera*	Fabaceae	10.7	*Kyphocarpa angustifolia*	Amaranthaceae	10.8
14	*Eragrostis rigidior*	19.5	*Tarchonanthus camphoratus*	Asteraceae	10.0	*Asparagus africanus*	Asparagaceae	10.7
15	*Pogonarthria squarrosa*	18.0	*Searsia lancea*	Anacardiaceae	9.4	*Justicia anagalloides*	Acanthaceae	10.3
16	*Schmidtia pappophoroides*	17.9	*Vachellia hebeclada*	Fabaceae	8.6	*Gazania krebsiana*	Asteraceae	9.1
17	*Eragrostis racemosa*	17.5	*Ziziphus zeyheriana*	Rhamnaceae	8.6	*Solanum campylacanthum*	Solanaceae	9.0
18	*Trachypogon spicatus*	17.4	*Searsia pyroides*	Anacardiaceae	8.1	*Indigofera daleoides*	Fabaceae	8.8
19	*Schizachyrium sanguineum*	16.1	*Combretum molle*	Combretaceae	8.0	*Monsonia angustifolia*	Geraniaceae	8.5
20	*Panicum maximum*	15.3	*Terminalia sericea*	Combretaceae	7.6	*Hermannia depressa*	Malvaceae	8.4
21	*Stipagrostis uniplumis*	14.7	*Dombeya rotundifolia*	Malvaceae	7.4	*Cyanotis speciosa*	Commelinaceae	8.3
22	*Melinis nerviglumis*	14.4	*Combretum apiculatum*	Combretaceae	7.1	*Hermannia tomentosa*	Malvaceae	8.3
23	*Eragrostis superba*	14.2	*Vachellia nilotica*	Fabaceae	6.2	*Lippia scaberrima*	Verbenaceae	8.3
24	*Cymbopogon caesius*	14.0	*Euclea undulata*	Ebenaceae	5.9	*Chamaecrista mimosoides*	Fabaceae	8.2
25	*Eustachys paspaloides*	13.8	*Combretum zeyheri*	Combretaceae	5.7	*Indigofera comosa*	Fabaceae	8.0
26	*Aristida stipitata*	13.2	*Vangueria infausta*	Rubiaceae	5.5	*Nidorella hottentotica*	Asteraceae	8.0
27	*Andropogon schirensis*	12.9	*Euclea crispa*	Ebenaceae	5.3	*Hibiscus pusillus*	Malvaceae	7.7
28	*Triraphis andropogonoides*	12.6	*Zanthoxylum capense*	Rutaceae	5.2	*Waltheria indica*	Malvaceae	7.7
29	*Tragus berteronianus*	12.5	*Protea caffra*	Proteaceae	5.0	*Kohautia amatymbica*	Rubiaceae	7.4
30	*Loudetia simplex*	12.0	*Pappea capensis*	Sapindaceae	5.0	*Limeum viscosum*	Limeaceae	7.4

that could be determined from the plot locality description data, or failing this, locality clues present in the title of the project or source publication. The sampling density of plots is low. For the 2 985 plots selected from the NW plus 20 km buffer, this is a sampling density of approximately 1 plot per 50 km^2; however, only 785 plots fall within the NW equating to a sampling density of approximately 1 plot per 130 km^2.

In total the NVD dataset contains 28 705 records for 1 610 species (Table 3). This equates to a sampling density of approximately 1 record per 5 km^2. Note that only genus and species are considered here and no subspecific taxa are considered. In contrast to the vegetation survey plot data, the global species list, derived from POSA herbarium record data for the province at the genus and species levels, contains 3 040 taxa of which 407 are not native (Table 4). That means for indigenous species (2 633 taxa) only 61% of species known to occur in the province have been recorded in nearly 3 000 vegetation survey plots.

Vegetation type identification key

An identification key for the vegetation types of the NW (Table 6) was developed based on 15 broad environmental variables grouped into five variable categories (Table 5). The identification key is able to discriminate and identify all 36 terrestrial vegetations types that occur in the province plus the three 'azonal' types associated with hydrologically driven ecosystems.

Summary of changes made to the vegetation map

Changes to the NW vegetation map are summarised according to the potential types of changes described by the National Vegetation Map Committee (Table 7). The changes in vegetation type extents are summarised in Table 8.

Table 4. The 100 most widespread indigenous plant species in North West province as recorded in the POSA herbarium dataset. QDS = the number of unique quarter degree squares in the North West province in which a species is recorded (total QDS in NW = 229)

	Species name	Family	QDS		Species name	Family	QDS		Species name	Family	QDS
1	*Aristida congesta*	Poaceae	103	35	*Aptosimum elongatum*	Scrophulariaceae	51	69	*Gymnosporia buxifolia*	Celastraceae	40
2	*Eragrostis curvula*	Poaceae	94	36	*Ozoroa paniculosa*	Anacardiaceae	51	70	*Indigofera daleoides*	Fabaceae	40
3	*Commelina africana*	Commelinaceae	93	37	*Ziziphus mucronata*	Rhamnaceae	51	71	*Panicum maximum*	Poaceae	40
4	*Digitaria eriantha*	Poaceae	92	38	*Helichrysum nudifolium*	Asteraceae	50	72	*Pavetta zeyheri*	Rubiaceae	40
5	*Aristida stipitata*	Poaceae	78	39	*Solanum campylacanthum*	Solanaceae	49	73	*Pavonia burchellii*	Malvaceae	40
6	*Stipagrostis uniplumis*	Poaceae	75	40	*Vahlia capensis*	Vahliaceae	49	74	*Wahlenbergia undulata*	Campanulaceae	40
7	*Melinis repens*	Poaceae	74	41	*Pollichia campestris*	Caryophyllaceae	48	75	*Cyperus decurvatus*	Cyperaceae	39
8	*Searsia pyroides*	Anacardiaceae	74	42	*Barleria macrostegia*	Acanthaceae	47	76	*Eragrostis rigidior*	Poaceae	39
9	*Diospyros lycioides*	Ebenaceae	71	43	*Hermbstaedtia odorata*	Amaranthaceae	47	77	*Hibiscus pusillus*	Malvaceae	39
10	*Grewia flava*	Malvaceae	70	44	*Lantana rugosa*	Verbenaceae	47	78	*Polygala hottentotta*	Polygalaceae	39
11	*Themeda triandra*	Poaceae	65	45	*Senna italica*	Fabaceae	47	79	*Trichoneura grandiglumis*	Poaceae	39

Table 4. The 100 most widespread indigenous plant species in North West Province as recorded in the POSA herbarium dataset. QDS = the number of unique quarter degree squares in the North West province in which a species is recorded (total QDS in NW = 229) (continued)

	Species name	Family	QDS		Species name	Family	QDS		Species name	Family	QDS
12	*Dicoma anomala*	Asteraceae	64	46	*Commelina livingstonii*	Commelinaceae	46	80	*Eustachys paspaloides*	Poaceae	38
13	*Rhynchosia totta*	Fabaceae	62	47	*Monsonia angustifolia*	Geraniaceae	46	81	*Helichrysum argyrosphaerum*	Asteraceae	38
14	*Cymbopogon pospischilii*	Poaceae	61	48	*Ziziphus zeyheriana*	Rhamnaceae	46	82	*Phyllanthus parvulus*	Phyllanthaceae	38
15	*Eragrostis lehmanniana*	Poaceae	61	49	*Cymbopogon caesius*	Poaceae	45	83	*Croton gratissimus*	Euphorbiaceae	37
16	*Eragrostis superba*	Poaceae	61	50	*Eragrostis gummiflua*	Poaceae	45	84	*Cyphocarpa angustifolia*	Amaranthaceae	37
17	*Felicia muricata*	Asteraceae	61	51	*Nidorella resedifolia*	Asteraceae	45	85	*Limeum viscosum*	Limeaceae	37
18	*Setaria sphacelata*	Poaceae	59	52	*Tragus berteronianus*	Poaceae	45	86	*Schoenoplectus muricinux*	Cyperaceae	37
19	*Schmidtia pappophoroides*	Poaceae	58	53	*Corchorus asplenifolius*	Malvaceae	44	87	*Aristida adscensionis*	Poaceae	36
20	*Sporobolus fimbriatus*	Poaceae	58	54	*Eragrostis chloromelas*	Poaceae	44	88	*Elephantorrhiza elephantina*	Fabaceae	36
21	*Vachellia karroo*	Fabaceae	57	55	*Hilliardiella elaeagnoides*	Asteraceae	44	89	*Eragrostis pallens*	Poaceae	36
22	*Eragrostis trichophora*	Poaceae	56	56	*Sphedamnocarpus pruriens*	Malpighiaceae	44	90	*Ipomoea bolusiana*	Convolvulaceae	36
23	*Pogonarthria squarrosa*	Poaceae	56	57	*Tarchonanthus camphoratus*	Asteraceae	44	91	*Scabiosa columbaria*	Dipsacaceae	36
24	*Bulbostylis burchellii*	Cyperaceae	55	58	*Lippia scaberrima*	Verbenaceae	43	92	*Sida chrysantha*	Malvaceae	36
25	*Enneapogon scoparius*	Poaceae	55	59	*Elionurus muticus*	Poaceae	42	93	*Triraphis andropogonoides*	Poaceae	36
26	*Geigeria burkei*	Asteraceae	54	60	*Gazania krebsiana*	Asteraceae	42	94	*Chlorophytum fasciculatum*	Agavaceae	35
27	*Heteropogon contortus*	Poaceae	54	61	*Gomphocarpus fruticosus*	Apocynaceae	42	95	*Olea europaea*	Oleaceae	35
28	*Panicum coloratum*	Poaceae	54	62	*Ipomoea obscura*	Convolvulaceae	42	96	*Salvia runcinata*	Lamiaceae	35
29	*Anthephora pubescens*	Poaceae	53	63	*Searsia leptodictya*	Anacardiaceae	42	97	*Schizachyrium sanguineum*	Poaceae	35
30	*Cynodon dactylon*	Poaceae	53	64	*Teucrium trifidum*	Lamiaceae	42	98	*Terminalia sericea*	Combretaceae	35
31	*Cyperus margaritaceus*	Cyperaceae	53	65	*Xenostegia tridentata*	Convolvulaceae	42	99	*Asparagus suaveolens*	Asparagaceae	34
32	*Aerva leucura*	Amaranthaceae	52	66	*Fingerhuthia africana*	Poaceae	41	100	*Chamaecrista biensis*	Fabaceae	34
33	*Brachiaria nigropedata*	Poaceae	52	67	*Hermannia tomentosa*	Malvaceae	41				
34	*Anthospermum rigidum*	Rubiaceae	51	68	*Mundulea sericea*	Fabaceae	41				

Table 5. Summary of the environmental variables used to construct the identification key in Table 6 used to define and map vegetation types

Hierarchical order of variable	Variable category	Variable name
1	Flooding	(a) alluvial (b) terrestrial
2	Bioregion	(a) Bushveld (b) Kalahari (c) Highveld
3	Terrain	(a) plains (b) mountainous/rocky habitats (including pediments)
4	Geology	(a) aeolian (b) quartzite and sandstone (c) shale and mudstone (d) dolomite (e) igneous mafic (f) igneous felsic
5	Soil	(a) sand (b) clay

Table 6. An identification key to the vegetation types of the North West province based on broad environmental and vegetation structure characteristics

Key level	Environmental variable		Vegetation type
1	Alluvial Vegetation *Vegetation types where the occasional presence of surface water is a primary determinant of the vegetation type, such as valley bottoms, alluvial, wetland or occasionally flooded. Also referred to as azonal vegetation types.*		
1.1	North: Central Bushveld Bioregion	1	Subtropical Alluvial Vegetation
1.2	West: Eastern Kalahari Bioregion	2	Southern Kalahari Mekgacha
1.3	South: Grassland Bioregion	3	Highveld Alluvial Vegetation
2	Terrestrial Vegetation		
2.1	North: Central Bushveld Bioregion		
2.1.1	Mountains and koppies		
2.1.1.1	Shale and mudstone	4	Dwarsberg-Swartruggens Mountain Bushveld
2.1.1.2	Dolomite	5	Madikwe Dolomite Bushveld
2.1.1.3	Norite/gabbro (mafic)	6	Norite Koppies Bushveld
2.1.1.4	Pilanesberg	7	Pilanesberg Mountain Bushveld
2.1.1.5	Quartzite and sandstone	8	Waterberg Mountain Bushveld
2.1.1.6	Granite (felsic)	9	Central Sandy Mountain Bushveld
2.1.2	Plains		
2.1.2.1	Heavy clay (vertisols)		
2.1.2.1.1	West	10	Dwaalboom Thornveld
2.1.2.1.2	Swartruggens (clay soils)	11	Zeerust Thornveld
2.1.2.1.3	Central/Rustenburg	12	Marikana Thornveld
2.1.2.1.4	East/Springbokvlakte	13	Springbokvlakte Thornveld
2.1.2.2	Sand		

Table 6. An identification key to the vegetation types of the North West province based on broad environmental and vegetation structure characteristics (continued)

Key level	Environmental variable		Vegetation type
2.1.2.2.1	Aeolian/Kalahari sand		
2.1.2.2.1.1	West of Crocodile River/Pilanesberg	14	Western Sandy Bushveld
2.1.2.2.1.2	East of Crocodile River/Pilanesberg (more mixed veld broadleaf and acacia)	15	Western Sandy Bushveld (East)
2.1.2.2.2	Fersiallitic soils (medium sandy clay loams with good drainage, derived from mafic (basic) rocks)/undulating landscapes with pronounced catenas	16	Central Sandy Bushveld
2.1.2.2.3	Silica rich sand in valleys derived from quartzite hills (and sometimes Kalahari sand), valleys of the Magaliesberg	17	Moot Plains Bushveld
2.2	West: Eastern Kalahari Bioregion		
2.2.1	Mountains and koppies	18	Kuruman Mountain Bushveld
2.2.2	Plains		
2.2.2.1	Calcrete or dolomite		
2.2.2.1.1	Thornveld	19	Morokweng Thornveld
2.2.2.2.2	Bushveld	20	Ghaap Plateau Vaalbosveld
2.2.2.2	Deep sand over calcrete		
2.2.2.2.1	East	21	Stella Bushveld
2.2.2.2.2	West	22	Kuruman Vaalbosveld
2.2.2.3	Deep sand over dorbank		
2.2.2.3.1	Sand eroding, dorbank and calcrete (along streams) exposed	23	Vryburg Thornveld
2.2.2.3.2	Deep sand (mixed), Molopo catchment	24	Mafikeng Bushveld
2.2.2.3.2	Deep sand (mixed), east of Harts River	25	Schweizer-Reneke Bushveld
2.2.2.3.4	Deeper sand (red)	26	Molopo Bushveld
2.2.2.4	Deep alluvial soils, no occasional flooding	27	Schmidtsdrif Thornveld
2.3	South: Grassland Bioregion		
2.3.1	Mountains and koppies		
2.3.1.2	Quartzite		
2.3.1.2.1		29	Gold Reef Mountain Bushveld
2.3.1.2.2	Montane above 1600 m/pockets of deep sandy soils	30	Waterberg-Magaliesberg Summit Sourveld
2.3.1.3	Shale and mudstone	31	Gauteng Shale Mountain Bushveld
2.3.1.4	Igneous (basalt: dolerite, andesite, etc.)	32	Andesite Mountain Bushveld
2.3.1.5	Granite (includes koppies and plains)	33	Vredefort Dome Granite Grassland
2.3.2	Plains		
2.3.2.1	Sandy soils		
2.3.2.1.1	Potchefstroom eastwards (soil clay content > 20%, depth > 0.5 m) tall grassland > 0.5 m, average annual rainfall > 600 mm	34	Rand Highveld Grassland
2.3.2.1.2	Central (soil clay content < 20%, depth > 0.5 m) tall grassland >0.5 m, average annual rainfall < 600 mm	35	Vaal-Vet Sandy Grassland

Table 6. An identification key to the vegetation types of the North West province based on broad environmental and vegetation structure characteristics (continued)

Key level	Environmental variable		Vegetation type
2.3.2.1.3	West (soil clay content < 25%, depth < 0.5 m) short grassland < 0.5 m often with calcrete in the landscape, average annual rainfall < 600 mm	36	Western Highveld Sandy Grassland
2.3.2.2	Dolomite		
2.3.2.2.1	Mostly grassland	37	Carletonville Dolomite Grassland
2.3.2.2.2	Prominent woody element present, sinkholes filled with Aeolian sand (dolines)	38	Vaal Reefs Dolomite Sinkhole Woodland
2.3.2.3	Clay, undulating landscapes with shallow stony soils derived from igneous, sedimentary or metamorphic rocks		
2.3.2.3.1	West of Bloemhof (*Vachellia tortilis*), average annual rainfall < 500 mm, < 35 frost days per annum	39	Kimberley Thornveld
2.3.2.3.2	East of Bloemhof (*Vachellia caffra* and *V. karroo*), average annual rainfall > 500 mm, > 35 frost days per annum	40	Klerksdorp Thornveld
2.4	Evergreen forest	41	Northern Afrotemperate Forest

Table 7. Summary of the changes made to the North West province vegetation map. Changes are summarised according to the potential type of changes described in the South African National Ecosystem Classification System Handbook* (SANBI 2023)

No.	Types of change
	Minor change
MN1	**Boundary shifts (realignment)** All vegetation type boundaries have been remapped from scratch. See text for rational behind updating boundary mapping. As the current map is based on a map first developed in the 1980s, it is inevitable that most boundaries will change given the better mapping tools and resolution of spatial data available for mapping. Remapping of boundaries does not imply that the original land type map or concept is wrong, just that the boundaries are inaccurate.
MN2	**Creation of a subtype/community within an existing vegetation type** Within FOz 2 **Northern Afrotemperate Forest** a new subvegetation type, **Olea Sclerophyllous Forest**, is discussed but not proposed as a recognised unit as yet. This forest unit is widespread in eastern southern Africa within other vegetation types typically on slopes where fire is excluded.
MN3	**Change in vegetation type name (without spatial or description changes).** *Special circumstances for this change are described in the handbook. Not applicable.
MN4	**Change in vegetation type description, e.g., list of endemic species** All vegetation type descriptions have been updated based on: (1) Mucina and Rutherford (2006) vegetation map description. (2) Bredenkamp and Brown (2003a) vegetation map descriptions. (3) Field observations. (4) Species information in the NVD relevé database. (5) Vegetation accounts in relevant scientific papers, theses and reports. (6) Inputs from expert stakeholders. Endemic species have not been re-assessed. Refer to Hahn (2013) for a detailed analysis and description of species endemic to the NW.
MN5	**Boundary shifts when neighbouring country or coastal borders are redefined** Not applicable.

Table 7. Summary of the changes made to the North West province vegetation map. Changes are summarised according to the potential type of changes described in the South African National Ecosystem Classification System Handbook* (SANBI 2023) (continued)

No.	Types of change
MN6	**The creation of new polygons of an existing vegetation type that may be disjunct from existing polygons of that type and beyond a reasonable* range extension or reduction.** *To be determined by the National Vegetation Map Committee on a case-by-case basis. Two existing vegetation types are included in the province that were previously not mapped as occurring in the province, namely, **Subtropical Alluvial Vegetation** and **Waterberg Mountain Bushveld**. The current map does not have any alluvial vegetation category in the Bushveld region. Given the presence of several large rivers, as well as extensive floodplain ecosystems it is necessary to bring **Subtropical Alluvial Vegetation** into the province to accommodate these ecosystems. This alluvial ecosystem type is not indicated as occurring in the province in the 2018 version of the National Vegetation Map, however, it should be noted that this type was present in the 2006 version of the National Vegetation Map to accommodate the Kgomo Kgomo floodplain along the Moretele River. **Waterberg Mountain Bushveld** occurs just north of the province. Mountain bushveld vegetation on quartzite along the northern border of the province should be assigned to this vegetation unit as these mountains are contiguous with the Waterberg Mountain complex (Partridge et al. 2010), and while the mountain bushveld vegetation is similar to that of the northern Bankenveld in terms of structure and species, the mountains are geographically separate.
	Major change
MJ1	**Removal of a vegetation type from the classification system or downgrading a type to a level below a vegetation type, e.g., subtypes.** Not applicable.
MJ2	**Create new vegetation type (replace existing) or upgrading of a subtype to a type.** Three new vegetation types are proposed namely, **Vryburg Thornveld, Morokweng Thornveld** and **Central Sandy Mountain Bushveld**. These are not new vegetation concepts. All three types have been recognised and mapped by previous authors; however, these units were (erroneously) lumped with other vegetation types with the creation of the 2006 National Vegetation Map. Both **Vryburg Thornveld** and **Morokweng Thornveld** exist as units in the land type map and are recognised as distinct phytosociological units by Smit (2000), namely, *Acacia erioloba – Acanthosicyos naudinianus – Dichrostachys cinerea* vlaktes (plains) and *Acacia mellifera – Acacia hebeclada – Heliotropium ciliatum* sandvlaktes (sandplains), respectively. In Bredenkamp and Brown (2003a) **Vryburg Thornveld** is retained as unit but not **Morokweng Thornveld**, however, in Mucina and Rutherford (2006) both units are lost. **Morokweng Thornveld** (Figure 8) is associated with a karst landscape with very extensive surface calcrete and dolomite. The vegetation is a short, arid thornveld that is floristically and structurally distinct from the surrounding woodlands on deep Kalahari sand. The most closely related existing vegetation type in terms of habitat type, Ghaap Plateau Vaalbosveld, is compositionally and structurally unrelated to this vegetation unit and therefore there are no grounds for extending the Ghaap Plateau Vaalbosveld vegetation type to include the vegetation of the Morokweng karstland. **Vryburg Thornveld** (Figure 9) occupies the headwaters of the Molopo River catchment that is characterised by incised/eroding landscapes along stream margins. Exposed dorbank and calcrete (along streams) occurs. Frequent springs, decanting from the neighbouring Ghaap Plateau, support hydromorphic grasslands and wetlands in the valley bottoms. The vegetation here is sparse woodland dominated by very tall *Vachellia erioloba* trees and scattered low *Vachellia hebeclada* thickets. Most of the broad-leaved woody elements and dense woodland structure of the related Mafikeng Bushveld are absent. Whilst **Vryburg Thornveld** exists as a vegetation type name in Bredenkamp and Brown (2003a), **Morokweng Thornveld** is an entirely novel derivation named after the town located in this vegetation type. **Central Sandy Mountain Bushveld** includes the vegetation on mountains and koppies currently included within the Central Sandy Bushveld vegetation type. The definition of Central Sandy Bushveld is refined to include only the plains vegetation type within the current delimitation of the vegetation type on soils derived from igneous rocks. Vegetation on vertic clay soils within the current delimitation of Central Sandy Bushveld are reassigned to Springbokvlake Thornveld. This split of central sandy woodland vegetation in mountain bushveld and (plains) bushveld also aligns better to the vegetation type model developed here.

Table 7. Summary of the changes made to the North West province vegetation map. Changes are summarised according to the potential type of changes described in the South African National Ecosystem Classification System Handbook* (SANBI 2023) (continued)

No.	Types of change
	Central Sandy Mountain Bushveld is being reinstated as a vegetation type having been grouped with Central Sandy Bushveld in the National Vegetaiton Map since 2006. It is a well-established vegetation type recognised by several previous authors. It is synonymous with Van der Meulen's *Combretum molle – Diheteropogon amplectens* order described in his vegetation map of the western Transvaal bushveld (Van der Meulen & Westfall 1979); Brown's *Pappea capensis – Combretum apiculatum* (mountain) bushveld vegetation type described for the vegetation study of the Borakalalo Nature Reserve (Brown & Bredenkamp 1994; Brown et al. 1995, 1996 and 1997); and Bredenkamp and Brown's (2003a) Mogosane Mountain Bushveld and Central Mixed Bushveld vegetation types in their vegetation map of the NW. The rationale for why this unit was not incorporated into the 2006 National Vegetation Map is not recorded anywhere.
MJ3	**Reassignment of a community in a vegetation type from an existing vegetation type to another existing vegetation type**
	Not applicable.
MJ4	**Extension of the range of an existing vegetation type far beyond the current extent (to be determined by committee)**
	See MN6 above.

Figure 8. A comparison of Morokweng Thornveld west of Morokweng (B) to what it is currently mapped as in the National Vegetation Map (A, Mafikeng Bushveld east of Heuningvlei), and what it is most similar to in terms of soil and geology (C, Ghaap Plateau Vaalbosveld north of Reivilo). Morokweng Thornveld is a short, open to dense thornveld dominated by the trees *Senegalia mellifera* and *Vachellia hebeclada*, with a sparse grass but rich herb layer and with abundant surface calcrete on dolomite geology. Mafikeng Bushveld occurs on deep red Kalahari sand and is a tall open mixed woodland with an abundance of geoxylic shrubs. Ghaap Plateau Vaalbosveld also has an abundance of surface calcrete on dolomite geology, but the vegetation has a distinctive grassland character dominated by *Themeda triandra* and dense trees are confined to distinctive kluftkarren geological features in the landscape.

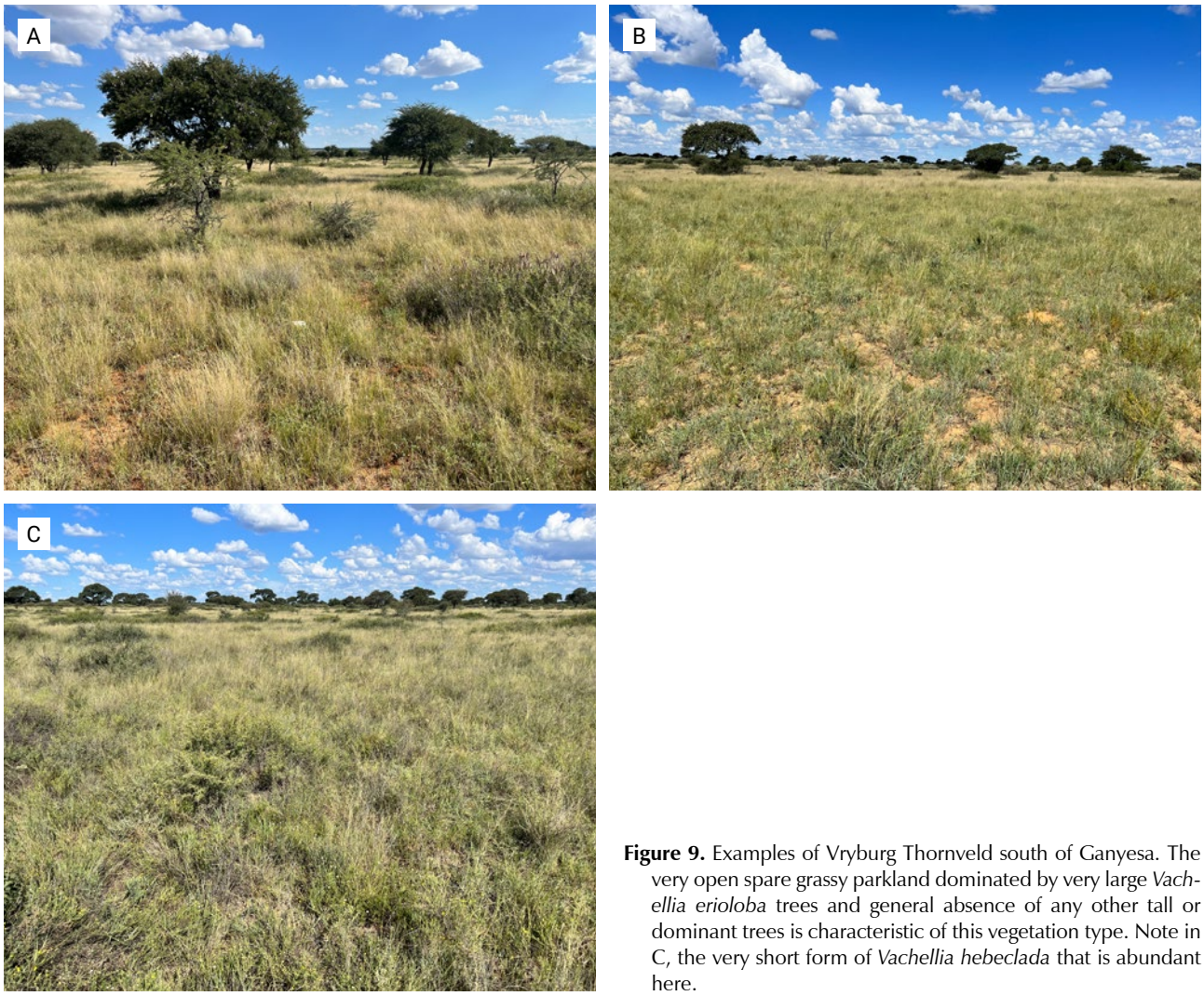

Figure 9. Examples of Vryburg Thornveld south of Ganyesa. The very open spare grassy parkland dominated by very large *Vachellia erioloba* trees and general absence of any other tall or dominant trees is characteristic of this vegetation type. Note in C, the very short form of *Vachellia hebeclada* that is abundant here.

Revised vegetation map

The revised vegetation map contains 1 810 polygons compared to the current vegetation map that has 159 polygons (Figure 10). Whilst the vegetation type concepts remain mostly unchanged from Mucina and Rutherford (2006), polygon boundaries have been entirely remapped, and this has resulted in significant changes in extent from most vegetation types (Table 8). The remapping of boundaries is an inevitable product of the much higher resolution mapping informants available to this project, as well as the application of the vegetation type identification key.

Updated descriptions of North West terrestrial vegetation types

The vegetation type descriptions have been updated (Supplementary Material 2: Vegetation type descriptions) to reflect new data available and to better align with the vegetation type identification key (Table 6). Descriptions are based on the original descriptions that appear in Mucina and Rutherford (2006) and where necessary these have been updated based on the inputs presented in Table 9.

Discussion

The revised vegetation map is significantly changed mainly with respect to where the boundaries of vegetation types are mapped. Whilst there are some changes proposed to the classification of vegetation types, for the most part, the current vegetation type concepts remain unchanged. The change in the mapping of vegetation type boundaries is an inevitable result of: (1) a clearer understanding of vegetation determinants (i.e., vegetation type classification framework or identification key); and more importantly, (2) the much-increased resolution and availability of mapping informants. It is very important to note that the significant change in mapped boundaries does not suggest or imply in any way that the current vegetation type concepts are invalid.

The vegetation identification key is important for informing the current vegetation map revision. It also

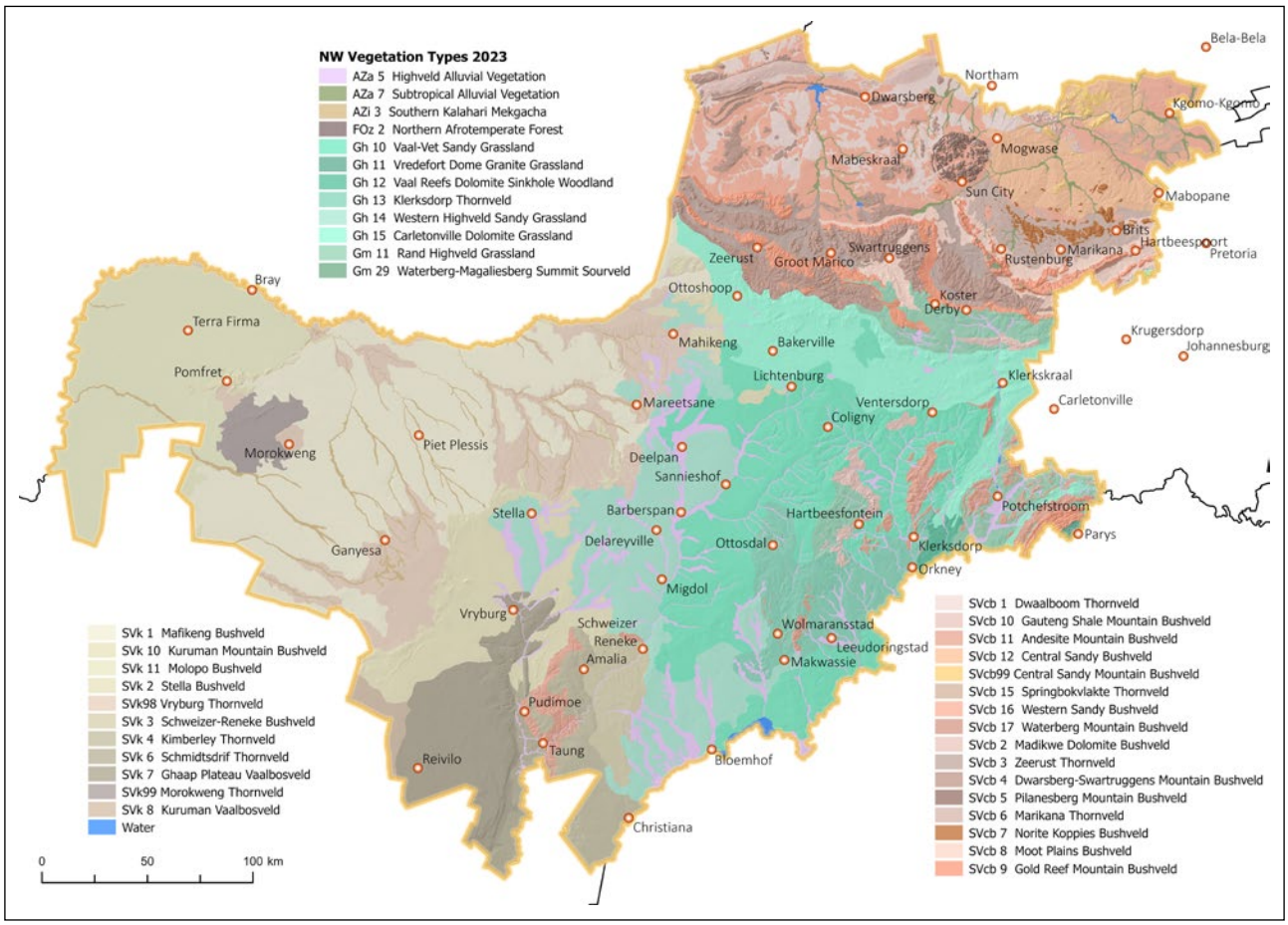

Figure 10. The revised 2023 vegetation map of the North West province (NW). The legend colour scheme follows that of the existing National Vegetation Map (NVM).

Table 8. Summary of the change in extent of South African vegetation types between the 2006 (2018) National Vegetation Map (NVM) and the 2023 revised North West province (NW) vegetation map

Mapcode	SA vegetation type name	Area (ha)		% Change 2006 to 2023
		NVM 2006	NW 2023	
AZa5	Highveld Alluvial Vegetation	175 789	424 274	141
AZa7	Subtropical Alluvial Vegetation		67 979	
AZi3	Southern Kalahari Mekgacha	22 392	126 031	463
FOz2	Northern Afrotemperate Forest	634	2 279	260
Gh10	Vaal-Vet Sandy Grassland	809 573	1 051 812	30
Gh11	Vredefort Dome Granite Grassland	5 354	4 449	-17
Gh12	Vaal Reefs Dolomite Sinkhole Woodland	29 856	26 543	-11
Gh13	Klerksdorp Thornveld	393 029	320 207	-19
Gh14	Western Highveld Sandy Grassland	858 938	675 345	-21
Gh15	Carletonville Dolomite Grassland	643 165	570 810	-11
Gm11	Rand Highveld Grassland	282 159	265 257	-6
Gm29	Waterberg-Magaliesberg Summit Sourveld	2 060	2 160	5
Gm8	Soweto Highveld Grassland	6 951		-100
SVcb1	Dwaalboom Thornveld	552 034	274 473	-50

Table 8. Summary of the change in extent of South African vegetation types between the 2006 (2018) National Vegetation Map (NVM) and the 2023 revised North West province (NW) vegetation map (continued)

Mapcode	SA vegetation type name	Area (ha)		% Change 2006 to 2023
		NVM 2006	NW 2023	
SVcb10	Gauteng Shale Mountain Bushveld	16 907	64 636	282
SVcb11	Andesite Mountain Bushveld	63 753	179 521	182
SVcb12	Central Sandy Bushveld	259 079	304 120	17
SVcb99	Central Sandy Mountain Bushveld		29 247	
SVcb15	Springbokvlakte Thornveld	157 706	22 489	-86
SVcb16	Western Sandy Bushveld	104 103	409 672	294
SVcb98	Western (Eastern) Sandy Bushveld		114 866	
SVcb17	Waterberg Mountain Bushveld		523	
SVcb2	Madikwe Dolomite Bushveld	74 839	83 900	12
SVcb3	Zeerust Thornveld	412 599	131 322	-68
SVcb4	Dwarsberg-Swartruggens Mountain Bushveld	264 463	412 887	56
SVcb5	Pilanesberg Mountain Bushveld	43 464	36 792	-15
SVcb6	Marikana Thornveld	151 015	126 150	-17
SVcb7	Norite Koppies Bushveld	21 859	41 946	92
SVcb8	Moot Plains Bushveld	249 632	139 696	-44
SVcb9	Gold Reef Mountain Bushveld	128 104	229 978	80
SVk1	Mafikeng Bushveld	1 401 610	1 122 451	-20
SVk10	Kuruman Mountain Bushveld	23 811	123 195	417
SVk11	Molopo Bushveld	1 569 288	1 015 032	-35
SVk2	Stella Bushveld	322 284	476 445	48
SVk3	Schweizer-Reneke Bushveld	202 752	133 540	-34
SVk4	Kimberley Thornveld	482 231	190 398	-61
SVk6	Schmidtsdrif Thornveld	44 792	66 082	48
SVk7	Ghaap Plateau Vaalbosveld	638 861	413 785	-35
SVk8	Kuruman Vaalbosveld	75 225	45 689	-39
SVk98	Vryburg Thornveld		648 532	
SVk99	Morokweng Thornveld		100 159	

serves a far greater purpose beyond just this vegetation map revision. Firstly, it enables users of the vegetation map to clearly understand how vegetation is assigned to different vegetation types and therefore users can apply the classification framework to mapping vegetation at finer spatial scales. When mapping vegetation at the provincial scale there are time and budget constraints limiting the amount of detail that can be mapped relative to what can be observed in the informants. It is not practically possible to manually map vegetation at infinitely fine scales over large regions. Therefore, there are inherent boundary or misclassification errors in the final map product due to mapping scale. Using the vegetation type identification key it is possible for users of the map to apply the classification framework at a fine or local spatial scale to improve mapping accuracy or interpretation for specific purposes, for example, fine-scale vegetation mapping for environmental impact assessments.

Secondly, the identification key can illuminate inconsistencies in the current vegetation type classification and

Table 9. Summary of the inputs used to update the vegetation type descriptions

Distribution	Where appropriate the description of vegetation type distribution within the NW has been updated to reflect the distribution as represented in the revised vegetation map
Altitude	Altitudinal ranges are updated for the NW based on the elevation derived from the Aster GDEM.
Vegetation and landscape features	Updated with Bredenkamp and Brown (2003a) and the authors observations.
Geology and soils	Updated with authors observations, Bredenkamp and Brown (2003a), agricultural land types and simplified geology. The lithostratigraphic geological descriptions used in the current vegetation type descriptions are dispensed with in favour of simplified descriptions of basic geological rock types that link more closely geology, general physical and chemical properties, e.g. quartzite, basalt, granite, etc.
Climate	Climate data is not added here as this information is deemed to remain unchanged from that published in Mucina and Rutherford (2006).
Important taxa	Is based on Bredenkamp and Brown (2003a), NVD relevé data, vegetation plots collected as part of this project and authors observations. Only species that are considered to be important for identifying or differentiating the vegetation type are listed. The original and more detailed list of important taxa as published in Mucina and Rutherford (2006) are dispensed with here as these tend to be lists of all taxa encountered in a vegetation type rather than being diagnostic or characteristic species of the vegetation type or specific communities with a vegetation type. Feedback from stakeholders has indicated that these lists contain little value in terms of understanding the structure and composition or differentiating vegetation types. Important taxa are listed in order of abundance or dominance (d = dominant species) where this data is available in existing descriptions. Where this information is not available species are listed alphabetically.
Conservation	Is not discussed here as this would require consideration of the extent of vegetation types outside of the province, as well as compilation of an updated landcover and protected area database. This analysis would be better addressed once this vegetation map has been integrated with the National Vegetation Map.
Remarks	Updated with authors and stakeholders' observations. Included here are observations regarding further work that needs to be done to clarify/update the vegetation type definition, description or mapping.
References	Updated with relevant references post Mucina and Rutherford (2006) and includes unpublished reports.

thus identify where vegetation types could be split, aggregated or new ones defined. For example, one such inconsistency highlighted with this project relates to the definition and mapping of Central Sandy Bushveld. This vegetation type contains both plains and mountain habitat, as well as several major geological rock types (granite and quartzite/sandstone). It is likely that applying a similar vegetation type classification as used here to elsewhere in South Africa will identify inconsistencies in the definition and mapping of vegetation types.

A stated objective of this project was to conduct a quantitative floristic analysis to find support for the vegetation type concepts using the available relevé database. This objective was not achieved within the allocated project time period. Quantitative floristic analysis to validate the vegetation type concepts used in the National Vegetation Map is a major research gap that should be addressed not only for the NW, but also more broadly in South Africa. These analyses should be earmarked as a future research priority.

There is some support in the literature for the vegetation type concepts as framed in the vegetation type identification key. For example, the Bredenkamp and Brown (2003b) analysis of the Bankenveld area supports the mountain vs plains vegetation distinction, as well as separation of grasslands based on moisture availability, soil texture and depth. Within the mountain category, vegetation units are separated based on aspect and elevation rather than geological rock type. This does suggest that within the current vegetation type classification there will be a necessary and pragmatic trade-off between ecological units that are easy to map and identify (viz. discrete mountains with similar geology) versus phytosociologically correct units that are more complex to map (viz. aspect and elevation gradients). Similarly, the Winterbach (1998) and Winterbach et al.

(2000) analysis of the Arid Sweet Bushveld region also supports the major environmental divisions associated with higher-order vegetation associations, namely, clay vs sandy soils on plains, and plains vs mountains. Both these studies suggest that it is highly likely that the current vegetation type concepts can be supported and further refined through quantitative floristic analysis.

A deficit of observations on the iNaturalist app for the NW was noted. iNaturalist is a very accessible and practical tool for collecting and identifying biodiversity information. Two training workshops were held with DEDECT officials to introduce them to the potential of the iNaturalist and the Carrymap apps. Within the province the iNaturalist app could have future applications for gathering biodiversity data, monitoring environmental compliance; to improve decision making in the EIA process; and to monitor the distribution of invasive alien species. Within the context of this study, iNaturalist proved very useful for capturing and linking field observations to a national database. Species observations in iNaturalist were uploaded together with context photographs of the vegetation type and linked to an iNaturalist National Vegetation Map project managed by SANBI. This project is using iNaturalist to collect representative photographs of all South African vegetation types.

An interesting observation with regards the species data is the large disparity between observations collected via survey plots versus herbarium records. Nearly 40% of the province's flora has never been recorded in a vegetation survey plot. This observation can be partly due to the fact that surveying flora for vegetation analysis (i.e., relevés) tends to under report or omit uncommon and rare species. This observation can also be due to under sampling of the province for vegetation analysis. The very low sampling density of relevés; the tendency for samples to be clumped rather than uniformly distributed; and the disparity in species records between herbarium versus plot data would suggest that from a vegetation description and analysis perspective that the NW is significantly under sampled. As highlighted above there is still a need for further floristic surveys and analysis to better understand and describe our vegetation types.

This revision of the NW vegetation map has focused on the terrestrial ecosystems of the province and therefore the descriptions of 'azonal' ecosystems are not updated here. Consideration of these ecosystems is, however, central to the mapping process, as well as understanding of terrestrial ecosystems. In the mapping process these ecosystems are generally always mapped first as they are often the easiest units to identify, more importantly they provide a concrete starting point for interpreting the input data in relation to the identification key and ultimately understanding vegetation/landscape patterns. The NW has for the most part relatively flat landscapes that support wide floodplain/alluvial ecosystems and extensive endorheic pan ecosystems. The province also straddles three major biogeographic regions that influence the vegetation composition of these ecosystems. Therefore, there is a great extent and diversity of azonal systems, and it has been necessary to map the larger occurrences of these ecosystems to have more consistent environmental and floristic definitions of terrestrial ecosystems.

In the revised vegetation map the extent of azonal ecosystems has been significantly extended from the 198 000 ha or 2% in the 2006 vegetation map to 618 000 ha or 6% of the province in the present map. Mapping has focused on azonal ecosystems associated with drainage lines and there has been no attempt to map endorheic pan systems except where these are associated with drainage lines.

It must be noted that during this project there was extensive discussion amongst stakeholders of the appropriateness of the term 'azonal'. In the NW context these ecosystems include all ecosystem types where the occasional occurrence of surface water and waterlogged soils is amongst the primary environmental determinants of ecosystem structure, function and definition. The term azonal could apply to any ecosystem with limited extent or that occurs widely across the landscape as a distinct feature within other ecosystems. The term is also discriminatory towards aquatic/wetland ecosystems as azonal can imply ecosystems of lesser importance or status. In the terrestrial realm collective terms such as grassland or savanna are used to group ecosystems. These terms are broadly descriptive of the nature of the contained ecosystems. Conversely, the term azonal in the context of the NW vegetation map does not convey the very important fact that the contained ecosystems are all determined and driven by water and hydrological processes. Whilst the use of the term 'azonal' is retained here, it is highly recommended that a new collective term for ecosystems driven by water be sought that is accepted by other terrestrial and aquatic/wetland ecologists. For the three azonal ecosystems considered in the NW vegetation map, the term 'alluvial' ecosystems would be a much more appropriate descriptive name.

Azonal ecosystems have been grouped into three existing ecosystem types, each associated with the three major river catchments/bioregions of the province. They are:

1. AZa 5 Highveld Alluvial Vegetation in the Highveld/Vaal River catchment including AzF3 Eastern Temperate Freshwater Wetlands.
2. AZi 3 Southern Kalahari Mekgacha in the Kalahari/Molopo River catchment.
3. AZa 7 Subtropical Alluvial Vegetation in the Bushveld/Crocodile River catchment.

Notable fluvial landscapes of the province include:

1. Kgomo-Kgomo/Tswaing area has extensive grassland floodplains (AZa 7 Subtropical Alluvial Vegetation) associated with several rivers flowing northwards out of Gauteng into the Pienaars/Moretele River and includes the Apies, Tshwane and Kutswane rivers. These floodplain ecosystems are unique within the NW and possibly within the Bushveld Bioregion. The only other area in South Africa with similar floodplain ecosystems is the Nylsvlei in Limpopo. Unfortunately, these ecosystems are being heavily impacted by sprawling peri-urban and rural settlements. This area is in great need of conservation action, as well as wetland rehabilitation.
2. The *Senegalia galpinii* riparian gallery forest on the Crocodile River, where the Moretele River enters, is one of the most iconic AZa 7 Subtropical Alluvial Vegetation riparian communities in the province.
3. The Mooi River catchment above the Klerkskraal Dam is possibly the largest and most intact mesic fluvial system on the western Highveld (mapped as AZa 5 Highveld Alluvial Vegetation in this map and as Temperate Freshwater Wetlands in the 2006 vegetation map), and as such should receive greater conservation focus, as it is essentially the last remaining intact grassland catchment landscape on the western Highveld.
4. Very extensive grassland floodplain systems (AZa 5 Highveld Alluvial Vegetation) are mostly associated with Gh 14 Western Highveld Sandy Grassland. These fluvial systems cover nearly 250 000 ha. Distinct features of these fluvial systems are the presence of surface calcrete; the general lack of well-defined river channels; and are often associated with networks of pans indicative of palaeo-river channels (mapped as AZi 10 Highveld Salt Pans in the SA Vegetation Map); and the singular dominance of the tree *Searsia lancea*.
5. A defining environmental characteristic of AZi 3 Southern Kalahari Mekgacha is the presence of surface calcrete indicating the 'riverbed'. A unique vegetation feature associated with this calcrete not identified by previous authors is the abundance of species with Nama Karoo affinities such as *Pentzia incana* (Asteraceae), *Ruschia griquensis, Ruschia semidentata, Ruschia spinosa* (Aizoaceae) and various Zygophyllaceae and Acanthaceae. This is the only vegetation type within the Kalahari bioregion where succulent taxa are encountered in any abundance and represents the only major incursion of Nama Karoo biome affinities into the NW and the Savanna biome.

Much of south-central NW has been ploughed for crop production and this makes observing vegetation type boundaries on the ground, or at least where they used to occur, almost impossible to observe. This is particularly difficult across the transitions of Highveld grassland types that are the primary target of cultivation. Whilst these boundaries are not clearly observable today, having a clear vegetation–environment model does make predicting where these boundaries are likely to be much easier. This reinforces the importance of having such a model for mapping and describing vegetation types, and it would be beneficial if this model could be extended to include all vegetation types in South Africa.

Conclusions

The revised vegetation map of the NW is a significant improvement on the 2018 National Vegetation Map and has been incorporated into the current NVM 2024 beta release. Firstly, the vegetation type classification model based on five broad environmental variables (flooding, bioregion, terrain, geology and soil) provides a consistent and explicit framework for understanding the distribution and hence mapping vegetation types. Whilst agricultural land types remain a good proxy for mapping vegetation, breaking these units down in their underlying environmental determinants (soil and topography) and mapping these provide better proxies for mapping vegetation. Secondly, the abundance of high-resolution remote sensing products, relative to the 1980s when land types were mapped, means that vegetation type boundary accuracy is significantly improved. Thirdly, although a quantitative phytosociological analysis was not able to be completed, based on the description of existing vegetation types, the available literature, stakeholder inputs and field observations, the current vegetation type concepts are valid units. It was necessary, however, to elevate three previously described vegetation concepts as new vegetation types to accommodate observable vegetation patterns in the landscape and also to align with the vegetation classification model.

It is recommended that the existing azonal vegetation type category be replaced with the term alluvial for the three azonal vegetation types in the NW where occasional flooding or waterlogging is a primary determinant of vegetation. This alluvial vegetation type unit also contains the majority of wetlands in the province.

This will not be the last word on the mapping of vegetation in the NW. Despite the wealth of phytosociological literature available for the province, there are still major gaps in our descriptive vegetation science knowledge in the province. Also, there is no research at all that relates phytosociological vegetation concepts to the modern South African vegetation type concepts, and the vegetation classification model or framework developed here might provide the basis for developing a similar framework for the entire country. Given the importance of vegetations types in environmental policy, planning and decision making, having clear, consistent

and defensible environmental definitions for vegetation types will help practitioners identify and map vegetation types on the ground.

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Supplementary material

Supplementary material 1:
Annotated plant checklist for the North West province

Only available online: http://dx.doi.org/10.38201/btha.abc.v54.10.S1

Supplementary material 2:
Vegetation type descriptions

1. FOz 2 Northern Afrotemperate Forest

Distribution	In the North West province (NW) forest is restricted to mesic fire-free sites on the Magaliesberg with small, scattered patches in the Pilanesberg, Swartruggens and on the Enzelsberg.
Altitude	Most patches occur at altitudes between 1 600 and 1 700 m.
Vegetation and landscape features	Low (in the Low Escarpment region with canopy reaching up to 20 m), relatively species-poor evergreen forests of afromontane origin and some of them still showing clear afromontane character. Found as small patches in kloofs and on subridge scarps typically in rock and bolder scree slopes.
Geology and soils	The Magaliesberg is comprised primarily of rough, large-grained quartzite, which weathers to coarse and shallow sandy soil. This supports mostly open savanna and grassland. However, there are a number of ravines/kloofs on north-facing slopes, as well as steep slopes on south-facing slopes that provides some protection from fires. Forests on the north-facing slopes are restricted to well-defined kloofs/ravines with sharp boundaries. Other conditions in these kloofs that contribute to the development of forests are the accumulation of deep soils (in contrast to the very shallow, coarse, sandy soils in most of the Magaliesberg), and the presence of perennial streams and moist seepage zones.
Important taxa	**Species of the north-facing slopes**: *Calodendrum capense* (d*), *Celtis africana* (d), *Diospyros whyteana* (d), *Englerophytum magalismontanum* (d), *Ficus burkei* (d), *Empogona lanceolata* (d), *Maytenus undata* (d), *Ochna holstii* (d), *Acokanthera oppositifolia, Apodytes dimidiata, Cussonia transvaalensis, Halleria lucida, Ilex mitis, Olea capensis* subsp. *enervis, Olea europaea* subsp. *cuspidata, Mimusops zeyheri, Olinia emarginata, Prunus africana, Rauvolfia caffra, Rothmannia capensis, Scolopia mundii, Secamone alpini, Solanum giganteum, Trema orientale, Vangueria bowkeri*. **Species of the south-facing slopes**: *Acalypha glabrata* var. *glabrata* (d), *Buddleja saligna* (d), *Celtis africana* (d), *Senegalia ataxacantha* (d), *Olea europaea* subsp. *cuspidata* (d), *Calodendrum capense, Dovyalis zeyheri, Maytenus undata, Myrsine africana, Pittosporum viridiflorum, Secamone alpini, Senegalia caffra, Solanum giganteum, Vangueria bowkeri*.
Remarks	**Biogeography**: The forests of the Magaliesberg are classified as Northern Afrotemperate Forests, together with the forests of the Waterberg in the current vegetation map, but the floristic composition of the forests in these mountain ranges is significantly different. Some species occur exclusively in the Magaliesberg (but not in the Waterberg) and vice versa. For instance, *Podocarpus latifolius* and *Curtisia dentata* are dominant species in many Waterberg forests, but these species are absent from the Magaliesberg. Conversely, species with a tropical affinity such as *Rauvolfia caffra* occur in the Magaliesberg, but not in the Waterberg. Both these forests are considered to be relic forests, as they are representative of communities that would have been more common under a former wetter climate. In the Magaliesberg, the presence of isolated specimens of species such as *Psydrax obovata* subsp. *elliptica* and *Scolopia mundii*, which are normally associated with high-rainfall escarpment habitats, provides some evidence for this.

*d = dominant species, see Table 9 in main text.

Remarks (continued)	**Vegetation dynamics**: Based on aerial and satellite image interpretation of the same areas over several decades, between the 1930s and 1940s to the present day, it is clear that the area covered by woody vegetation is expanding. This could be primarily attributed to protection from burning. Evidence of this expansion includes the presence of trees in dense forests that would ordinarily be dependent on germination and development in open habitats. Examples include large specimens of *Erythrina lysistemon* and *Senegalia ataxacantha* inside closed forests, as well as the presence of dense stands of forest pioneers such as *Trema orientalis* on the margins of some forests. The presence of extensive Olea Sclerophyllous Forest with its low tree species diversity could also be an indication of expanding forests with this distinct and widespread forest community forming a primary forest succession phase. **Conservation and utilisation**: Most of these forests are well-protected, being situated on private land where access is restricted. The primary uses are conservation, recreation, and for ecosystem services, e.g., sustainable water production. Many farming areas north of the Magaliesberg are dependent on the harvesting of water from the north-facing kloofs. Many of the kloofs are used for hiking throughout the year. The Mountain Club of South Africa's kloofs are accessible to members and to the public through permits. There is little evidence of current or historical exploitation. The only exception is Majakaneng Kloof, which is owned by a community property association, and where trees are heavily harvested for medicinal use. Forests on south-facing slopes tend to develop in moist, fire-protected positions in south-facing gullies and steep slopes below the cliffs with boulder and rock scree, where they are well-protected against fire. The forests on south-facing slopes, being drier and cooler, have a different floristic composition to the wetter kloof forests of the north-facing slopes. The forests on south-facing slopes tend to dominate on the higher altitudes just below the cliffs, and often grade into dense Olea Sclerophyllous Forest comprising *Olea europaea* subsp. *cuspidata, Celtis africana, Ziziphus mucronata* and *Buddleja saligna,* with no clear distinction between the boundary of the two forest types. However, Olea Sclerophyllous Forest is much less diverse in species, and often completely dominated by *Olea europaea* subsp. *cuspidata*. This forest type or community is widespread in the NW, as well as other parts of South Africa from the Eastern Cape to the northern provinces. It is typically found in fire refuges on deeper soils such as alluvial soils (bottom slope) or rock scree slopes (top slope). In the NW well-developed examples of this unit are found in the Magaliesberg, often associated with Northern Temperate Forests; dolines in Carletonville Dolomite Grassland; valleys in the Dwarsberg-Swartruggens Mountain Bushveld; and on koppies throughout the Bankenveld region.
References	Roberts (1961), Van Vuuren (1961), Killick (1963), Van Vuuren and Van der Schijff (1970), Van Zinderen Bakker (1971, 1973), Coetzee (1974, 1975), Van der Meulen (1978, 1979), Bredenkamp and Theron (1978, 1980), Westfall (1981), Cooper (1985), Westfall et al. (1984), Everard (1986), Behr and Bredenkamp (1988), Du Preez and Bredenkamp (1991), Du Preez (1991), Smit et al. (1993), Hill (1996), Eckhardt et al. (1997), Ellery et al. (2001), Siebert (2001), Van Staden (2002), Von Maltitz et al. (2003), Van Staden and Bredenkamp (2005, 2006), Geldenhuys and Mucina (2006).

2. Gh 10 Vaal-Vet Sandy Grassland

Distribution	North West and Free State provinces, south of Lichtenburg and Ventersdorp, stretching southwards to Klerksdorp, Leeudoringstad, Bothaville and to the Brandfort area north of Bloemfontein.
Altitude	1 200–1 620 m (median 1 420 m).
Vegetation and landscape features	Dry, medium (0.75–1.00 m) tussock grassland dominated by *Themeda triandra* with a karroid shrub element. In pockets of deeper sand Kalahari elements, such as stands of *Vachellia erioloba*, are present.
Geology and soils	Mostly Kalahari sand aeolian deposits with some colluvial soils overlaying various geologies. Dominant land types Bc and Bd with soil forms mostly Avalon, Westleigh and Clovelly. Red, eutrophic, plinthic soils, depth 0.5–1.0 m, average clay content 15–20%
Important taxa	**Grasses**: *Themeda triandra* (d*)*, Anthephora pubescens* (d)*, Eragrostis lehmanniana* (d)*, Aristida congesta, Brachiaria serrata, Cynodon dactylon, Eragrostis curvula, E. superba, Panicum coloratum, Tragus berteronianus, Triraphis andropogonoides*.

*d = dominant species, see Table 9 in main text.

Important taxa (continued)	**Shrubs**: *Asparagus laricinus* (d). **Herbs**: *Felicia muricata* (d)*, Pentzia globosa* (d), *Selago densiflora, Hibiscus pusillus, Ledebouria marginata*.
Remarks	Key identifying features of this vegetation type is the presence of *Asparagus laricinus*, as well as the abundance of narrow-leaf ironbark eucalyptus (*Eucalyptus crebra*) woodlots. These species are indicative of deep, freely draining, sandy soils. The absence of these woodlots is especially useful when marking the transition to Gh 14 Western Highveld Sandy Grassland. Pockets of aeolian sand in neighbouring vegetation units tend to contain Vaal-Vet Sandy Grassland. This is especially observable in Gh 15 Carletonville Dolomite Grassland. Locally, low cover of *Themeda triandra* and the associated increase in *Elionurus muticus, Cymbopogon pospischilii* and *Aristida congesta* is attributed to heavy grazing. *Seriphium plumosum* or bankrupt bush can also be prevalent in overgrazed situations. The bush encroaching tree species in this vegetation unit is *Vachellia karroo*. This vegetation type is highly suitable for cultivation, and it is currently extensively cultivated. In its definitive form occurring on deep soils on gentle gradients there are no impediments to ploughing and it is likely that this type has been largely eradicated by cultivation and is most likely extinct. Any intact examples of this vegetation unit that remain would be very important conservation targets.
References	Louw (1951), Morris (1973, 1976), Bredenkamp and Bezuidenhout (1990), Kooij (1990), Bezuidenhout and Bredenkamp (1991a), Kooij et al. (1990, 1992), Bezuidenhout et al. (1994a).

3. Gh 11 Vredefort Dome Granite Grassland

Distribution	Free State and North West provinces, central portion of the Vredefort Dome around Parys and Vredefort.
Altitude	1 330–1 540 m (median 1 400 m).
Vegetation and landscape features	Moderately undulating plains with medium (0.5–0.75 m) tussock grassland. Plains are interspersed with large granite-domed koppies.
Geology and soils	Coarse textured colluvial soils derived from the underlying granite bedrock. Ba land type with red dystrophic plinthic soils (Hutton, Mispah, Avalon forms), average depth < 0.5 m, average clay 20%.
Important taxa	**Grasses**: *Themeda triandra* (d*)*, Elionurus muticus* (d)*, Setaria sphacelata* var. *torta* (d)*, Brachiaria serrata, Cymbopogon pospischilii, Eragrostis chloromelas, E. racemosa, Heteropogon contortus, Trichoneura grandiglumis*. **Forbs**: *Barleria macrostegia, Helichrysum rugulosum, Hermannia depressa, Polygala hottentotta, Scabiosa columbaria, Turbina oblongata*.
Remarks	Vredefort Dome is an interesting geological structure – a strongly eroded remnant of one of the largest impact craters of the world, about 2.2 billion years old. This vegetation type is mostly very degraded through overgrazing and cropping. Examples of intact plains grassland are rare. Fields of bankrupt bush (*Seriphium plumosum*) are widespread.

*d = dominant species, see Table 9 in main text.

Remarks (continued)	The vegetation of the granite koppies in the vegetation type contain good examples of Olea Sclerophyllous Forest. This is a primary succession forest community that originates with the emergence of *Olea europaea* subsp. *cuspidata* from woodland vegetation to form a closed and contiguous evergreen forest cover. *Olea europaea* subsp. *cuspidata* is joined by *Celtis africana* and *Ziziphus mucronata* as dominant tree species. The development of this community is likely due to the general reduction in fire frequency in the landscape. This forest community is widespread in South Africa, encountered in most bushveld and woodland vegetation types in mesic, fire-protected positions. In terms of the vegetation type typology discussed in Results (Table 6), plains vs mountains is a key environmental discriminant of vegetation types. The woodland vegetation of the granite koppies mapped as part of this vegetation type has closer affinity to that of surrounding Gold Reef Mountain Bushveld vegetation types rather than to the grassland of this vegetation type. Therefore, these koppies should rather be grouped with the neighbouring Gold Reef Mountain Bushveld, Andesite Mountain Bushveld, or be assigned their own vegetation type.
References	Du Preez (1986), Bezuidenhout et al. (1988, 1994c), Bredenkamp et al. (1989), Du Preez and Venter (1990a, 1990b), Bezuidenhout (1993), Eckhardt et al. (1993), Fuls et al. (1992, 1993).

4. Gh 12 Vaal Reefs Dolomite Sinkhole Woodland

Distribution	NW, small area associated with the dolomite sinkholes in and around Stilfontein and Orkney (Vaal Reefs). The Vaal River forms the southern distribution limit of this vegetation unit.
Altitude	Altitude 1 280–1 380 m.
Vegetation and landscape features	Slightly undulating landscape dissected by prominent rocky chert/dolomite ridges and supporting a grassland-woodland vegetation complex. The most typical vegetation feature is the woodland, which occurs naturally in clumps around sand-filled dolines (sinkholes), which is characteristic of karst landscapes.
Geology and soils	This area occurs almost exclusively on the dolomites of the Malmani Subgroup (Chuniespoort Group, Transvaal Supergroup), where underground dissolution of the rock causes sinkholes, as well as caves. More than 50% of the main soil types are relatively shallow (50–150 mm) and rocky, with the dominant soil forms including Mispah, Glenrosa and shallow Hutton. Land type Fa.
Important taxa	**Trees**: *Vachellia erioloba* (d*), *Celtis africana* (d), *Searsia lancea* (d), *Senegalia caffra, Vachellia karroo, V. robusta* subsp. *clavigera*. **Tall shrubs**: *Diospyros lycioides* subsp. *lycioides* (d), *Ehretia rigida* (d), *Grewia flava* (d). **Shrubs**: *Asparagus suaveolens* (d), *Gymnosporia heterophylla* (d), *Pavonia burchellii* (d), *Sida dregei* (d), *Elephantorrhiza elephantina*. **Grasses**: *Aristida congesta* (d), *Digitaria eriantha* (d), *Eragrostis biflora* (d), *E. curvula* (d), *Themeda triandra* (d).
Remarks	The mapped extent of the dolomite sinkhole woodlands should be revisited at a more detailed scale than that offered by our current coverage. Clear separation (expressed in appropriate mapping coverage) between this unit and the adjacent Carletonville Dolomite Grassland is needed. These two units are closely related given the same underlying geology and soils. There is an observable gradient in tree abundance/density as one descends from the Vaal/Limpopo interfluve (Carletonville Dolomite Grassland) down into the Vaal River Valley (Vaal Reefs Dolomite Sinkhole Woodland) and the boundary between these two vegetation units is a cline rather than a clear demarcation.

*d = dominant species, see Table 9 in main text.

Remarks (continued)	Consideration should be given to updating the name of this vegetation unit. The 'sinkholes' referred to in the vegetation name are technically dolines, therefore a more technically correct name for this vegetation unit should be 'Vaal Reefs Dolomite Doline Woodland'. Aesthetically this is one of the more scenic landscapes in the western Grassland Biome having suffered less transformation relative to surrounding vegetation types and it certainly deserves high conservation priority (i.e., Highveld National Park at Potchefstroom).
References	Louw (1951), Acocks (1953, 1975, 1988), Morris (1973), Coetzee (1974), Van Wyk (1983), Van Wyk and Bredenkamp (1986), Bezuidenhout (1993), Bezuidenhout et al. (1994b, 1994c, 1994e), Siebert and Siebert (2005).

5. Gh 13 Klerksdorp Thornveld

Distribution	NW between Klerksdorp, Leeudoringstad, Wolmaransstad and Ottosdal with an outlying occurrence in the region of the Botsolano Game Reserve north of Mafikeng.
Altitude	1 240–1 580 m (median 1 380 m).
Vegetation and landscape features	Irregular undulating plains with dense to open 'Acacia' woodland clumps in a dry tussock grassland matrix.
Geology and soils	Relatively shallow, rocky, clayey colluvial soils on the foot slopes of basalt, quartzite or chert hills. Soils red eutrophic plinthic soils (Hutton form), depth < 0.5 m, average clay 20%. Land types Bc and Bd.
Important taxa	**Trees**: *Vachellia karroo* (d*), *Senegalia caffra* (d), *Celtis africana, Searsia lancea, S. pyroides, Ziziphus mucronata*. **Shrubs;** *Diospyros lycioides, Ehretia rigida, Grewia flava, Gymnosporia buxifolia*. **Grasses**: *Cynodon dactylon* (d), *Panicum coloratum* (d), *Sporobolus fimbriatus* (d), *Themeda triandra* (d), *Andropogon schirensis, Aristida congesta, Brachiaria serrata, Cymbopogon plurinodis, Digitaria eriantha, Diheteropogon amplectens, Eragrostis curvula, E. obtusa, E. superba, Elionurus muticus, Eustachys paspaloides, Heteropogon contortus, Setaria sphacelata, Sporobolus africanus, Tragus berteronianus, Triraphis andropogonoides*. **Forbs**: *Acalypha angustata, Anthospermum hispidulum, Asparagus africanus, Bulbostylis burchellii, Gnidia capitata, Helichrysum nudifolium, Hermannia lancifolia, Justicia anagalloides, Ledebouria marginata, Pavonia burchellii, Plexipus adenostachyus, Pollichia campestris, Raphionacme hirsuta, Rhynchosia totta* var. *venulosa, Solanum incanum, Teucrium trifidum, Triumfetta sonderi, Ziziphus zeyheriana*.
Remarks	The presence and dominance of *Senegalia caffra* is a defining characteristic of this vegetation type. This vegetation type grades into mountain bushveld types along a catena on steeper more rocky slopes, and with surrounding grassland types on deeper, sandier soils. Thus this vegetation type is transitional in character between Western Highveld Sandy Grassland (shallow sand with calcrete exposed), Vaal Vet Sandy Grassland (deep sandy soils with *Asparagus laricinus* dominant) and Andesite Mountain Bushveld, and therefore could be considered a grassland or bushveld vegetation type. This vegetation unit has a high grazing capacity, and this leads to overutilisation and degradation and subsequent invasion of *Vachellia karroo* into adjacent dry grassland.
References	Louw (1951), Morris (1973, 1976), Bredenkamp and Bezuidenhout (1990), Bezuidenhout (1993), Bezuidenhout et al. (1994c, 1994d), Bredenkamp and Brown (2003b).

*d = dominant species, see Table 9 in main text.

6. Gh 14 Western Highveld Sandy Grassland

Distribution	NW from Mareetsane and Deelpan in the north to Bloemhof and Christiana in the south, west of Sannieshof and Wolmaransstad as far as Stella.
Altitude	930–1 250 m (median 1 060 m).
Vegetation and landscape features	Flat to gently undulating plains with short (< 0.5 m), dry mixed tussock/lawn grassland, with karoo shrub elements and (very) scattered woody species occurring in bush clumps. Surface calcrete can be common.
Geology and soils	Shallow Kalahari sand aeolian soil overlaying calcrete, which can be exposed in places. These recent surface deposits overlie mainly basalt geologies. Soil is red-yellow, red apedal (Hutton), soil depth < 0.5 m with a calcrete hardpan, average clay 15%. Land type Ae. Note that the bottomlands in this vegetation unit have been mostly mapped as Highveld Alluvial Vegetation in this vegetation map.
Important taxa	**Trees**: *Vachellia hebeclada, Vachellia tortilis, Diospyros lycioides*. **Grasses**: *Anthephora pubescens* (d*), *Aristida diffusa* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *A. canescens, A. stipitata, Brachiaria serrata, Digitaria argyrograpta, Diheteropogon amplectens, Elionurus muticus, Eragrostis curvula, E. gummiflua, E. racemosa, Eustachys paspaloides, Melinis nerviglumis, Setaria sphacelata, Sporobolus discosporus, S. fimbriatus, Trichoneura grandiglumis, Triraphis andropogonoides*. **Forbs**: *Chamaecrista mimosoides, Dicoma anomala, Helichrysum callicomum, Hermannia depressa, Indigofera comosa, Kyphocarpa angustifolia, Leucas capensis, Mariscus indecorus, Polygala hottentotta, Sebaea grandis, Sida dregei, Solanum panduriforme, Vernonia oligocephala*.
Remarks	Many endorheic pans (Highveld Salt Pans – not mapped here) are associated with this vegetation unit, but these have been largely included in the Highveld Alluvial Vegetation unit in this map. There is a soil depth and aridity gradient from Vaal-Vet Sandy Grassland to Western Highveld Sandy Grassland. These two grassland types are closely related floristically. The short grassland stature and presence of calcrete, and the general absence of trees and especially of the shrub *Asparagus laricinus* and *Eucalyptus* woodlots are particularly indicative of the transition to Western Highveld Sandy Grassland. This vegetation type is suitable for cultivation, but the low rainfall makes it a high-risk area for agriculture. Historically this unit was extensively cultivated, however, presently very little dryland cultivation occurs in this vegetation type. Consequently, whilst there appears to be large extents of this grassland remaining, these are mostly old-fields, and the best examples and largest extents of this vegetation type are encountered in historically communal lands. Flax-leaf fleabane (*Erigeron bonariensis*) is an alien invasive annual daisy species that is a major invader in this vegetation type leading to a loss of grassland. This is especially prevalent on commercial farms where veld fires are suppressed. It is less of a problem in communal areas. *Vachellia tortilis* and to a lesser extent *Tarchonanthus camphoratus* contribute to bush encroachment in this vegetation type.
References	Van Zyl (1965), Morris (1973, 1976), Bezuidenhout (1993), Bezuidenhout et al. (1993, 1994c).

*d = dominant species, see Table 9 in main text.

7. Gh 15 Carletonville Dolomite Grassland

Distribution	NW (mainly), Gauteng and marginally into the Free State, The karst landscape associated with the Malmani dolomite geological system stretching east–west from Centurion and Bapsfontein in Gauteng Province through to the Botswana border via Ventersdorp, Lichtenburg and Ottoshoop, with a north-south arm running from Carletonville to west of Potchefstroom.
Altitude	1 170–1 780 m (median 1 510 m).
Vegetation and landscape features	Slightly undulating plains dissected by prominent rocky chert ridges and hills dominated by medium (0.75–1.00 m) sour, wiry, tussock grasslands on the plains and woodland elements on the hills, as well as open *Protea* woodland above 1 600 m. Large depressions or dolines created from infilled sinkholes are a characteristic feature of this landscape.
Geology and soils	Dolomite and chert of the Malmani dolomites supporting mostly shallow, rocky soils. Shallow rocky soils (Mispah and Glenrosa forms), average depth 0.1–0.4 m, average clay 15%. Land type Fa. **Note**: Depressions in this landscape contain aeolian or alluvial deposits that have soils typical of the Ab land type with red to yellow apedal soils (Hutton and Clovelly forms).
Important taxa	**Grasses**: *Diheteropogon amplectens* (d*), *Loudetia simplex* (d), *Schizachyrium sanguineum* (d), *Themeda triandra* (d), *Alloteropsis semialata, Andropogon shirensis, Aristida canescens, Bewsia biflora, Elionurus muticus, Eragrostis gummiflua, Eragrostis racemosa, Monocymbium ceresiiforme, Panicum coloratum, Pogonarthria squarrosa, Triraphis andropogonoides, Tristachya leucothrix, T. rehmannii.* **Forbs**: *Bulbostylis burchelli, Dianthus mooiensis, Helichrysum miconiifolium, Indigofera comosa, Kyphocarpa angustifolia, Ophrestia oblongifolia, Parinari capensis, Searsia magalismontana, Tylosema esculentum, Protea welwitschii*.
Remarks	This vegetation type in the NW has complex phytosociological patterns as extensive recent aeolian and alluvial deposits remain in depressions in the karst landscape. The alluvial deposits in dolines are mostly associated with Olea Sclerophyllous Forest. These alluvial deposits have largely been mined for diamonds and hence there are very few intact examples of this habitat and vegetation type remaining in this landscape. The pockets of aeolian sand contain Gh 10 Vaal-Vet Sandy Grassland or Gm 11 Rand Highveld Grassland. The erratic distribution of cultivated fields throughout this vegetation type are indicative of the presence of these pockets of sand. Rock piles adjacent to cultivated lands are indicative of Carletonville Dolomite Grassland being cleared for agriculture. A characteristic feature of this vegetation type is the absence of surface water. The karst geology means most surface water drains into the bedrock below. This water discharges from the ground water around the periphery of this vegetation type where the dolomite geology makes contact with the underlying bedrock of surrounding vegetation types. This gives rise to numerous springs or 'eyes' and associated peat wetlands that are a feature of the NW landscape surrounding the various karst landscapes in the province, namely, Carletonville Dolomite Grassland, Ghaap Plateau Vaalbosveld and Morokweng Thornveld. This vegetation type forms an important catchment for most major rivers flowing in the province. Vegetation types on dolomite geology are the only types in the province where the typology includes both plains and mountain environmental groups. This definition is consistently applied to all dolomite vegetation types in South Africa and therefore the typology rule is not changed here.
References	Louw (1951), Morris (1973, 1976), Coetzee (1974), Coetzee and Werger (1975), Van Wyk (1983), Van Wyk and Bredenkamp (1986), Bezuidenhout and Bredenkamp (1990), Scogings and Theron (1990), Bezuidenhout et al. (1994b, 1994c, 1994f), Bredenkamp et al. (1994), Grobler (2000), Hartmann (2001), Siebert and Siebert (2005), Grobler et al. (2006), Daemane et al. (2010),Veldsman (2021).

*d = dominant species, see Table 9 in main text.

8. Gm 11 Rand Highveld Grassland

Distribution	Gauteng, North West, Free State and Mpumalanga provinces, slopes and valleys between rocky ridges above 1 300 m. Occurs in the NW in two areas north and south of the Malmani dolomites. In the north on the Highveld around Derby and Koster above the Swartruggens hills, and in the southeast near Potchefstroom.
Altitude	1 300–1 700 m (median 1 530 m).
Vegetation and landscape features	Wide, gently sloping valleys/plains interspersed with low ridges or hills. Tall (1 m), wiry, sour grassland in the east with shorter (0.75 m) grassland in the west. Open *Protea* woodland occurs above 1 600 m. Most common grasses on the plains belong to the genera *Themeda, Eragrostis, Heteropogon* and *Elionurus*. Low, sour shrubland and woodland on rocky outcrops and steeper slopes belongs to SVcb 9 Gold Reef Mountain Bushveld.
Geology and soils	Colluvial soils derived from underlying geology, which is varied and includes basalt/dolerite, shale/mudstone and quartzite geologies. Dystrophic and eutrophic red soils (Hutton and Clovelly forms), average depth 0.50–0.75 m, average clay 25%. Land types Ba and Bc.
Important taxa	**Eastern extent**: **Grasses**: *Cymbopogon caesius* (d*), *C. plurinodis* (d), *Eragrostis curvula* (d), *Themeda triandra* (d), *Aristida congesta, Brachiaria serrata, Cynodon dactylon, Eragrostis racemosa, E. superba, Heteropogon contortus, Setaria sphacelata var. torta*. **Forbs**: *Anthospermum hispidulum, Felicia muricata, Graderia subintegra, Helichrysum miconiifolium, H. nudifolium, Hermannia depressa, Hibiscus pusillus, Justicia anagalloides, Lippia scaberrima, Vernonia oligocephala, Ziziphus zeyheriana*. **Western extent**: **Grasses**: *Anthephora pubescens* (d), *Eragrostis lehmanniana* (d), *Themeda triandra* (d), *Aristida congesta, Cynodon dactylon, Eragrostis curvula, E. superba, Tragus berteronianus*. **Forbs**: *Hibiscus pusillus, Ledebouria marginata, Felicia muricata* (d), *Pentzia globosa* (d), *Selago densiflora*.
Remarks	This vegetation unit is very varied and geographically disjunct and requires further investigation. Most importantly, the underlying geology of this vegetation group is very diverse. As most soils are colluvial being derived from the underlying bedrock, a closer environmental/phytosociological investigation is required to determine if this vegetation type warrants splitting based on geology and/or biogeography. Bankrupt bush encroachment is prevalent in many areas due to lack of regular fire.
References	Acocks (1953, 1975, 1988), Bezuidenhout (1988), Scogings and Theron (1990), Bezuidenhout and Bredenkamp (1991b), Coetzee (1993), Coetzee et al. (1994, 1995), Smit et al. (1997), Burgoyne et al. (2000), Grobler (2000), Grobler et al. (2006).

*d = dominant species, see Table 9 in main text.

9. Gm 29 Waterberg-Magaliesberg Summit Sourveld

Distribution	Limpopo and North West provinces and marginally into Gauteng, isolated patches on summits of the Waterberg (including the Sandrivierberge, Hoekberge, Hanglipberge and Swaershoekberge), Pilanesberg and Magaliesberg.
Altitude	Altitude 1 500–2 088 m in the Waterberg, 1 853 m in the Magaliesberg and 1 687 m in the Pilanesberg.
Vegetation and landscape features	Higher slopes and summit positions including crests, and steep rocky scarps and cliff faces, covered with grassland (and accompanying rocky outcrops) dominated by wiry tussock grasses. Patches of open *Protea caffra* savannoid vegetation and open shrubland with *Englerophytum magalismontanum* and *Ancylobothrys capensis* are common and typical of this sourveld vegetation type.
Geology and soils	Acidic sandy, loamy to gravel soil derived from coarse sandstone, quartzite, and conglomerate. Land type Ib and Fa.
Important taxa	**Trees**: *Englerophytum magalismontanum, Protea caffra* subsp. *caffra, Protea roupelliae* subsp. *roupelliae, Acacia caffra, Brachylaena rotundata, Combretum moggii, Combretum molle, Faurea saligna, Vangueria infausta, Zanthoxylum capense, Elephantorrhiza burkei, Protea gaguedi, Searsia dentata*. **Grasses**: *Loudetia simplex, Aristida transvaalensis, Bulbostylis burchellii, Coleochloa setifera, Diheteropogon amplectens, Eragrostis nindensis, Melinis nerviglumis, Schizachyrium sanguineum, Trachypogon spicatus, Tristachya biseriata*. **Shrubs**: *Ancylobothrys capensis, Lopholaena coriifolia, Passerina montana, Searsia magalismontana* subsp. *magalismontana, Acalypha angustata, Euphorbia clavarioides* var. *truncata, Euphorbia schinzii, Elephantorrhiza elephantina, Parinari capensis, Selaginella dregei, Xerophyta retinervis*.
Remarks	Embedded within this sourveld there are abundant rocky sheets found on exposed mountain tops and ridges, supporting sparse edaphic grassland/herbland with resurrection plants such as *Myrothamnus flabellifolius, Xerophyta retinervis* and *Selaginella dregei*. It is here where succulents (some endemic) of the genera *Frithia*, *Khadia* and *Delosperma* (Aizoaceae), *Adromischus* (Crassulaceae), *Anacampseros* (Anacampserotaceae) and numerous low succulent representatives of *Euphorbia* are found.
References	Acocks (1953, 1975, 1988), Coetzee (1974, 1975), Coetzee and Werger (1975), Van der Meulen (1979), Westfall (1981), Burgoyne et al. (2000), Van Staden (2002), Bredenkamp and Brown (2003a, 2003b), Van Staden and Bredenkamp (2005), Van Staden et al. (2021).

10. SVcb 1 Dwaalboom Thornveld

Distribution	Limpopo and North West provinces, flats both north and south of the Dwarsberge and associated ridges mainly west of the Crocodile River in the Dwaalboom area but including a patch around Sentrum. South of the ridges it extends eastwards from the Nietverdiend area, north of the Pilanesberg to the Northam area.
Altitude	Altitude 900–1 200 m.
Vegetation and landscape features	Plains with layer of scattered, low to medium-high, deciduous microphyllous trees and shrubs with a few broad-leaved tree species, and an almost continuous herbaceous layer dominated by grass species. *Vachellia tortilis* and *V. nilotica* dominate on the medium clays (at least 21% clay in the upper soil horizon but high in the lower horizons; on particularly heavy clays (> 55% clay in all horizons) most other woody plants are excluded and the diminutive *V. tenuispina* dominates at a height of less than 1 m above ground. On the sandy clay loam soils (with not more than 35% clay in the upper horizon but high in the lower horizons) *Senegalia erubescens* is the most prominent tree. The alternation of these substrate types creates a mosaic of different 'Acacia' woodlands.
Geology and soils	Vertic black ultramafic clays which developed from norite and gabbro, also locally in small depressions along streams. Some areas have less clay. Some with high base status and eutrophic red soils. Land type Ea.

Important taxa	**Trees**: *Vachellia nilotica, V. tortilis* subsp. *heteracantha, Senegalia erubescens, S. fleckii, S. mellifera* subsp. *detinens, Combretum imberbe, Searsia lancea, Ziziphus mucronata, Vachellia hebeclada* subsp. *hebeclada, Combretum hereroense, Diospyros lycioides* subsp. *lycioides, Euclea undulata, Grewia flava, Tarchonanthus camphoratus*. **Grasses**: *Aristida bipartita, Bothriochloa insculpta, Digitaria eriantha* subsp. *eriantha, Ischaemum afrum, Panicum maximum, Cymbopogon pospischilii, Eragrostis curvula, Sehima galpinii, Setaria incrassata*. **Shrubs**: *Vachellia tenuispina, Abutilon austro-africanum, Aptosimum elongatum, Hirpicium bechuanense, Pavonia burchellii, Solanum delagoense, Kalanchoe rotundifolia, Talinum caffrum, Heliotropium ciliatum, Kohautia caespitosa* subsp. *brachyloba*.
Remarks	Contains some very clayey soils that swell when wet and shrink when dry. On the clays, woody plant biomass is generally low, and productivity of woody plants is usually lower than that of herbaceous plants. These areas with ultramafic soils are, contrary to Sekhukhuneland, low in species diversity and in endemic species. Erosion is very low to low. Main use is extensive cattle grazing.
References	Bosch (1971), Coetzee (1971), Morris (1972), Van der Meulen (1979), Van der Meulen and Westfall (1980), Pauw (1988), Rutherford (1993), Winterbach (1998), Viljoen et al. (2014).

11. SVcb 2 Madikwe Dolomite Bushveld

Distribution	North West and Limpopo provinces, extends along the low dolomite ridge from the international border at Ramotswa in the west via the Rand Van Tweede Poort, Tlhaapitse and Maakane to west of the Crocodile River near Thabazimbi. It is also found on dolomite hills between Assen and Northam.
Altitude	Altitude 950–1 450 m (median 1 150 m).
Vegetation and landscape features	Gentle ridges and low hills up to about 100–150 m above the surrounding plains. Open (plains) to dense (slopes) woodland with tree and shrub layers often not clearly distinct, especially on steeper slopes; they are dominated by deciduous trees, particularly *Combretum apiculatum* and *Kirkia wilmsii* (especially in the east). Herbaceous layer continuous, dominated by grasses.
Geology and soils	Shallow, stony to rocky soils of the Glenrosa and Mispah forms on dolomite. Land type is mainly Fa.
Important taxa	**Trees**: *Combretum apiculatum, Searsia lancea, Searsia leptodictya, Ziziphus mucronata, Sclerocarya birrea, Ozoroa paniculosa*. **Shrubs**: *Vitex zeyheri, Tarchonanthus camphoratus, Grewia flava, Grewia bicolor, Grewia monticola, Ximenia americana*. **Grasses**: *Heteropogon contortus, Enneapogon scoparius, Aristida congesta, Panicum coloratum, P. maximum*. **Forbs**: *Clerodendrum glabrum, Brachystelma gracillimum, Euphorbia perangusta*.
Remarks	Some species distributions are associated with the east–west climatic gradient, for example *Kirkia wilmsii* is restricted to the eastern parts of the unit where it forms large monospecific forests on mountain slopes. These *Kirkia* forests are indicative of dolomite bands in the bedrock, and they do not occur on other geologies. These forest are especially apparent in autumn when their orange autumn foliage stands out from the surrounding landscape. In contrast to the bush encroachment seen on the red clay loams surrounding this unit, the rocky soils of dolomitic origin support a more open canopy structure and are resistant to bush encroachment.
References	Zacharias (1994), Hudak and Wessman (2001), Stalmans and De Wet (2003).

*d = dominant species, see Table 9 in main text.

12. SVcb 3 Zeerust Thornveld

Distribution	NW, extends along the valleys/plains from the Lobatsi River in the west via Zeerust, Groot Marico and Mabaalstad to the flats between the Pilanesberg and western end of the Magaliesberg in the east (including the valley of the lower Selons River).
Altitude	Altitude mainly 1 000–1 250 m.
Vegetation and landscape features	Deciduous, open to dense short thorny woodland, dominated by 'Acacia' species with herbaceous layer of mainly grasses on deep, high base-status and some clay soils on plains and lowlands, also between rocky ridges of Dwarsberg-Swartruggens Mountain Bushveld.
Geology and soils	Gentle catenal sequences from deep, red-yellow, apedal, freely drained with high base-status on upper slopes grading to sodic vertic or melanic clays in valley bottoms. Land type mainly Ae.
Important taxa	**Trees**: *Vachellia nilotica, Vachellia tortilis, Senegalia fleckii, Senegalia galpinii, Senegalia mellifera*. **Shrubs**: *Grewia flava*, *Aloe marlothii*. **Grasses**: *Eragrostis lehmanniana, Panicum maximum* (d)*, Aristida congesta, Cymbopogon plurinodis*. **Forbs**: *Agathisanthemum bojeri, Blepharis integrifolius, Chaetacanthus costatus, Chamaecrista absus, Chamaecrista mimosoides, Cleome maculata, Clerodendrum ternatum, Dicoma anomala, Indigofera filipes, Kyphocarpa angustifolia, Limeum viscosum, Lophiocarpus tenuissimus, Sida chrysantha, Stylosanthes fruticosa*.
Remarks	This unit is somewhat more temperate than the Dwaalboom Thornveld that borders it to the north. It occurs in the valleys of the Swartruggens Mountains. The presence of sodic soils at the base of a catena with bare soils adjacent to a wooded streamline with a dense band of *Vachellia tortilis* above is indicative of this vegetation type.
References	Van Wyk (1959), Van der Meulen (1979), Van der Meulen and Westfall (1980), Malan and Van Niekerk (2005).

13. SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld

Distribution	NW, occurs on hills and ridges east of the Lobatsi River through the Zeerust and the Swartruggens areas to Mabeskraal and the Selons River Valley in the east. Also occurs on the parallel ridges of the Dwarsberge from Witkleigat in the west to the hills of the Dwarsberg area in the east.
Altitude	Altitude about 1 000–1 500 m.
Vegetation and landscape features	Rocky low- to medium-high hills and ridges with some steep faces in places. Height above the surrounding plains can reach about 300 m. Mixed bushveld woodland with variable vegetation structure depending on slope, exposure, aspect and local habitat – various combinations of tree and shrub layers often with dense grass layer. Bush clumps also occur.
Geology and soils	Predominately shale and mudstone with stony shallow soils of the Glenrosa and Mispah soil forms. Land type mainly Fb.
Important taxa	**Trees**: *Senegalia caffra, Olea europaea* subsp. *africana, Buddleja saligna, Combretum molle, Dombeya rotundifolia*. **Grasses**: *Loudetia simplex, Schizachyrium sanguineum, Setaria lindenbergiana, Cymbopogon plurinodis, Elionurus muticus, Heteropogon contortus, Melinis nerviglumis, Setaria sphacelata* var. *sphacelata, Themeda triandra, Trachypogon spicatus, Tristachya biseriata*. **Shrubs**: *Vangueria infausta, Nuxia glomerulata, Erythrophysa transvaalensis, Athrixia elata, Pavonia burchellii, Searsia magalismontana* subsp. *magalismontana, Searsia rigida* var. *rigida*.

Remarks	This vegetation has some similarities with the surrounding Gold Reef Mountain Bushveld; however, it is generally drier and warmer than this unit and is associated with shale/mudstone as opposed to quartzite for Gold Reef Mountain Bushveld. This unit extends into Botswana, for example on the hills around Lobatse. Alien species include *Cereus jamacaru* and particularly *Acacia mearnsii* that form extensive thickets especially on the ecotone with the cooler and moister Rand Highveld Grassland vegetation type.
References	Van der Meulen (1979), Zacharias (1994), Bredenkamp (1999), Viljoen et al. (2014).

14. SVcb 5 Pilanesberg Mountain Bushveld

Distribution	NW, hills and mountains immediately north of Sun City and west of Heystekrand (Mankwe District).
Altitude	Altitude about 1 100–1 500 m.
Vegetation and landscape features	Broad-leaved deciduous bushveld with trees and shrubs with wiry grass layer on slopes of rocky mountains and hills, with mountain summits more grassy and valley floors sometimes less woody but the latter may be related to past disturbance.
Geology and soils	The alkaline complex consists of potassium- and sodium-rich, silica-poor rocks, mainly foyaite, lava and tuff with some syenite. Wide range of elements found, particularly rare earth elements and fluorine in the form of CaF_2 (fluorite). Due to the original volcanic actions, subsequent fracturing, emplacement of intrusions, collapse and resurgence of magma and radial emplacement of dykes, a complex geological pattern exists. Pilanesberg is one of the very few large alkaline ring complexes in the world, approximately 1.3 million years old. Soils are shallow, rocky lithosols on the hills and mountains of the Glenrosa and Mispah soil forms, but with deeper, sandy soils on the valley floors. Land type is Ib.
Important taxa	**Trees**: *Combretum apiculatum, Combretum molle, Combretum zeyheri, Strychnos cocculoides, Croton gratissimus, Englerophytum magalismontanum, Searsia leptodictya, Vangueria parvifolia, Diplorhynchus condylocarpon, Elephantorrhiza burkei, Grewia flava, Hibiscus calyphyllus, Mundulea sericea, Steganotaenia araliacea, Vitex rehmannii, Polygala hottentotta, Xerophyta retinervis, Erythrophysa transvaalensis*. **Grasses**: *Chrysopogon serrulatus, Elionurus muticus, Panicum maximum, Enneapogon scoparius, Hyperthelia dissoluta, Panicum deustum*.
Remarks	This unit is a meeting ground for several species of *Grewia*, for example northwestern limits of *G. occidentalis*, southwestern limits of *G. monticola* and *G. hexamita* and southeastern limits of *G. retinervis*. The vegetation of the southern slopes of this unit is similar to that of the southern slopes of the northeastern end of the Magaliesberg (Gold Reef Mountain Bushveld), whereas the northern slopes of the two units have distinct physiognomic differences. The valley floor vegetation is mapped as Central Sandy Bushveld. The Pilanesberg Alkaline Ring Complex is a near circular (diameter 23–27 km) ring dyke complex constituting an intrusive and extrusive massif with the original volcanic caldera completely eroded away leaving a broken ring of hills and low mountains, as well as the eroded intrusions of the core remaining in the form of many hills and low mountains. Valley floors between the hills and mountains tend to be at most 1–2 km wide.
References	Van Wyk (1959).

15. SVcb 6 Marikana Thornveld

Distribution	North West and Gauteng provinces, occurs on plains from the Rustenburg area in the west, through Marikana and Brits to the Pretoria area in the east.
Altitude	Altitude about 1 050–1 450 m.
Vegetation and landscape features	Open, grassy 'Acacia' woodland occurring on gently undulating plains.
Geology and soils	Most of the area is underlain by the mafic intrusive rocks of the Bushveld Igneous Complex which give rise to heavy black cotton soils (vertic melanic clays). Land type Ea.
Important taxa	**Trees**: *Vachellia karroo, Vachellia tortilis, Vachellia nilotica, Ziziphus mucronata*. **Shrubs**: *Diospyros lycioides, Grewia flava*. **Grasses**: *Aristida bipartita, Bothriochloa insculpta, Digitaria eriantha, Ischaemum afrum, Panicum maximum, Cymbopogon plurinodis, Eragrostis curvula, Sehima galpinii, Setaria incrassata*. **Forbs**: *Abutilon austro-africanum, Aptosimum depressum, Heliotropium ciliatum, Hibiscus trionum, Hirpicium bechuanense, Nidorella hottentotica, Kalanchoe rotundifolia, Pavonia burchellii, Rhynchosia minima, Solanum panduriforme, Talinum caffrum*.
Remarks	Historically this vegetation unit presented as open grass-covered plains. Today, however, due to bush encroachment most of this unit presents as a dense 'Acacia' woodland. The only examples of the open savanna form of this vegetation unit are to be found in communal areas.
References	Van der Meulen (1979), Van Rooyen (1983, 1984), Panagos et al. (1998), Lamprecht (2010), Lamprecht et al. (2011).

16. SVcb 7 Norite Koppies Bushveld

Distribution	North West and Gauteng provinces on 'The Norite Hills' occurring between Rustenburg and Pretoria, north of the Magaliesberg.
Altitude	Altitude about 1 100–1 350 m.
Vegetation and landscape features	Variable woodland, low, semi-open to closed, up to 5 m tall, consisting of dense deciduous shrubs and trees with very sparse undergrowth on shallow rocky soils, with large areas of rock sheet/boulders not covered by vegetation. Tree and shrub layers are continuous. The stands of this unit are found on norite outcrops and koppies, many occurring as inselbergs above the surrounding plains.
Geology and soils	Gabbro (norite is a type of gabbro) of the Bushveld Igneous Complex that give rise to hills with large rocks and boulders and very shallow lithosols. Soils are well-drained, Glenrosa and Mispah forms. Gabbro is a coarse-grained igneous rock that is relatively low in silica and rich in iron, magnesium and calcium. Such rock is described as mafic. Land type Ib.
Important taxa	**Trees**: *Combretum molle, Croton gratissimus, Ficus abutilifolia, Pappea capensis, Bridelia mollis, Psydrax livida, Volkameria glabra, Combretum apiculatum, Diplorhynchus condylocarpon, Dombeya rotundifolia, Euclea natalensis, Euphorbia cooperi, Ficus glumosa, Lannea discolor, Peltophorum africanum, Sclerocarya birrea, Triaspis glaucophylla*. **Shrubs**: *Grewia flavescens, Pouzolzia mixta, Vitex zeyheri, Jatropha latifolia*. **Grasses**: *Chrysopogon serrulatus, Setaria lindenbergiana*. **Forbs**: *Cyphostemma lanigerum, Helinus integrifolius, Hermannia floribunda, Hibiscus subreniformis, Hibiscus schinzii, Pellaea viridis, Turraea obtusifolia, Urera tenax*.

Remarks	Vegetation patterns on norite koppies are primarily determined by the amount of rockiness and aspect, warmer north-facing slopes and cooler south-facing slopes bearing floristically distinct vegetation. A number of the woody species e.g., species of *Ficus*, are typical chasmophytes, penetrating the rocks with their roots (Van der Meulen 1979). The vegetation unit is transitional between xeric lowland bushveld and mesophyllous woodland in cooler more moist upland areas associated with the Magaliesberg. It may be considered to be a more xeric expression of these upland areas (Van der Meulen 1979). There are no endemic plant species associated with this vegetation unit. The unique character of this vegetation unit is derived from the combination of species (communities) and structure of vegetation due to the unique geological structure of the inselbergs. Mining is primarily in the form of granite quarries on koppies, but also affects surrounding lower-lying areas. Areas close to human settlements are often severely disturbed and many woody species may have been harvested from these areas for fuel or building materials. Weeds, including a number of declared aliens, are more common in these disturbed sites. Erosion is very low to moderate. The granite-like hills and koppies west of Madikwe towards the Botswana border are currently not considered part of this vegetation unit. Given further investigation it is likely that this vegetation unit could extend further to the west.
References	Van der Meulen (1979), Panagos (1996), Lamprecht (2010), Lamprecht et al. (2011).

17. SVcb 8 Moot Plains Bushveld

Distribution	North West and Gauteng provinces, main belt occurs immediately south of the Magaliesberg from the Selons River Valley in the west through Maanhaarrand, filling the valley bottom of the Magalies River, proceeding east of the Hartebeespoort Dam between the Magaliesberg and Daspoort mountain ranges to Pretoria. It also occurs as a narrow belt immediately north of the Magaliesberg from Rustenburg in the west to just east of the Crocodile River in the east; also south of the Swartruggens–Zeerust line.
Altitude	Altitude typically about 1 050–1 450 m.
Vegetation and landscape features	Open to closed, low, often thorny savanna dominated by various species of 'Acacia' in the bottom-lands and plains, as well as woodlands of varying height and density on the lower hillsides. Herbaceous layer is dominated by grasses.
Geology and soils	Soils varied, mostly stony with colluvial clay-loam or sand derived from shale (south of the Magaliesberg), norite (north of the Magaliesberg), or quartzite. Catenas are distinctive with red-yellow apedal freely drained, dystrophic sandy soils on the top slope near the base of hills down to eutrophic vertic and melanic clays in the bottom-lands. Land types Ba, Bc and Ea.
Important taxa	**Trees**: *Vachellia nilotica, Vachellia tortilis, Searsia lancea, Terminalia sericea, Buddleja saligna, Euclea undulata, Olea europaea, Grewia occidentalis, Gymnosporia polyacantha, Mystroxylon aethiopicum*. **Grasses**: *Heteropogon contortus, Setaria sphacelata, Themeda triandra, Aristida congesta, Chloris virgata, Cynodon dactylon, Sporobolus nitens, Tragus koelerioides*. **Shrubs**: *Aptosimum elongatum, Felicia fascicularis, Lantana rugosa, Teucrium trifidum, Kalanchoe paniculata, Jasminum breviflorum, Listia bainesii, Achyropsis avicularis, Evolvulus alsinoides, Helichrysum nudifolium, Hermannia depressa, Osteospermum muricatum, Phyllanthus maderaspatensis*.
Remarks	Plant communities characteristically vary in relation to catena position. Top slope communities on sandy soils are dominated by broad-leaved woodland (e.g., *Terminalia sericea*). These communities are structurally and floristically very similar to the Central Sandy Bushveld vegetation type. Bottom-lands are dominated by 'Acacia' woodland communities on clay rich soils. Plant communities here are similar to Zeerust Thornveld or Marikana Thornveld.
References	Coetzee (1975), Van der Meulen (1979).

18. SVcb 9 Gold Reef Mountain Bushveld

Distribution	North West, Gauteng, Free State and Mpumalanga provinces, occurs on the quartzite ridges of the Swartruggens, Magaliesberg, Witwatersrand, Gatsrand, Suikerbosrand, and Vredefort Dome mountain ranges.
Altitude	Altitude 1 200–1 750 m.
Vegetation and landscape features	Quartzite rocky hills and ridges mostly dominated by wiry, sour grasses on summits with more woody vegetation on slopes associated with distinct floristic differences (e.g., preponderance of *Senegalia caffra* on the southern slopes, *Protea* 'savannas' above 1600 m on southern aspects). Tree cover is variable dependent on soil depth, aspect and rockiness. Tree and shrub layers are often continuous. Herbaceous layer is dominated by grasses. A heterogenous vegetation type with several distinct plant communities discernible based on aspect, slope and rockiness.
Geology and soils	Quartzite bedrock that gives rise to shallow, dystrophic, gravelly lithosols of the Mispah form. Land types mainly Ib and Fb.
Important taxa	**Trees**: *Senegalia caffra, Combretum molle, Protea caffra, Celtis africana, Dombeya rotundifolia, Englerophytum magalismontanum, Ochna pretoriensis, Searsia leptodictya, Vangueria infausta, Vangueria parvifolia, Ziziphus mucronata, Afrocanthium gilfillanii, Ehretia rigida, Grewia occidentalis, Gymnosporia buxifolia, Mystroxylon aethiopicum*. **Grasses**: *Loudetia simplex, Panicum natalense, Schizachyrium sanguineum, Trachypogon spicatus, Alloteropsis semialata, Bewsia biflora, Digitaria tricholaenoides, Diheteropogon amplectens, Sporobolus pectinatus, Tristachya biseriata, Tristachya leucothrix*. **Shrubs**: *Athrixia elata, Pearsonia cajanifolia, Searsia magalismontana, Searsia rigida, Ancylobothrys capensis*. **Herbs**: *Helichrysum nudifolium, Helichrysum rugulosum, Pentanisia angustifolia, Senecio venosus, Xerophyta equisetoides, Cheilanthes contracta, Hypoxis hemerocallidea, Pellaea calomelanos*.
Remarks	This is a very widespread vegetation type stretching across four provinces; however, the dominant species and general physiognomic characteristics of the vegetation type are consistent across its range. All endemic and/or rare plant species in the region are associated with this vegetation type (e.g., *Aloe peglerae, Frithia pulchra, Euphorbia knobelii, Burmannia madagascariensis, Myrsine pillansii, Nuxia glomerulata*). It therefore deserves a disproportionally higher conservation importance value than other vegetation types. This vegetation type is regarded as the 'typical' or 'climax' Bankenveld vegetation type. Many small quartzite ridges that are present in this unit have not been mapped. In addition, some quartzite ridges in Gauteng are currently incorrectly mapped in the National Vegetation Map as Andesite Mountain Bushveld (e.g., Bronberg).
References	Van Vuuren and Van der Schijff (1970), Bredenkamp (1975), Coetzee (1975), Bredenkamp (1977), Bredenkamp and Theron (1978), Behr and Bredenkamp (1988), Bezuidenhout et al. (1988), Du Preez and Venter (1990b) Coetzee et al. (1993), Bezuidenhout et al. (1994c), Coetzee et al. (1994, 1995), Grobler et al. (2002), Pfab (2002), Reddy et al. (2001, 2012), Bredenkamp and Brown (2003a).

19. SVcb 10 Gauteng Shale Mountain Bushveld

Distribution	Gauteng and North West provinces, Occurs on shale and mudstone ridges and hills throughout Gauteng and into eastern NW, notably, the Gatsrand south of Carletonville–Westonaria–Lenasia, and Moot area of the Magaliesberg between Pretoria and Tarlton, and south of Koster.
Altitude	Altitude 1 300–1 750 m.
Vegetation and landscape features	Low, broken ridges varying in steepness and with high surface rock cover. Vegetation is a short (3–6 m tall), semi-open woody thicket or woodland.

Geology and soils	Mostly shale and mudstone that give rise to shallow, rocky lithosols of the Mispah form. Bottom slopes can have deeper rocky, colluvial soils. Land type Fb.
Important taxa	**Trees**: *Senegalia caffra, Dombeya rotundifolia, Vachellia karroo, Celtis africana, Combretum molle, Cussonia spicata, Englerophytum magalismontanum, Protea caffra, Searsia leptodictya, Vangueria infausta, Zanthoxylum capense, Ziziphus mucronata, Asparagus laricinus, Afrocanthium gilfillanii, Osteospermum incanum, Dichrostachys cinerea, Diospyros austroafricana, Diospyros lycioides, Ehretia rigida, Euclea crispa, Grewia occidentalis, Gymnosporia polyacantha, Olea europaea, Tephrosia capensis, Tephrosia longipes*. **Grasses**: *Hyparrhenia dregeana, Cymbopogon caesius, Cymbopogon pospischilii, Digitaria eriantha, Eragrostis curvula*. **Shrubs**: *Acalypha angustata, Asparagus suaveolens, Athrixia elata, Felicia muricata, Indigofera comosa, Searsia magalismontana, Elephantorrhiza burkei, Kalanchoe neglecta, Ancylobothrys capensis*. **Herbs**: *Macledium zeyheri, Helichrysum nudifolium, Helichrysum rugulosum, Hermannia lancifolia, Hibiscus pusillus, Selaginella dregei, Senecio venosus, Hilliardiella aristata, Hilliardiella elaeagnoides, Cheilanthes contracta, Scadoxus puniceus*.
Remarks	This vegetation type is floristically and structurally similar to Andesite Mountain Bushveld with geology as a key differentiating variable. Gauteng Shale Mountain Bushveld is associated with sedimentary shale and mudstone of sedimentary origin, whereas Andesite Mountain Bushveld is associated with andesite rocks of volcanic origin. The vegetation structure and composition of Gauteng Shale Mountain Bushveld together with Andesite Mountain Bushveld and Gold Reef Mountain Bushveld typify the Bankenveld vegetation concept.
References	Coetzee (1972, 1974), Scogings and Theron (1990), Bezuidenhout et al. (1994c, 1994e), Bredenkamp and Brown (2003a).

20. SVcb 11 Andesite Mountain Bushveld

Distribution	Gauteng, North West, Mpumalanga and Free State provinces, Andesite and related igneous rocky ridges and koppies through the region.
Altitude	Altitude about 1 350–1 800 m.
Vegetation and landscape features	Dense, medium-tall thorny mixed bushveld with a well-developed grass layer on hill slopes.
Geology and soils	Andesite volcanic rock that gives rise to shallow, rocky, clayey soils of mainly Mispah and Glenrosa soil forms. Land types Ib and Fb.
Important taxa	**Trees**: *Senegalia caffra, Vachellia karroo, Celtis africana, Protea caffra, Zanthoxylum capense, Ziziphus mucronata, Euclea crispa, Searsia pyroides, Diospyros lycioides, Gymnosporia polyacantha, Lippia javanica, Rhamnus prinoides*. **Grasses**: *Eragrostis curvula, Hyparrhenia finitima, Setaria sphacelata, Themeda triandra, Cymbopogon pospischilii, Digitaria eriantha, Elionurus muticus, Eragrostis racemosa, Eragrostis superba, Panicum maximum*. **Shrubs**: *Asparagus suaveolens, Searsia rigida, Teucrium trifidum, Isoglossa ciliata, Rhoicissus tridentata, Commelina africana, Pseudopegolettia tenella, Aloe davyana*.
Remarks	See remarks for Gauteng Shale Mountain Bushveld.
References	Bredenkamp (1975, 1977), Bredenkamp and Theron (1976, 1978, 1980), Du Preez and Venter (1990a, 1990b), Coetzee et al. (1995), Grobler (2000), Reddy et al. (2001, 2012), Bredenkamp and Brown (2003a), Daemane et al. (2010, 2012).

21. SVcb 12 Central Sandy Bushveld

Distribution	Limpopo, Mpumalanga, Gauteng and North West provinces, on undulating terrain, occurs mainly in a broad arc south of the Springbokvlakte from the Pilanesberg in the west through Hammanskraal and Groblersdal to GaMasemola in the east. A generally narrow irregular band along the northwestern edge of the Springbokvlakte (including Modimolle) extending into a series of valleys and lower-altitude areas within the Waterberg including the upper Mokolo River Valley near Vaalwater, the corridor between Rankins Pass and the Doorndraai Dam, and the lowlands from the Mabula area to south of the Hoekberge. Some isolated sandy patches found on the Springbokvlakte are assigned to Western Sandy Bushveld.
Altitude	Ranges from 900–1 450 m (median 1 070 m).
Vegetation and landscape features	Closed to open broad-leaved woodland with grass-dominated herbaceous layer, relatively low basal cover on dystrophic sands. Undulating plains and valleys, sometimes between mountains, with distinct catenas supporting tall, deciduous *Terminalia sericea* and *Burkea africana* woodland on deep sandy soils (with the former often dominant on the lower slopes of sandy catenas) and low, broad-leaved *Combretum* woodland on shallow rocky or gravelly soils. Species of *Vachellia*, *Ziziphus* and *Euclea* are found on flats and lower slopes on eutrophic sands and some less sandy soils.
Geology and soils	Fersiallitic soils - medium sandy clay loams with good drainage, derived from mafic (basic) granite rocks of the Bushveld Igneous Complex. Undulating landscapes with pronounced catenas. Fa and Fb land types with coarse textured sandy soils. Average depth 0.45 m. Average clay 10%. Well-drained, deep Hutton or Clovelly soils often with a catenary sequence from Hutton at the top to Clovelly on the lower slopes; shallow, skeletal Glenrosa soils also occur.
Important taxa	**Trees**: *Burkea africana, Combretum apiculatum, Combretum zeyheri, Terminalia sericea, Combretum imberbe, Peltophorum africanum, Sclerocarya birrea, Ochna pulchra*. **Grasses**: *Brachiaria nigropedata, Eragrostis pallens, E. rigidior, Panicum maximum, Brachiaria serrata, Elionurus muticus, Eragrostis nindensis, Loudetia simplex, Mosdenia leptostachys, Perotis patens, Themeda triandra, Trachypogon spicatus*. **Herbs**: *Agathisanthemum bojeri, Arthrosolen sericocephalus, Clerodendrum triphyllum, Dicerocaryum zanguebarium, Dichapetalum cymosum, Felicia fascicularis, Indigofera daleoides, Justicia anagalloides, Plexipus hederaceus, Waltheria indica*.
Remarks	*Vachellia sieberiana* occurs in the transition zone with grassland in the east, while *V. caffra* and *Faurea saligna* are dominant in the transition zone to Central Sandy Mountain Bushveld in the western parts of this unit. Central Sandy Bushveld is similar to Western Sandy Bushveld, but the former occurs on aeolian Kalahari sand (often shallow over clay soils) and is generally a taller more open bushveld type. *Vachellia tortilis* and other 'Acacia' species may dominate on heavy clay soil in valleys, but this is assigned to Springbokvlakte Thornveld. This vegetation unit includes probably the most intensively studied South African savanna field site of the South African Savanna Ecosystem Programme in the Nylsvlei Nature Reserve (Limpopo Province). This vegetation type is a complex unit that comprises a variety of distinct vegetation units. In this revision it is proposed that the mountain bushveld vegetation currently included in this unit in the National Vegetation Map is separated out into a new vegetation type (Central Sandy Mountain Bushveld). On the plains, there is also justification for the separation of the *Combretum* woodland on gravelly Glenrosa soils to be separated out from the *Terminalia-Burkea* woodland on deeper sandy Hutton/Clovelly soils. The former is the dominant type that occurs in the NW, whereas the latter is more dominant in the southern Waterberg where the soils are derived from quartzite rather than granite.
References	Grunow (1965), Coetzee et al. (1976), Van der Meulen (1979), Van der Meulen and Westfall (1980), Lubke et al. (1983), Lubke and Thatcher (1983), Scholes and Walker (1993), Brown (1997), Brown et al. (1995, 1996, 1997), Dörgeloh (1998, 1999a, 1999b), Brown and Bredenkamp (2004).

22. SVcb XX[1] Central Sandy Mountain Bushveld

Distribution	Limpopo, Mpumalanga, Gauteng and North West provinces, Mountainous terrain distributed in a broad arc from the Moretele River northwards into the Waterberg.
Altitude	850–1 450 m (median 1 100 m).
Vegetation and landscape features	Mostly dense broad-leaved mountain bushveld on slopes. Tree layer well-developed consisting of trees taller than three meters with canopy cover of 70–80%. Steep slopes on mountains with mostly skeletal rocky soils, as well as rocky pediments. Includes densely wooded ravines and kloofs that do not contain forest.
Geology and soils	Mostly quartzite of the Rayton Group or coarse-grained granite of the Nebo Granite Group that both give rise to shallow coarse-grained sandy soils with high rock content. Ib land type with shallow rocky soils. Average depth 0.3 m. Average clay 20%.
Important taxa	**Trees**: *Pappea capensis, Combretum apiculatum, Combretum molle, Combretum zeyheri, Bridelia mollis, Gymnosporia glaucophylla, Spirostachys africana, Grewia monticola, Grewia subspathulata, Ochna inermis, Sclerocarya birrea, Lannea discolor, Dombeya rotundifolia, Diplorhynchus condylocarpon* and *Pterocarpus rotundifolius*. Trees such as *Kirkia wilmsii, Croton gratissimus* and *Mimusops zeyheri* are restricted to sheltered ravines. **Grasses**: *Brachiaria deflexa, Aristida canescens, Aristida diffusa, Panicum maximum, Enneapogon scoparius, Chrysopogon serrulatus, Eustachys paspaloides, Digitaria eriantha, Eragrostis rigidior, Melinis repens* and *Enneapogon scoparius*. **Fern**: *Pellaea calomelanos*.
Remarks	See comments for Central Sandy Bushveld. Having been grouped with Central Sandy Bushveld or Western Sandy Bushveld in the National Vegetation Map since 2006 this vegetation type is being reinstated as a vegetation type. It is a well-established vegetation type recognised by Van der Meulen and Westfall (1979); Brown and Bredenkamp (1994); Brown et al. (1995, 1996 and 1997); and Bredenkamp and Brown (2003b). It is synonymous with Van der Meulen's *Combretum molle–Diheteropogon amplectens* Order described in his vegetation map of the western Transvaal bushveld (Van der Meulen & Westfall 1979); Brown's *Pappea capensis–Combretum apiculatum* (mountain) bushveld vegetation type described for the vegetation study of the Borakalalo Nature Reserve (Brown & Bredenkamp 1994, Brown et al. 1995, 1996 and 1997); and Bredenkamp and Brown (2003b) Mogosane Mountain Bushveld and Central Mixed Bushveld vegetation types in their vegetation map of the NW. Note that to the north and the southeast this unit transitions into related mountain bushveld units, namely, Waterberg Mountain Bushveld and Loskop Mountain Bushveld, respectively.
References	Van der Meulen and Westfall (1979), Bredenkamp and Brown (2003b), Brown and Bredenkamp (1994), Brown et al. (1995, 1996, 1997).

23. SVcb 15 Springbokvlakte Thornveld

Distribution	Limpopo, Mpumalanga, North West and Gauteng provinces, flats from Zebediela in the northeast to Hammanskraal and Assen in the southwest, as well as from Bela-Bela and Mookgophong in the northwest to Marble Hall and Rust de Winter in the southeast.
Altitude	Altitude about 900–1 200 m.
Vegetation and landscape features	Black cotton soil flats with open to dense, low thorn savanna dominated by 'Acacia' species or open grassland with a very low shrub layer.

[1]Vegetation type number to be assigned by the National Vegetation Map Committee.

Geology and soils	Vertisols derived from mafic volcanic rocks of the Bushveld Igneous Complex. Land type Ea.
Important taxa	**Trees**: *Vachellia tortilis, Vachellia karroo, Vachellia nilotica, Vachellia tenuispina, Ziziphus mucronata, Dichrostachys cinerea, Grewia flava*. **Grasses**: *Aristida bipartita, Dichanthium annulatum, Ischaemum afrum, Setaria incrassata, Brachiaria eruciformis*. **Herbs**: *Aspilia mossambicensis, Corchorus trilocularis, Hibiscus trionum, Indigastrum parviflorum, Nidorella hottentotica, Orthosiphon suffrutescens, Rhynchosia minima, Isolepis capensis, Mesogramma apiifolium, Kleinia longiflora, Jamesbrittenia micrantha, Ptycholobium plicatum*.
Remarks	The black clay soils of this unit are characterised by pronounced swelling and cracking with wet and dry cycles, considerable soil cracking when dry, a loose soil surface, high calcium carbonate content in the soil and gilgai micro-relief. Consequently, they are referred to as self-mulching soils and few perennial plants are able to tolerate the physical stress of this soil dynamic leading to a vegetation type with considerably lower species diversity than surrounding vegetation types. They are also referred to as black cotton soils as they are highly suitable for the cultivation of cotton and as a consequence have been extensively cleared for cultivation. Environmentally and floristically this unit is very similar to Marikana Thornveld. The open, grassy savanna form of this vegetation type is very rarely encountered anymore due to bush encroachment and habitat loss through cultivation. Some examples are still to be found in communal areas.
References	Galpin (1926), Coetzee et al. (1976), Van der Meulen (1979), Van der Meulen and Westfall (1980), Winterbach (1998).

24. SVcb 16 Western Sandy Bushveld

Distribution	Limpopo and North West provinces, occurs on flats and undulating plains from Assen near the Crocodile River westwards to the Botswana border between the Swartruggens and Dwarsberg mountain ranges. Also, around Thabazimbi northwards to Steenbokpan and west of the Waterberg Mountains.
Altitude	Mostly at altitudes of 900–1 200 m.
Vegetation and landscape features	Tall, open or closed broad-leaved woodland on gently undulating flats with sandy soils. Bottomlands with clay soils, which are dominated by microphyllous 'Acacia' tree species, belong to the Dwaalboom Thornveld vegetation type.
Geology and soils	Kalahari sand. Quaternary surface deposits comprising remnants of a formerly more widespread covering of Kalahari sand that stretched eastwards as far as the Springbokvlakte. The underlying geology is variable but has no influence on the current surface geology of this vegetation unit. Soils are plinthic catenas, eutrophic, red-yellow apedal, freely drained, high base status, Hutton and Clovelly soil forms. Land types mainly Ae.
Important taxa	**Trees**: *Vachellia erioloba, Senegalia nigrescens, Sclerocarya birrea, Combretum apiculatum, Combretum imberbe, Terminalia sericea, Combretum zeyheri, Lannea discolor, Ochna pulchra, Peltophorum africanum, Combretum hereroense, Euclea undulata, Coptosperma supra-axillare, Dichrostachys cinerea, Grewia bicolor, Grewia flava, Grewia monticola*. **Grasses**: *Anthephora pubescens, Digitaria eriantha, Eragrostis pallens, Eragrostis rigidior, Schmidtia pappophoroides, Aristida congesta, Aristida diffusa, Aristida stipitata, Eragrostis superba, Panicum maximum, Perotis patens*.

Important taxa (continued)	**Shrubs**: *Clerodendrum ternatum, Indigofera filipes, Justicia flava*. **Herbs**: *Blepharis integrifolia, Chamaecrista absus, Evolvulus alsinoides, Geigeria burkei, Cyphocarpa angustifolia, Limeum fenestratum, Limeum argute-carinatum, Lophiocarpus tenuissimus, Monsonia angustifolia*.
Remarks	There are many floristic similarities between this vegetation type and Central Sandy Bushveld. The key difference is that this type occurs on relic aeolian Kalahari sands, whereas the latter is associated with coarse sandy-loam soils derived from the underlying granite rocks. This vegetation type also tends to be taller, more open bushveld whereas the latter is shorter and denser. Large specimens of tree species such as *Vachellia erioloba, Sclerocarya birrea* subsp. *caffra, Senegalia erubescens, V. nigrescens* and *Combretum imberbe* are characteristic of this unit whereas these species are absent from Central Sandy Bushveld. On deeper sands *Terminalia sericea* can form tall, dense stands. Rural settlements between the Pilanesberg, Swartruggens and Dwarsberg is often associated with this unit as the surrounding thornveld units on black cotton soils are not suitable for settlement.
References	Bosch (1971), Herbst (1973), Peel (1990), Peel et al. (1991), Brown and Bredenkamp (1994, 2004), Brown et al. (1995, 1996, 1997), Brown (1997), Winterbach (1998), Winterbach et al. (2000), Stalmans and De Wet (2003).

25. SVcb 17 Waterberg Mountain Bushveld

Distribution	Limpopo Province extending into the far northeast of the NW, Waterberg Mountains, including the foothills, escarpment and tablelands south of the line between Lephalale and Marken and north of Bela-Bela and west of Mokopane and with outliers in the southwest such as the Boshofsberge and Vlieëpoortberge near Thabazimbi.
Altitude	Altitude about 1 000–1 600 m and generally at a lower altitude than the Gm 29 Waterberg-Magaliesberg Summit Sourveld.
Vegetation and landscape features	Rugged mountains with vegetation grading from *Faurea saligna–Protea caffra* bushveld on higher slopes (in turn grading into the Waterberg-Magaliesberg Summit Sourveld) through broad-leaved deciduous bushveld (dominated by *Diplorhynchus condylocarpon*) on rocky mid- and foot slopes to *Burkea africana–Terminalia sericea* savanna in the lower-lying valleys, as well as on deeper sands of the plateaus. The grass layer is moderately developed or well developed.
Geology and soils	Mainly sandstone and quartzite rocks that give rise to dystrophic, acidic sandy, loamy to gravelly soil. Glenrosa and Mispah Forms. Land types mainly Ib, Fa and Ad.
Important taxa	**Trees**: *Vachellia karroo, Senegalia caffra, Burkea africana, Combretum apiculatum, Croton gratissimus, Cussonia transvaalensis, Faurea saligna, Heteropyxis natalensis, Ochna pulchra, Protea caffra, Albizia tanganyicensis, Combretum molle, Englerophytum magalismontanum, Ficus burkei, Ficus glumosa, Ochna pretoriensis, Pseudolachnostylis maprouneifolia, Searsia lancea, Terminalia sericea, Vangueria infausta, Vangueria parvifolia, Diplorhynchus condylocarpon, Elephantorrhiza burkei, Combretum moggii, Combretum nelsonii, Dichrostachys cinerea, Euclea crispa, Lasiosiphon kraussianus, Olea capensis, Searsia pyroides, Strychnos pungens, Vitex rehmannii*. **Grasses**: *Loudetia simplex, Schizachyrium sanguineum, Trachypogon spicatus, Brachiaria serrata, Digitaria eriantha, Elionurus muticus, Enneapogon scoparius, Setaria sphacelata, Themeda triandra, Tristachya leucothrix*. **Shrubs**: *Anthospermum rigidum, Barleria affinis, Felicia muricata, Helichrysum kraussii, Protea welwitschii, Searsia rigida, Dichapetalum cymosum, Parinari capensis, Aloe chabaudii, Lopholaena coriifolia, Ancylobothrys capensis, Rhoicissus revoilii*. **Herbs**: *Berkheya insignis, Chamaecrista mimosoides, Geigeria elongata, Hibiscus meyeri, Xerophyta equisetoides, Haemanthus humilis, Hypoxis rigidula*.

Important taxa (continued)	**Biogeographically important taxa**: Northern Sourveld Endemic, *Encephalartos eugene-maraisii, Chorisochora transvaalensis*. **Central Bushveld endemic**, *Erythrophysa transvaalensis, Mosdenia leptostachys*. **Waterberg endemic**, *Grewia rogersii, Vangueria triflora, Oxygonum delagoense*.
Remarks	Carrying capacity of the vegetation for domestic stock animals is low, especially during the dry season (viz, 'sourveld').
References	Coetzee et al. (1981), Westfall (1981), Westfall et al. (1983, 1984), Ben-Shahar (1988), Van Staden (2002), Van Staden and Bredenkamp (2005), Van Staden et al. (2021).

26. SVk 1 Mafikeng Bushveld

Distribution	NW, west of Mafikeng and south of the Botswana border westwards to around Vergeleë, southwards to Piet Plessis and Setlagole.
Altitude	Altitude 1 100–1 400 m.
Vegetation and landscape features	Dense, well developed, tall (> 5 m) woodland with high canopy cover on deep sand.
Geology and soils	Aeolian Kalahari sand of Tertiary to Recent age on flat sandy plains, soils deep (> 1.2 m). Clovelly and Hutton soil forms. Land types Ah and Ai.
Important taxa	**Trees**: *Vachellia erioloba, Terminalia sericea, Ziziphus mucronata, Vachellia luederitzii, Dichrostachys cinerea, Grewia flava, Searsia tenuinervis, Diospyros austroafricana, Ehretia rigida, Rhigozum obovatum, Tarchonanthus camphoratus, Vachellia hebeclada, Grewia retinervis*. **Grasses**: *Anthephora pubescens, Cymbopogon pospischilii, Digitaria eriantha, Eragrostis lehmanniana, Eragrostis pallens, Eragrostis superba, Eragrostis trichophora, Schmidtia pappophoroides, Stipagrostis uniplumis, Aristida congesta, Aristida meridionalis, Aristida mollissima, Aristida stipitata, Brachiaria nigropedata, Digitaria argyrograpta, Melinis repens, Tragus koelerioides, Urochloa panicoides, Panicum kalaharense*. **Shrubs**: *Aptosimum elongatum, Felicia muricata, Lasiosiphon polycephalus, Helichrysum zeyheri, Pomaria burchellii, Lantana rugosa, Talinum arnotii, Elephantorrhiza burkei, Lycium cinereum, Asparagus africanus*. **Herbs**: *Barleria macrostegia, Erlangea misera, Harpagophytum procumbens, Hermannia tomentosa, Hermbstaedtia odorata, Indigofera daleoides, Limeum fenestratum, Nidorella microcephala, Oxygonum delagoense, Senna italica, Ledebouria marginata*.
Remarks	The absence of *Vachellia haematoxylon* (but present in Molopo Bushveld) is characteristic in this vegetation type. In the east near the Molopo River–Harts River interfluve this unit grades into Vryburg thornveld.
References	Smit (2000).

27. SVk 2 Stella Bushveld

Distribution	NW, North of Vryburg around Stella westwards to Louwna and eastwards to about 20 km west of Delareyville, with patches extending toward the Mafikeng area,
Altitude	Altitude 1 250–1 400 m.
Vegetation and landscape features	Flat to gently undulating deep sand-covered plains with open grassy savanna woodland dominated by very large *Searsia lancea* and (less so) *Vachellia erioloba* trees and *Tarchonanthus camphoratus* shrubs.

Geology and soils	Aeolian Kalahari sand with a calcrete layer at depth overlying a variety of geologies. Deep (> 0.4 m), red-yellow apedal, freely drained soils with high base status. Land types Ae and Ag.
Important taxa	**Trees**: *Searsia lancea, Vachellia erioloba, Tarchonanthus camphoratus, Senegalia caffra, Vachellia hebeclada, Vachellia karroo, Dichrostachys cinerea, Grewia flava, Diospyros lycioides, Ehretia rigida, Grewia flava*. **Grasses**: *Cenchrus ciliaris, Cymbopogon pospischilii, Eragrostis rigidior, Panicum coloratum, Themeda triandra, Aristida congesta, Cynodon dactylon, Eragrostis superba, Eragrostis obtusa, Pogonarthria squarrosa, Sporobolus fimbriatus, Tragus koelerioides*. **Shrubs**: *Asparagus laricinus*. **Herbs**: *Chrysocoma ciliata, Hertia pallens, Osteospermum muricatum, Pentzia viridis, Asparagus africanus, Babiana bainesii, Dicoma capensis, Hermannia quartiniana, Hibiscus pusillus, Indigofera alternans, Indigofera daleoides, Lippia scaberrima, Rhynchosia confusa, Schkuhria pinnata, Solanum supinum, Osteospermum scariosum*.
Remarks	This vegetation type represents the ecotone between the Highveld grasslands to the east and Kalahari bushveld to the west, hence on the margins of this vegetation unit it will grade into these neighbouring vegetation types. As the depth of sand decreases and the underlying calcrete becomes exposed then this unit grades into Western Highveld Sandy Grassland. Due to lack of fire, *Tarchonanthus camphoratus* tends to bush encroach leading to a closed bushveld structure. Flax-leaf fleabane (*Erigeron bonariensis*) is an alien invasive annual daisy species that is a major invader in this vegetation type leading to a loss of grassland. This is particularly a problem on commercial farms where veld fires are suppressed.
References	Smit (2000).

28. SVk 3 Schweizer-Reneke Bushveld

Distribution	NW, Schweizer-Reneke area in the east to Amalia in the west and from the farming areas of around Broedersput in the north to Never Mind (Christiana District) in the south.
Altitude	Altitude 1 250–1 400 m.
Vegetation and landscape features	Gently undulating, deep sand covered plains supporting open, tall camelthorn (*Vachellia erioloba*) woodland sometimes with a dense understory of smaller trees comprising *Vachellia karroo, Searsia lancea, Diospyros lycioides, Grewia flava* and *Tarchonanthus camphoratus*.
Geology and soils	Aeolian Kalahari sand. Deep (0.9–1.2 m) sandy soils, with Hutton and Clovelly the dominant soil forms. Land type Ah.
Important taxa	**Trees**: *Vachellia erioloba, Vachellia karroo, Searsia lancea, Diospyros lycioides, Grewia flava, Tarchonanthus camphoratus, Diospyros pallens, Ehretia rigida, Gymnosporia buxifolia, Searsia tridactyla*. **Grasses**: *Anthephora pubescens, Digitaria eriantha, Heteropogon contortus, Stipagrostis uniplumis, Themeda triandra, Aristida congesta, Aristida stipitata, Chloris virgata, Eragrostis biflora, Eragrostis rigidior, Eragrostis superba, Eragrostis trichophora, Sporobolus fimbriatus*. **Shrubs**: *Asparagus laricinus, Vachellia hebeclada*. **Herbs**: *Aptosimum elongatum, Chrysocoma ciliata, Lasiosiphon polycephalus, Pentzia viridis, Asparagus africanus, Barleria macrostegia, Hermannia tomentosa, Hibiscus pusillus, Indigofera daleoides, Lippia scaberrima, Osteospermum muricatum, Pollichia campestris, Rhynchosia adenodes, Dipcadi papillatum, Nerine krigei*.

Remarks	Very similar to Stella Bushveld but is distinguished by the dominance of very large camelthorn trees (not a feature of Stella Bushveld where *Searsia lancea* is dominant), deeper sand and absence of calcrete near the surface. Very few examples of this vegetation remain as almost the entire extent of this vegetation type has been lost to cultivation.
References	Smit (2000).

29. SVk 4 Kimberley Thornveld

Distribution	North West, Free State and Northern Cape provinces, Most of the Kimberley, Hartswater, Bloemhof and Hoopstad Districts, as well as substantial parts of the Warrenton, Christiana, Taung, Boshof and to some extent the Barkly West Districts. Also includes pediment areas in the Herbert and Jacobsdal Districts.
Altitude	Altitude 1 050–1 400 m.
Vegetation and landscape features	Gently undulating sand-covered plains. Grassy with irregular to well-developed, short tree layer comprising *Vachellia tortilis*, *Senegalia mellifera, Vachellia karroo, Vachellia erioloba* and *Boscia albitrunca*. Grass layer open with much uncovered soil.
Geology and soils	Gently undulating plains of aeolian Kalahari sand overlying Andesitic lavas (basalt). Shallow (0.3 m) sandy loams (15% clay) of the Hutton soil form on top of calcrete. Land type Ae.
Important taxa	**Trees**: *Vachellia tortilis, Vachellia hebeclada, Vachellia karroo, Senegalia mellifera, Searsia lancea, Vachellia erioloba, Tarchonanthus camphoratus, Searsia tridactyla, Ehretia rigida, Grewia flava*. **Grasses**: *Aristida congesta, Cymbopogon pospischilii, Digitaria eriantha, Enneapogon cenchroides, Enneapogon scoparius, Eragrostis lehmanniana, Eragrostis rigidior, Heteropogon contortus, Themeda triandra*. **Herbs**: *Aloe grandidentata, Barleria macrostegia, Lippia scaberrima*.
Remarks	This vegetation type and Western Highveld Sandy Grassland share the same land type and the latter grades into this vegetation type along the east-west aridity gradient. *Senegalia mellifera* and *Vachellia tortilis* are the primary bush encroaching species in this vegetation type.
References	Bezuidenhout (1994, 1995, 2009), Smit (2000).

30. SVk 6 Schmidtsdrif Thornveld

Distribution	Northern Cape, Free State and North West provinces, foot slopes and mid slopes to the southeast and below the Ghaap Plateau from around Douglas in the southwest via Schmidtsdrif towards Taung in the northeast. A small less typical section is found east of the Ghaap Plateau from Warrenton towards Hertzogville.
Altitude	Altitude 1 000–1 350 m.
Vegetation and landscape features	Alluvial terraces in the valley floor of the Harts River. Mostly a short or tall closed shrubby thornveld dominated by *Senegalia mellifera* and *Vachellia tortilis*.
Geology and soils	Red, clay rich (> 30%) alluvial soils with a diagnostic B horizon. Land type Dc.
Important taxa	**Trees**: *Vachellia tortilis, Senegalia mellifera, Ziziphus mucronata, Grewia flava*.

Important taxa (continued)	**Grasses**: *Aristida meridionalis, Enneapogon cenchroides, Eragrostis lehmanniana, Eragrostis obtusa, Enneapogon desvauxii*. **Herbs**: *Aptosimum albomarginatum, Barleria rigida, Justicia incana, Pentzia incana, Hermannia affinis, Hermannia comosa, Ptycholobium biflorum, Roepera pubescens, Lacomucinaea lineata, Lepidium bonariense, Amaranthus praetermissus, Heliotropium ciliatum, Indigastrum parviflorum, Osteospermum muricatum, Seddera capensis, Stachys hyssopoides*.
Remarks	Due to its very favourable agricultural soils much of this vegetation type has been lost to cultivation, as well as settlements.
References	Gubb (1980), Crowe et al. (1981), Bezuidenhout (1994, 2009), Smit (2000).

31. SVk 7 Ghaap Plateau Vaalbosveld

Distribution	Northern Cape and North West provinces, flat plateau from around Campbell in the south, east of Danielskuil through Reivilo to around Vryburg in the north.
Altitude	Altitude 1 100–1 500 m.
Vegetation and landscape features	Flat, rocky karst plateau mostly open grassland with well-developed shrub layer dominated by *Tarchonanthus camphoratus* and *Vachellia karroo*. Tall (> 5 m), dense bush clumps comprising *Vachellia karroo, Searsia lancea, Olea europaea* and *Ziziphus mucronata* occur on low, linear ridges (termed grikes or kluftkarren, see remarks below) that bisect the karst landscape and can run for many kilometres.
Geology and soils	Limestone pavement overlying dolomite with shallow, rocky soils (0.10–0.25 m) of Mispah and Hutton soil forms. Land type Fc.
Important taxa	**Trees**: *Tarchonanthus camphoratus, Searsia lancea, Vachellia karroo, Vachellia erioloba, Senegalia mellifera, Vachellia tortilis, Boscia albitrunca, Olea europaea, Rhigozum trichotomum, Ziziphus mucronata, Diospyros austroafricana, Diospyros pallens, Ehretia rigida, Euclea crispa, Grewia flava, Gymnosporia buxifolia, Lessertia frutescens, Searsia tridactyla, Vachellia hebeclada*. **Grasses**: *Themeda triandra, Anthephora pubescens, Cenchrus ciliaris, Digitaria eriantha, Enneapogon scoparius, Eragrostis lehmanniana, Schmidtia pappophoroides, Aristida congesta, Aristida diffusa, Cymbopogon pospischilii, Enneapogon cenchroides, Enneapogon desvauxii, Eragrostis echinochloidea, Eragrostis obtusa, Eragrostis rigidior, Eragrostis superba, Fingerhuthia africana, Heteropogon contortus, Sporobolus fimbriatus, Stipagrostis uniplumis, Tragus koelerioides*. **Shrubs**: *Aptosimum elongatum, Chrysocoma ciliata, Helichrysum zeyheri, Hermannia comosa, Lantana rugosa, Leonotis pentadentata, Melolobium lampolobum, Peliostomum junceum, Pentzia globosa, Pentzia viridis, Roepera pubescens, Hertia pallens, Lycium cinereum, Thesium hystrix, Asparagus africanus*. **Herbs**: *Barleria macrostegia, Geigeria filifolia, Geigeria ornativa, Gisekia africana, Helichrysum cerastioides, Heliotropium ciliatum, Hermbstaedtia odorata, Hibiscus marlothianus, Hibiscus pusillus, Jamesbrittenia aurantiaca, Limeum fenestratum, Lippia scaberrima, Selago densiflora, Vahlia capensis, Aloe grandidentata, Pentzia stellata*.
Remarks	The Ghaap Plateau is recognised as part of the Griqualand West Centre of Endemism. Important taxa include (GW = Griqualand West endemic, K = Kalahari endemic, D = Broadly disjunct distribution): *Calobota cuspidosa* GW, *Nuxia gracilis* D, *Blepharis marginata* GW, *Putterlickia saxatilis* GW, *Tarchonanthus obovatus* GW, *Euphorbia patula* GW, *Prepodesma orpenii* GW (endemic genus), *Digitaria polyphylla* GW, *Panicum kalaharense* K, *Corchorus pinnatipartitus* GW, *Helichrysum arenicola* K, *Orbea knobelii* K.

Remarks (continued)	Unlike the Malmani karst geology that is mostly covered by Tertiary deposits, both the Ghaap Plateau and the Morokweng karst landscapes can be described as exposed limestone pavements with a very characteristic karst geological weathering pattern immediately observable in aerial imagery. The weathering of these landscapes give rise to low (< 5 m high) linear ridges that run for many kilometres and at odd angles to one another. These are solution fissures that follow joins or faults in the underlying dolomite and the geological term for these ridges is grikes or kluftkarren. These kluftkarren are characteristically covered in woodland vegetation, and in communal areas settlement is often concentrated on these features to avoid occasional flooding. *Tarchonanthus camphoratus* is a woody encroaching species that can dominate the vegetation in parts of the landscape.
References	Smit (2000), Frisby (2016), Frisby et al. (2019).

32. SVk 8 Kuruman Vaalbosveld

Distribution	North West and Northern Cape provinces, east of Kuruman to Lykso, south of Bendell towards Good Hope.
Altitude	Altitude 1 300–1 500 m.
Vegetation and landscape features	Flat to gently undulating shallow sand-covered plains with open grassy savanna woodland characterised by *Vachellia erioloba, Vachellia karroo, Searsia lancea* and *Ziziphus mucronata*. Shrub layer is poorly developed, with *Grewia flava* and *Tarchonanthus camphoratus* and the grass layer is open, with much bare soil in places.
Geology and soils	Aeolian Kalahari sand overlying dolomites of the Ghaap Plateau. Calcrete layer is present. Soils are shallow (< 0.6 m), red sand with a high base status of the Hutton and Clovelly forms. Land types Ae and Ai.
Important taxa	**Trees**: *Searsia lancea, Vachellia erioloba, Vachellia karroo, Ziziphus mucronata, Tarchonanthus camphoratus, Cadaba aphylla, Diospyros austroafricana, Diospyros lycioides, Grewia flava, Gymnosporia buxifolia*. **Grasses**: *Anthephora pubescens, Aristida meridionalis, Anthephora argentea, Eragrostis lehmanniana, Stipagrostis uniplumis, Aristida stipitata, Cymbopogon caesius, Digitaria eriantha, Fingerhuthia africana, Pogonarthria squarrosa, Schmidtia pappophoroides, Themeda triandra, Tragus koelerioides*. **Shrubs**: *Amphiglossa triflora, Anthospermum rigidum, Helichrysum zeyheri, Elephantorrhiza burkei, Rhynchosia holosericea*. **Herbs**: *Acrotome inflata, Dicoma schinzii, Geigeria ornativa, Heliotropium strigosum, Stachys spathulata, Osteospermum scariosum*.
Remarks	Being a dolomite or karst landscape there are many sinkholes that have been filled-in with aeolian sand. These are called dolines. In the Malmani karst landscape (Carletonville Dolomite Grassland) dolines support Olea Sclerophyllous Forest. In this landscape dolines support conspicuous clumps of *Vachellia erioloba*. Kuruman Vaalbosveld is environmentally, structurally and floristically very similar to Stella Bushveld, and both are closely related to Ghaap Plateau Vaalbosveld. Aridity increases from east to west as one descends off the Ghaap Plateau. Kuruman Vaalbosveld is an arid form of Stella Bushveld, and both these vegetation types are distinguished from Ghaap Plateau Vaalbosveld by the presence of a continuous sand layer with no surface limestone (calcrete) or rockiness. Extensive exposures of calcrete, particularly associated with drainage lines and freshwater springs, belong to the Southern Kalahari Mekgacha vegetation type.
References	Smit (2000).

33. SVk 10 Kuruman Mountain Bushveld

Distribution	Northern Cape and North West provinces, from the Asbestos Mountains southwest and northwest of Griekwastad, along the Kuruman Hills north of Danielskuil, passing west of Kuruman town and re-emerging as isolated hills, i.e., Makhubung and the hills around Pomfret in the north. In the NW includes all mountains and hills west of the Harts River that fall in the Molopo River catchment.
Altitude	Altitude 1 100–1 800 m.
Vegetation and landscape features	Open to dense mixed woodland on rolling, rock hills and koppies with generally gentle to moderate slopes and includes the rocky pediment or apron at the base of hills. Grass layer is well developed.
Geology and soils	Various geologies including sandstone, banded ironstone and basalt (andesite). Soils mostly lithosols on upper slopes with deeper, sandy, rocky soils on lower slopes and pediments. Land types Ib and Fb towards the east.
Important taxa	**Trees**: *Searsia lancea, Senegalia mellifera, Dichrostachys cinerea, Diospyros austroafricana, Euclea crispa, Euclea undulata, Olea europaea, Searsia pyroides, Searsia tridactyla, Vachellia nilotica, Tarchonanthus camphoratus, Tephrosia longipes, Searsia ciliata, Boscia albitrunca*. **Shrubs**: *Amphiglossa triflora, Anthospermum rigidum, Gomphocarpus fruticosus, Helichrysum zeyheri, Lantana rugosa, Wahlenbergia nodosa, Ebracteola wilmaniae, Hertia pallens, Rhynchosia totta*. **Grasses**: *Andropogon chinensis, Andropogon schirensis, Anthephora pubescens, Aristida congesta, Digitaria eriantha, Themeda triandra, Triraphis andropogonoides, Aristida diffusa, Brachiaria nigropedata, Bulbostylis burchellii, Cymbopogon caesius, Diheteropogon amplectens, Elionurus muticus, Eragrostis chloromelas, Eragrostis nindensis, Eustachys paspaloides, Heteropogon contortus, Melinis repens, Schizachyrium sanguineum, Trichoneura grandiglumis*. **Herbs**: *Dicoma anomala, Dicoma schinzii, Geigeria ornativa, Helichrysum cerastioides, Heliotropium strigosum, Hibiscus marlothianus, Kohautia cynanchica, Cyphocarpa angustifolia, Boophone disticha, Pellaea calomelanos*. **Griqualand West endemics**: *Calobota cuspidosa, Justicia puberula, Tarchonanthus obovatus, Euphorbia patula, Digitaria polyphylla, Sutera griquensis, Euphorbia patula*.
Remarks	Many species in this unit are widely distributed to the northeast of the subcontinent and reach their southwestern limit in this unit (e.g., *Andropogon schirensis*). There are distinct floristic differences with the relatively nearby and parallel mountains of Koranna-Langeberg Mountain Bushveld. For example, *Croton gratissimus* is common in the Koranna-Langeberg Mountain Bushveld unit but rare in Kuruman Mountain Bushveld. *Calobota cuspidosa* shows just the reverse distributional pattern between these units. The Harts River is used here as the biogeographic and mapping divide between Andesite Mountain Bushveld (east) and Kuruman Mountain Bushveld (west) vegetation types. There are observable floristic changes in this vegetation unit associated with geology and the east–west rainfall gradient. Tree density decreases westwards with the western mountains being more open and dominated by thorn trees. Further floristic analysis is required to determine where the boundary of these two vegetation types is located. Bush encroachment is a major problem in this vegetation type. Both *Senegalia mellifera* and *Dichrostachys cinerea* can form vast impenetrable thickets such as around Pomfret and Heuningvlei.
References	Smit (2000), Van Wyk and Smith (2001).

34. SVk 11 Molopo Bushveld

Distribution	North West and Northern Cape provinces, in the Molopo area from Bray and Werda in the north on the border with Botswana, southwards through Morokweng and Tosca in the east and Vorstershoop to McCarthy's Rest and Eldorado in the west to Bendell in the south.
Altitude	1 000–1 300 m.

Vegetation and landscape features	Flat to gently undulating sandy plains with open Kalahari woodland to a closed shrubland interspersed with numerous small pans. Grass layer is usually very well developed and open.
Geology and soils	Red aeolian Kalahari sand overlying dorbank. Surface calcrete is not present. Soils are deep (> 1.2 m) and sandy (Hutton and Clovelly soil forms). Land type mainly Ah.
Important taxa	**Trees**: *Vachellia erioloba, Boscia albitrunca, Terminalia sericea, Vachellia luederitzii, Vachellia haematoxylon, Lycium hirsutum, Rhigozum trichotomum, Grewia flava, Lycium villosum, Searsia burchellii, Vachellia hebeclada*. **Grasses**: *Aristida meridionalis, Aristida stipitata, Cenchrus ciliaris, Eragrostis lehmanniana, Anthephora argentea, Megaloprotachne albescens, Panicum kalaharense, Aristida congesta, Eragrostis biflora, Eragrostis pallens, Eragrostis rigidior, Pogonarthria squarrosa, Schmidtia kalahariensis, Schmidtia pappophoroides, Stipagrostis ciliata, Stipagrostis uniplumis*. **Shrubs**: *Aptosimum albomarginatum, Aptosimum marlothii, Eriocephalus ericoides, Justicia divaricata, Justicia incana, Elephantorrhiza burkei, Momordica balsamina*. **Herbs**: *Acanthosicyos naudinianus, Acrotome angustifolia, Acrotome inflata, Dicoma schinzii, Geigeria ornativa, Helichrysum cerastioides, Hermannia tomentosa, Hermbstaedtia fleckii, Limeum arenicolum, Limeum fenestratum, Limeum argute-carinatum, Leobordea platycarpa, Senna italica, Sericorema remotiflora, Tephrosia purpurea, Tribulus terrestris*.
Remarks	An extensive unit with increasing diversity of savanna plant species towards the north and northeast. The abundance of small pans throughout this unit and the sparser woody element separate this unit from Mafikeng Bushveld.
References	Smit (2000).

35. SVk XX[*] Vryburg Thornveld

Distribution	NW, headwaters of the Molopo River catchment below the northern edge of the Ghaap Plateau, stretching in an arc from Ganyesa in the south to Mahikeng in the north. Also associated with the eroding flanks of larger west flowing rivers thus it is encountered as far west as Bray along the Molopo River.
Altitude	1 000–1 420 m (median 1 270 m).
Vegetation and landscape features	Open, tall woodland dominated by very tall *Vachellia erioloba* trees and scattered low *Vachellia hebeclada, Senegalia mellifera* and *Dichrostachys cinerea* thickets. *Terminalia sericea* is present but not characteristic or dominant of this vegetation type.
Geology and soils	Aeolian sand with red-yellow, free-draining, apedal soils with high base status (Clovelly and Hutton forms). Average depth 1.2 m. Average clay 8%. Land type Ah.
Important taxa	**Trees**: *Acacia erioloba* (d*), *A. hebeclada* (d), *A. karroo, A. mellifera* (d), *Terminalia sericea*. **Shrubs**: *Tarchonanthus camphoratus* (d), *Dichrostachys cinerea, Grewia flava, Ehretia rigida, Elephantorrhiza elephantina*. **Grasses**: *Anthephora pubescens* (d), *Aristida meridionalis* (d), *Eragrostis pallens* (d), *E. lehmanniana*(d), *Stipagrostis uniplumis* (d), *Cynodon dactylon, Aristida stipitata, Cymbopogon plurinodis, Digitaria eriantha, Eragrostis trichophora, Schmidtia pappophoroides*. **Forbs**: *Asparagus africanus, Chenopodium album, Erlangea misera, Felicia muricata, Gnidia polycephala, Hermannia tomentosa, Indigofera daleoides, Lantana rugosa, Senna italica, Verbesina encelioides*.

[2]Vegetation type number to be assigned by the National Vegetation Map Committee.

Remarks	The undulating and eroding character of this landscape with exposed dorbank and calcrete (along streams), as well as the presence of springs and hydromorphic grasslands is definitive of this vegetation type. Most of the broad-leaved woody elements and the dense woodland that characterise the neighbouring Mafikeng Bushveld are absent or much reduced here. Eroding slopes mostly expose dorbank hardpan. Only in drainage lines is calcrete encountered (viz. Southern Kalahari Mekgacha). The numerous springs in this landscape are decanting groundwater from the Ghaap Plateau. Consequently, rural settlement in this vegetation type is very high relative to surrounding Kalahari vegetation types.
References	Smit (2000), Bredenkamp and Brown (2003b).

36. SVk XX[3] Morokweng Thornveld

Distribution	NW, Kalahari region around the town of Morokweng.
Altitude	1 060–1 230 m (median 1 148 m).
Vegetation and landscape features	Mostly flat karst landscape with open to dense, low (1–2 m) thornveld with sparse grass layer dominated by herbs and karroid shrubs.
Geology and soils	Dolomite with shallow rocky sandy soils (Glenrosa or Mispah forms) with extensive surface calcrete/limestone present. Average depth < 0.3 m. Average clay 6%. Land type Fc.
Important taxa	**Trees**: *Senegalia mellifera* (d*), *Vachellia hebeclada* (d), *Boscia albitrunca* (d), *Grewia flava* (d), *Lycium cinereum, Vachellia erioloba*. **Grasses**: *Eragrostis lehmanniana* (d), *Tragus racemosus* (d), *Aristida congesta, Brachiaria marlothii, Enneapogon cenchroides, Enneapogon scoparius, Stipagrostis uniplumis*. **Shrubs and forbs**: *Acrotome inflata, Asparagus africanus, Felicia muricata, Geigeria ornativa, Hermannia modesta, Hermannia tomentosa, Hermbstaedtia odorata, Kyphocarpa angustifolia, Limeum viscosum, Melhania rehmannii, Phyllanthus maderaspatensis, Senna italica, Sericorema remotiflora, Tephrosia purpurea*.
Remarks	This is a new vegetation type that is restricted to the NW. Whilst the geology is similar to that of the Ghaap Plateau, the lower rainfall supports a short arid thornveld as opposed to a grassy open woodland encountered in the more mesic Ghaap Plateau Vaalbosveld. Soil biogenic crusts are very well developed in this vegetation type approaching 'elephant skin' structure/texture.
References	Smit (2000).

[3]Vegetation type number to be assigned by the National Vegetation Map Committee.

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