Characteristics and affinities of the fynbos vegetation on Mariepskop, Limpopo Province, South Africa

by

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Summary

Prior to this in-depth phytosociological classification and biogeographical study, the only other intense floristic study focussing on all plant species done specifically on Mariepskop was the work by Van der Schijff and Schoonraad (1971 The aims of the study were to: (1) describe and map the plant communities above 1800m at Mariepskop; (2) analyse the life forms in each community using Raunkiaer's (1934) classification as modified by Mueller-Dombois and Ellenberg (1974) in order to assess similarities with the Cape fynbos flora and; (3) investigate the geographic distribution of the identified plant species and their association with the Cape fynbos flora. Results from the phytosociological study indicated three plant communities and four subsequent subcommunities. The life form spectra for the three communities combined did not show similarity with Grassland Biome spectra but did however show similarities to the Fynbos Biome spectrum at Swartboskloof, where the ratio of the life forms was similar compared to the present study area. The codominant life forms for the Fynbos Biome are phanerophytes (35.2%), chamaephytes (28.1%) and hemicryptophytes (33.5%), while the codominant life forms on Mariepskop were also phanerophytes (32.3%), chamaephytes (28.6%) and hemicryptophytes (29.1%). In terms of phytogeography, out of a total of 61 species found at the summit of Mariepskop, 23 species (38% of all species) had a northern-southern distribution, 17 species (28%) had a north-eastern distribution and 21 (34%) species had a strictly northern distribution. The current pilot study has improved our understanding of the floristic and life form composition of the vegetation on the summit of Mariepskop and has provided a platform for future ecological studies such as unravelling the directionality of the migration of 'Cape taxa' (either from or to the Cape) as well as the ecology of mountain summit vegetation scattered along southern Africa.

I, **Nadine Coetzer** *declare that the thesis/dissertation, which I hereby submit for the degree* **MSc Environmental Ecology** *at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.*

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CHAPTER 1

Introduction

African high elevation conditions in climate and soil above 1800 m are considered to be unique and can lead to high levels of endemism in plants, animals and bryophytes (Hilliard and Burtt 1987, Van Wyk and Smith 2001, Carbutt and Edwards 2006, Mucina and Rutherford 2006). Vegetation at high elevations is exposed to intensified environmental stresses such as low ambient temperatures, high wind velocities, elevated levels of evaporation and high levels of ultraviolet radiation (Körner 1999). Generally, moving up along the slopes, tall forests gradually give way to scrub forest which is followed by bushland and thicket with dwarf shrubland at the summit (White 1978). Mountains may be regarded as similar to “an archipelago of islands in an “ocean” of low-level vegetation types that act as an isolation factor” (MacArthur and Wilson 2001). This, in turn, prevents plant species with poor seeddispersal mechanisms from dispersing over wide ranges and allows for high levels of endemism to develop at these high elevations (Hilliard and Burtt 1987). High levels of site-specific endemism imply that inselbergs and mountains have high levels of biotic diversity (Körner 2000), and often yield unique phytosociological associations (Sarthou & Villiers, 1998). However, numerous species on inselbergs may also be present in the surrounding vegetation (Mutke *et al.* 2001).

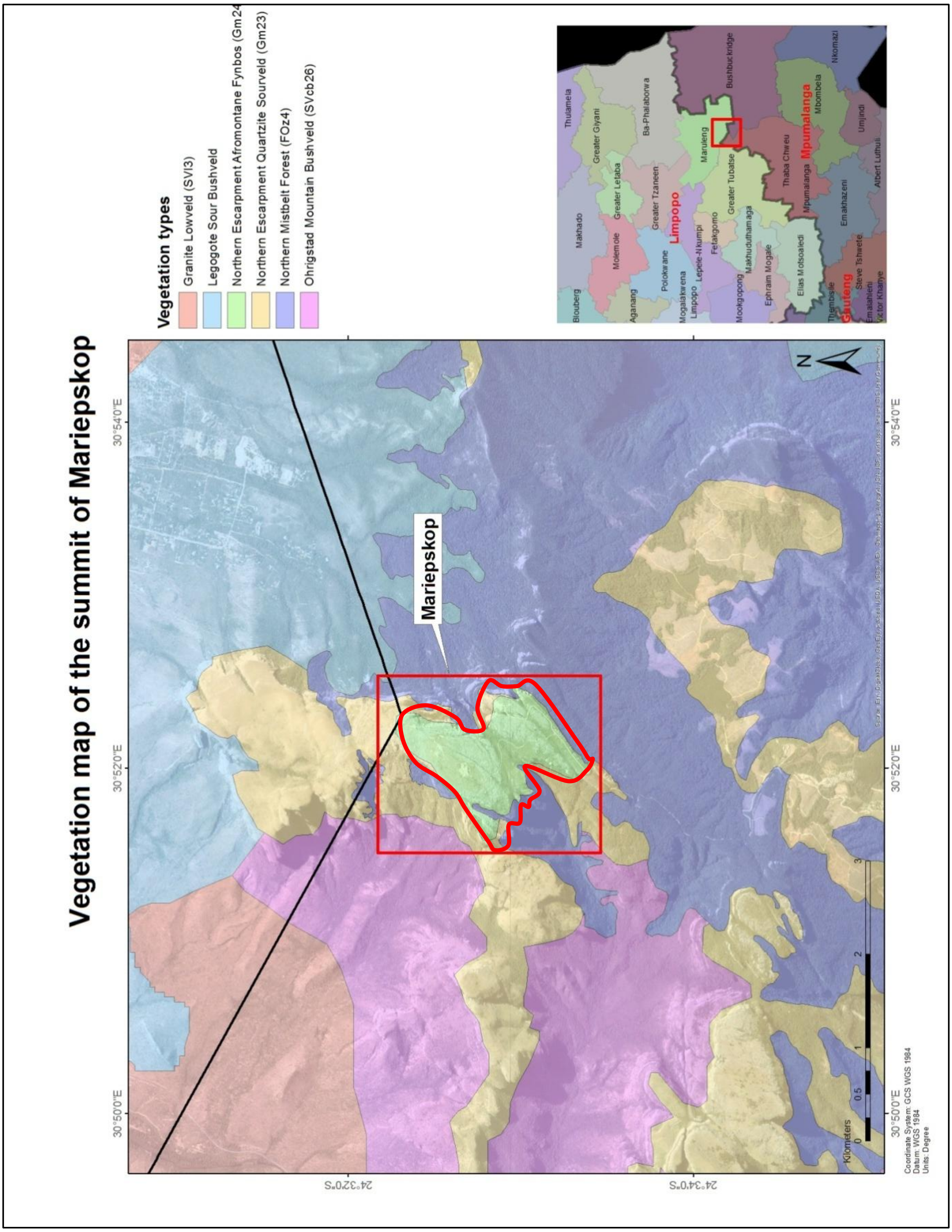

Figure 1.1. Vegetation types on and around Mariepskop, focusing specifically on the summit as indicated by the red box (based on Mucina and Rutherford 2006).

1.1. Life forms and biome affinities

A biome is characterized by plant life forms (Smith 1980) with relevant biotic features closely tied to environmental conditions (Rutherford *et al.* 1994). Biomes are not determined floristically (Van Wyk and Smith 2001), but are distinguished primarily on the basis of dominant plant life forms in climax systems (Odum 1971, Smith 1980). Raunkiaer (1934) suggested that the different life forms can be distinguished on the basis of the location of a plant's renewal buds and can be seen as an adaptation to the unfavourable season during a plant's life, generally the dry season (Danin and Orshan 1990). The broad life form categories, following Raunkiaer's (1934) classification as modified by Mueller-Dombois and Ellenberg (1974), are phanerophytes, chamaephytes, hemicryptophytes, geophytes and therophytes (discussed in Chapter 2).

Much of African montane vegetation, especially the southern Afromontane Region, is characterized by a mosaic of forest patches ('islands') in a 'sea' of grassland, either with or without heathland elements (Meadows and Linder 1989). Typical genera which characterize the Cape fynbos include *Leucospermum* (Proteaceae), *Restio* (Restionaceae) and *Erica* (Ericaceae) (Linder 2003). The vegetation found in summer rainfall montane environments such as the Chimanimani Mountains structurally resemble heathy 'fynbos' (Taylor 1978), where the main elements (namely restioid, ericoid and proteoid) are present but do not dominate from a biomass point of view (Phipps & Goodier 1962; Wild 1964). Other examples of families and genera of Cape affinity, and having generally sclerophyllous, small, narrow and rolled leaves found in the Afromontane and Afroalpine regions include Polygalaceae (*Muraltia*), Rosaceae (*Cliffortia*), Rhamnaceae (*Phylica*) and Fabaceae (*Aspalathus*).

1.2. Phytogeography

The typical 'Cape' taxa and growth forms are not restricted to the Cape Floristic Region (CFR) but can also be found in high elevation grasslands and shrublands of the Afromontane highlands such as Mariepskop. Typical Cape floristic elements belonging to the Ericaceae, Proteaceae and Restionaceae are clearly noticeable at high elevations on Mariepskop (Van der Schijff and Schoonraad 1971, Van Wyk and Smith 2001). For example, about 40% of the 114 species of the genus *Protea* occur outside the Fynbos Biome either in these montane grassland and fynbos habitats or savannah (plateau woodland) (Rourke and Anderson 1980), which includes the summit of Mariepskop. Another example is the genus *Erica* with about 190 of the 1369 species in southern Africa found elsewhere in Africa and Madagascar other than the

Fynbos Biome and 11 *Erica* species can be found on or near Mariepskop (Van der Schijff and Schoonraad 1971, Oliver 1991, Cowling and Richardson 1995). Other high elevation regions in southern Africa containing fynbos elements include the Amatole Mountains, Eastern Cape (Trollope 1971), Platberg, eastern Free State (Brand *et al.* 2008, 2009) and Maloti Mountains, Lesotho (Killick 1979, Talukdar 1994). Mariepskop supports fynbos outliers with genera within the families Proteaceae, Restionaceae and Ericaceae (Van der Schijff and Schoonraad 1971).

1.2.1. Afromontane Regions

Mariepskop at the northern end of the Drakensberg Escarpment, and the Drakensberg has in the past mostly been regarded as Afromontane Region (White 1978). The Afromontane Region is an archipelago-like regional centre of endemism with 3000 (75%) of its 4000 species considered endemic (White 1983). Floristically, the CFR vegetation of southern Africa can broadly be divided into two broad major subdivisions namely Mountain and Coastal Fynbos, both having similar physiognomic features and species, but differing in species composition (Taylor 1978). As the names suggest, Coastal Fynbos is found in coastal areas, whereas Mountain Fynbos is found on mountain ranges, which stretch from Cape Agulhas northwards beyond the Cederberg (Taylor 1978). As previously mentioned, typical 'Cape Fynbos' taxa are not restricted to the CFR and the Fynbos Biome (which are loosely equivalent), but occur throughout sub-Saharan Africa, Madagascar and the Mascarene Islands in cool, montane high elevation environments, known as the Afromontane Region, where rainfall is high and soils are highly leached (Killick 1978, Cowling and Richardson 1995, Carbutt and Edwards 2001, Van Wyk and Smith 2001). Although Cape Fynbos species richness decreases to the west and the north; their contribution, however to floras of these Afromontane regions is substantial (Cowling 1983, Carbutt and Edwards 2001, Linder 2003). For example Hilliard and Burtt (1987) concluded that about 20% of the genera recorded in the southern Drakensberg are 'centred within the Cape region'. A study undertaken by Hedberg (1951) in East Africa concluded that about 4% of Afroalpine flora elements form a 'Cape element'.

Classifying high-elevation montane regions has been problematic as various authors use different terminology for the same altitudinal range. In the Natal Drakensberg, Killick (1963) and Edwards (1967), recommended that vegetation at elevations between 1830 and 2865 m.a.s.l. should be classified as part of the *subalpine belt*, a South African term to describe the vegetation below the tree limit at the summit and/or upper slopes of the Drakensberg in South Africa as well as the higher parts of Lesotho (Killick 1963, Edwards 1967). This belt is clearly recognizable by its distinctive environment (i.e. intensified weather conditions), found in the Drakensberg between the montane and alpine belts, the latter which has its own unique climax community, which is an *Erica-Helichrysum* dwarf shrubland (Killick 1978). The alpine belt (the vegetation found above the tree limit on high mountains at elevations between 1830 and 2865 m.a.s.l.) has also been named the austro-afro-alpine belt in Lesotho as well as the Drakensberg Alpine Belt to distinguish it from the afro-alpine belt found on the East African mountains (Coetzee 1967, Van Zinderen Bakker and Werger 1974). Other incorrect terms for the same altitudinal range include the ericaceous belt as well as the 'ericoid' subalpine zone, used to describe similar vegetation elsewhere in Africa and Malaysia (Hedberg 1951). However, generally the tree-dominated ericaceous 'belt' is the treeline ecotone separating the alpine and montane belts rather than a altitudinal belt in the true sense of the definition, while the subalpine zone cannot be compared to alpine belts as these are two separate belts (Körner *et al*. 2011). The vegetation on Mariepskop (Van der Schijff and Schoonraad 1971) and other similar vegetation have been described as forming part of the Afromontane Forest Belt (forested parts) as well as upper montane and ericaceous belt (Killick 1978, Körner *et al*. 2011).

Mariepskop is located on the border of both the Mpumalanga and Limpopo provinces in South Africa (30° 52' E, 24° 30' S). The Mariepskop complex, facing east from the Blyde River Canyon, forms part of the eastern side of the Drakensberg Escarpment and is the highest peak in the northern Drakensberg Escarpment at 1945 metres above sea level (Van der Schijff and Schoonraad 1971). The summit of Mariepskop above 1800 m covers an area of 160 ha, mainly within the Grassland Biome and encompasses three vegetation types (Mucina and Rutherford 2006) namely the Northern Escarpment Afromontane Fynbos (Gm 24), within which the majority of the summit and this study area falls, the Northern Escarpment Quartzite Sourveld (Gm 23) and the Northern Mistbelt Forest (FOz 4) (Figure 1.1).

Mariepskop falls within two major biomes namely the Grassland Biome and the Forest Biome (Mucina and Rutherford 2006). In terms of characteristic life forms, the Grassland Biome is generally dominated by hemicryptophytes (>75%), generally graminoids of the family Poaceae, with geophytes (<3%), chamaephytes and therophytes (both <1%) also present (Rutherford *et al.* 1994). The Forest Biome is characterized by the dominance of phanerophytes (>85%) as well as hemicryptophytes (<10%) and chamaephytes (<5%). Geographically, Mariepskop falls in the Grassland Biome with the summit forming part of the Northern

Escarpment Afromontane Fynbos vegetation type (Gm 24). Even though vegetation above 1800 m on Mariepskop is classified as part of the Grassland Biome, the name Northern Escarpment Afromontane Fynbos vegetation type (Mucina and Rutherford 2006) suggests the presence and/or dominance of Afromontane fynbos elements. The presence of woody shrubs structurally resembling heathy 'fynbos' could possibly be explained by the absence of fire in certain rocky habitats, which act as fire refugia but not indicate a possible outlier of the Fynbos Biome. Therefore, a focused phytosociological and phytogeographical study of the vegetation on the summit of Mariepskop is needed to improve our understanding of the plant communities and affinities of the vegetation, as well as the associated fauna. Also, as a result of the confusing nomenclature for the same type of region consisting of similar vegetation, clarification in terms of naming is needed specifically for the summit of Mariepskop.

The only in-depth floristic study documenting the plant species at Mariepskop was by Van der Schijff and Schoonraad (1971). Other phytosociological studies, where Mariepskop was included were studies done on grassland-associated vegetation of the Black Reef Quartzite formation (Matthews *et al.* 1991), high altitude hygrophilous vegetation regions (Matthews *et al.* 1992), the complete phytosociological study on the north-eastern mountain sourveld (Matthews 1991) and forested fragments below 1800 m (Lötter and Beck 2004).

Aims

Taking into account all the environmental information as well as the lack of an up-to-date phytosociological study for the potentially interesting and biogeographically important plant species and vegetation on Mariepskop, a need exists for a detailed phytosociological and phytogeographical study to define the species composition and to elucidate the geographical affinities of the fynbos on Mariepskop. The aims of the study were to:

- describe and map the plant communities above 1800 m at Mariepskop;
- analyse the life forms in each community using Raunkiaer's (1934) classification as modified by Mueller-Dombois and Ellenberg (1974) in order to assess similarities with the Cape fynbos vegetation structure;
- investigate the geographic distribution of the identified plant species and their association with the flora of the CFR, as the typical genera which characterize summer rainfall montane environments structurally resemble the Cape fynbos structure found in the CFR (which include genera such as *Leucospermum* (Proteaceae), *Restio* (Restionaceae) and *Erica* (Ericaceae) (Linder 2003).

CHAPTER 2

Literature study

2.1. Life forms and biome affinities

Traditionally, biomes are distinguished on the basis of the quantitative link between climate and life form combinations (Rutherford *et al.* 1994), based almost entirely on vegetation characteristics (Rutherford *et al.* 2006). Biomes are defined primarily on the basis of combinations of dominant life or growth forms and not on the basis of taxonomic characteristics (floral or faunal) (Rutherford 1997). Secondarily, biomes are defined on the basis of major climatic features, e.g. rainfall that affects most biota (Rutherford *et al.* 1994). Mucina and Rutherford (2006) derived their biomes, made up of vegetation units defined on floristic criteria, with a bottom-up approach which makes for "a perfect match between biome boundaries and floristically determined boundaries". Recently however, defining of biomes have shifted towards using remote sensing technology and basing biome definitions on leaf longevity and morphology of trees (Woodward *et al*. 2004). Thus, biomes would no longer be seen as static but rather as change in life-form composition over time as a result of a variety of environmental factors. Biomes, in reality, are not as clear-cut but rather have alternate states which primarily depend on environmental factors such as disturbance regime (i.e. fire) and climate (Woodward *et al*. 2004; Staver *et al*. 2011).

Raunkiaer (1934) proposed that plant life forms are distinguished from each other on the basis of the location of a plant's renewal buds which best expresses its adaptation to unfavourable seasons. The broad life forms categories following Raunkiaer's (1934) classification, as modified by Mueller-Dombois and Ellenberg (1974), are phanerophytes, chamaephytes, hemicryptophytes, geophytes and therophytes. Phanerophytes can be defined as woody plants or herbaceous evergreen perennials which are taller than 500 mm or their shoots do not die back periodically to the 500 mm height limit. Generally speaking, phanerophytes include single-stemmed trees (larger than multi-stemmed shrubs), palms, tree ferns, bottle trees, bamboos, lianas and plants resembling the banana plant. Nanophanerophytes also form part of this life form which are smaller phanerophytes (no taller than 2 m) but still larger than chamaephytes. Examples of phanerophytes would be *Burkea africana*, *Protea repens* and *Acacia tortilis*.

Chamaephytes are plants whose mature branch or shoot system remains perennially within 500 mm above the ground surface or plants that grow taller than 500 mm, but whose shoots die back periodically to that height limit. Chamaephytes can generally be recognized as being dwarf shrubs, low succulents or cushion plants. Examples of chamaephytes include *Erica dominans*, *Eriocephalus ericoides* and *Chrysocoma ciliata*.

Hemicryptophytes are perennial herbaceous plants (including the biennials) with periodic shoot reduction to a remnant shoot system that lies relatively flat on the ground surface. Hemicryptophytes are generally recognized as being perennial, graminoids, aphyllous restioids and perennial broad-leaved herbs such as *Ficinia nigrescens, Gazania krebsiana* and *Themeda triandra*.

Geophytes are those plants which have periodic reduction of the complete shoot system to storage organs that are imbedded in the soil. These plants are generally plants with bulbs, corms, tubers, non-graminoid rhizomes and rootstocks with examples being *Kniphofia linearifolia*, *Watsonia densiflora* and *Brunsvigia natalensis*.

Lastly, therophytes are annual plants whose shoot and root systems die after seed production and which complete their whole life cycle within a year. Therophytes are recognized as being herbaceous graminoids and forbs which are generally annual or ephemeral such as *Eragrostis viscosa*, *Melinis repens* and *Wahlenbergia capensis* (Rutherford *et al.* 1994).

2.2. Biomes of southern Africa

South Africa comprises of a wide variety of biomes ranging from the relatively moist, winter-rainfall region in the western part of the country within which the Fynbos, and further north, the arid Succulent Karoo Biomes and a small patch of the Desert Biome. While moving east into a summer-rainfall regime, the Nama-Karoo and Savanna Biomes are encountered, followed by the Grassland Biome in the cool, elevated interior and; lastly the Forest Biome found scattered in fragments across southern Africa (Figure 2.1) (Mucina and Rutherford 2006). The remaining biomes found in South Africa include the Indian Ocean Coastal Belt (matrix of coastal forest and grassland), and the Albany Thicket Biome, which is a unique combination of the elements of the Savanna, Nama Karoo and Subtropical Forest Biomes (Mucina and Rutherford 2006). The three largest biomes that account for 80% of the total area in South Africa are the Savanna (32.5%), Grassland (28%) and Nama-Karoo Biomes (19.5%)(Mucina and Rutherford 2006). As the majority of Mariepskop falls within the Grassland Biome with the small forested parts forming part of the Forest Biome, emphasis will be placed on the Grassland Biome in this discussion.

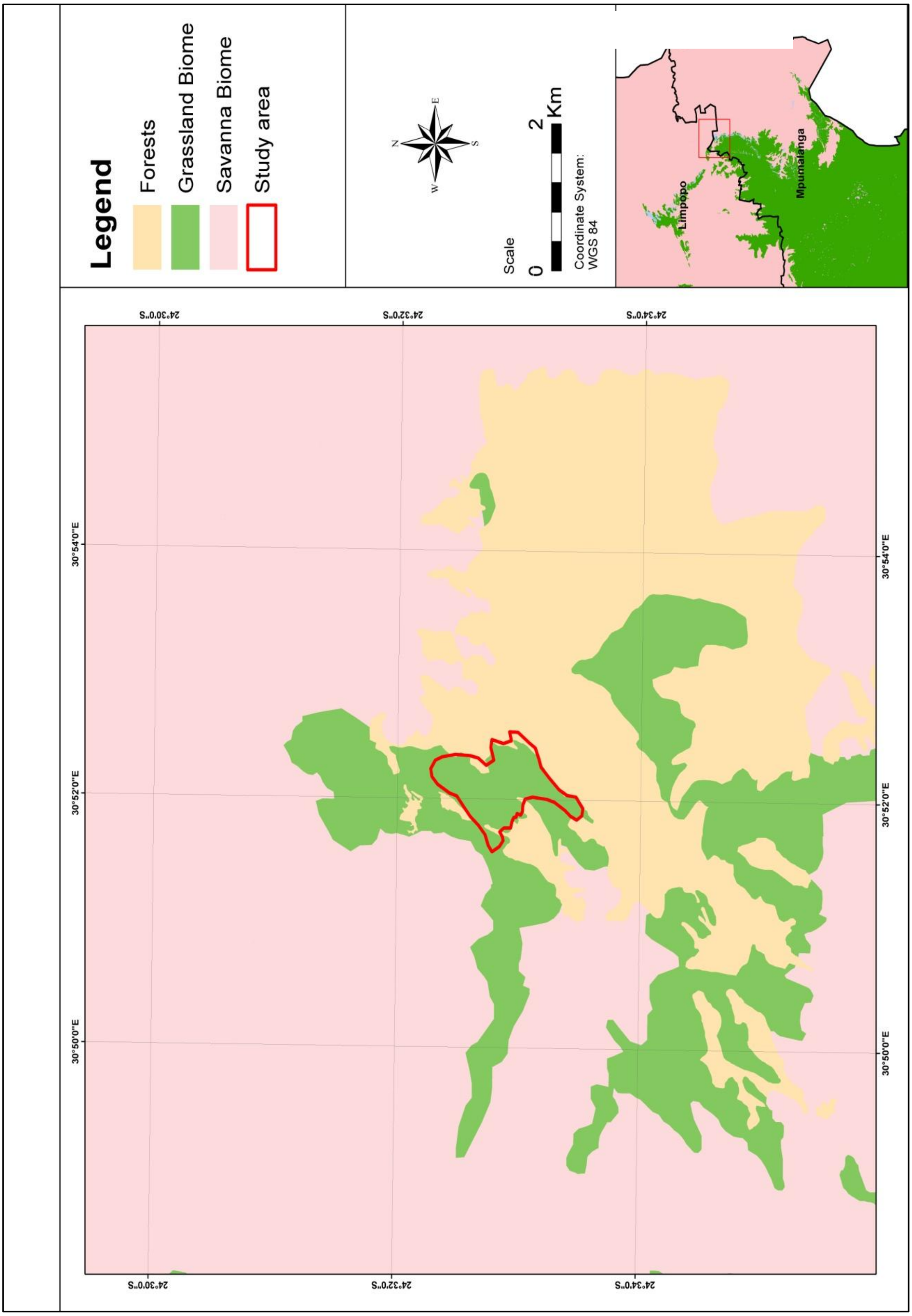

Figure 2.1. Biomes of South Africa with Mariepskop (red outline) falling in both the Grassland Biome as well as the Forest Biome (Mucina and Rutherford 2006).

The Grassland Biome - The Grassland Biome has interfaces with three biomes, namely the Savanna Biome (largest interface), the Nama-Karoo Biome as well as the indigenous afrotemperate forests of the Forest Biome (Figure 2.2). The interface with forests occurs in many places but it is particularly apparent along the escarpment where forest patches occur on steep, south-facing slopes where soil moisture content is particularly high or in deep and sheltered kloofs (Von Maltitz *et al.* 2003). With regards to fynbos, although a small interface exists between these two vegetation types, a dynamic relationship exists where satellite grasslands can be found in the Fynbos Biome, in the mountains of the Eastern Cape, and *vice versa*, satellite fynbos in grasslands of the Northern Escarpment region (Mucina and Rutherford 2006). Distant satellite populations may have been the result of recent invasion or they may be relictual, with the latter being the most probable. These relictual satellite populations are generally confined to specific and specially favourable environments such as the conditions on mountain summits (White 1978). Cape species present in these satellite fynbos patches decrease as the distance increases away from the Fynbos Biome while the Afromontane species increase along the same gradient (Rutherford *et al.* 2006).

Each biome is subdivided into bioregions which differ from each other on the basis of climatic variables such as temperature, incidence of frost and mean annual precipitation. The Grassland Biome has four bioregions namely the Drakensberg Grassland Bioregion, the Dry Highveld Grassland Bioregion, the Sub-Escarpment Grassland Bioregion and the Mesic Highveld Grassland Bioregion, the latter in which Mariepskop forms part of. Based specifically on moisture availability, these bioregions within the Grassland Biome can be roughly divided into two classes namely moist and dry grassland (Ellery *et al.* 1995). Moist grassland is characterized by leached, dystrophic soils; sour grasses with a high canopy cover; high plant production and high frequency of fire events, whereas dry grasslands are characterized by the complete opposite, i.e. less leached and eutrophic soils; sweet, palatable grasses and lower canopy cover; lower plant production as well as a lower frequency of fire events (Mucina *et al.* 2006). Moist grassland with sour grass species generally receives more than 600 mm of rain annually whereas dry grassland receives less than 600 mm annually. In South Africa the moist, sour grasslands are found at higher elevation where water supply is high and geology gives rise to low base status of the soils. At lower altitudes the dry, sweet grasslands occur where water supply is lower compared to the high altitudes, and the soils have a higher base status as a result of the parent material present at these lower altitudes. Mariepskop specifically falls within the unique subgroup of Mesic Highveld Grassland which forms part of the moist grassland class. Where surface topography are favourable, certain moist grassland areas would allow for dominance of woody species over grasses, which would lead to the development of shrublands, as observed on Mariepskop (Mucina *et al.* 2006).

The main reason for the observed vegetation structure in high elevation grasslands can be well explained by various environmental factors such as strongly seasonal precipitation (moisture availability), soil type (nutrient availability), minimum temperatures during the winter months and fire (Rutherford *et al.* 1994). Seasonality of rainfall together with the occurrence of fog within the Grassland Biome plays a vital role in moisture availability. Summer rainfall with droughts occurring during the winter months causes the growing season to last only about six months of the year (October through March). Fog is present along the upper slopes of the Great Escarpment and seaward scarps, which could explain the presence of the hygrophilous mistbelt vegetation also observed on Mariepskop (Mucina and Rutherford 2006). The occurrence of frost is common in this biome during the coldest months of the year (June through August) as the elevation and aridity during these months intensify the occurrence of frost events. A variety of soil types are found in grasslands with the soils being relatively fertile and deep. Summit grasslands, such as those on Mariepskop, usually occur embedded within the Savanna Biome and the vegetation is believed to be different as a result of differences in soils. Soils are not as well-developed in the summit grasslands compared to the soils generally found within the Savanna Biome. The unique geological formations found on the outcrops as well as extreme climatic conditions create unique environmental conditions on mountain summits (Mucina and Rutherford 2006).Ungulate grazing also influences vegetation structure but has a substantially larger influence on grasslands at lower altitudes (Mucina and Rutherford 2006).

Fire also plays a vital role in maintaining both structural and textural patterns of the Grassland Biome. Studies have shown that the exclusion of fire can lead to “a succession trend towards shrublands with fynbos affinities and then to forest in grasslands with annual rainfall of more than 650 mm” (Bond *et al.* 2003). The satellite Afromontane or ‘grassy’ fynbos patches found in grasslands of the Northern Escarpment Region, such as those on Mariepskop, are found on nutrient-poor soils in areas protected from fire (Mucina and Rutherford 2006). The exclusion of fire, either naturally or as a result of anthropogenic reasons could possibly be an explanation as to why we observe the shrubland climax vegetation resembling fynbos on various rocky outcrops and mountain summits in southern Africa, such as Mount Chimanimani (Zimbabwe), Mount Mulanje (Malawi) as well as on the summit of Mariepskop (Van der Schijff & Schoonraad, 1971) where fire has been excluded for over 40 years.

In terms of characteristic life forms, the Grassland Biome is generally dominated by hemicryptophytes (>75%), which are generally graminoids belonging to the families Poaceae, Restionaceae and Cyperaceae with geophytes (<3%), chamaephytes and therophytes (both <1%) also being present (**Table 2.1**) (Rutherford *et al.*1994).

Table 2.1. Relative dominance in terms of percentage canopy cover per life form (Rutherford et al. 1994)

Biome	Example	P*	Ch*	H*	Th*	G*
Desert	Central Namib	0	0.1	3.6	96.3	0.0
Succulent Karoo	Robertson Karoo	7.0	85.4	4.0	2.3	1.3
Grassland	Eastern Free State	0.0	0.3	96.7	0.1	2.9
Forest	Drakensberg	86.9	4.1	8.8	0.0	0.2
Savanna	Lowveld	43.3	5.6	50.6	0.4	0.0
Nama Karoo	Upper Orange River	1.2	63.4	36.2	0.1	0.1
Fynbos	South Western Cape	35.2	33.5	28.1	0.0	3.2

*P = phanerophyte; Ch = chamaephyte; H = hemicryptophyte; Th = therophyte; G = geophyte

The Forest Biome – Indigenous forests in South Africa interface with almost all the biomes except for the Desert and Succulent Karoo biomes and can be found scattered in small patches throughout South Africa ranging from the Soutpansberg in the north to Maputaland in the east, along the Great Escarpment and all the way through to the Cape Peninsula on the western side of South Africa (Mucina and Geldenhuys 2006). These small forest patches, resembling ‘islands’, are generally embedded within the other biomes including the Fynbos, Albany Thicket, Savanna as well as the Grassland Biome (Mucina and Geldenhuys 2006).

Naturally, forest edges consist of a variety of growth forms and sizes forming a ‘soft edge’ and are a transitional area or ecotone between the forest and surrounding vegetation. As a result, these ecotones generally have a higher biodiversity than either the surrounding vegetation or forest as the ecotone contains species of both (Mucina and Geldenhuys 2006). It would therefore be expected that the ecotone found on Mariepskop between forest and grassland would contain elements of the Grassland and Forest Biome as well as shrubby transitional vegetation.

2.3. Vegetation associated with Afromontane and Afroalpine regions

The Grassland Biome coincides with two major phytochoria (geographic area with a relatively uniform taxonomic composition of plant species) in South Africa namely the Kalahari-Highveld Regional Transition Zone and the Afromontane Region. The mountainous landscape within which Mariepskop is located, falls within the Afromontane Region (White 1983). Therefore, it is also of interest to briefly analyse the vegetation types found in the communities of this region, although technically discussions regarding the Afromontane Region are generally confined to phytogeographical discussions (*see 2.5. Phytogeography*),

In terms of vegetation types, the type found predominantly in Afromontane communities in southern Africa, excluding the Cape region, is grassland with a mixture of temperate (e.g. chamaephytes and hemicryptophytes) and tropical species (e.g. phanerophytes). The other vegetation type generally found in these communities is forest, dominated by *Podocarpus* spp., as well as ericaceous shrublands, which resemble the fynbos found in the Cape Region (Killick 1978, White 1978, 1983). Generally, vegetation within the Afromontane Region can be best described as “dense forests, but also grasslands and savannas, which are possibly secondary” (White 1978). The Afroalpine Region on the other hand, has fairly rich flora with several endemics as well as some affinities to the flora of the CFR (Killick 1978). The vegetation is characterized by alpine grasslands and dwarf shrub communities and, as previously mentioned, can be found at elevations above 2895 m, which is above the tree limit.

It is important to note that there has been disagreement among chorologists, ecologists and palynologists regarding the term alpine to describe the vegetation in South Africa of upper slopes and the summits of mountains in the Western Cape and KwaZulu-Natal (Killick 1963, Edwards 1967, Acocks 1988), as well as the upper reaches of the Malotis in Lesotho (Van Zinderen Bakker 1981; 1983, Acocks 1988). Although alpine growth forms (i.e. mat-forming dwarf shrublets, rosettes and cushions) were common above 1800 m, the absence of permanent snow deposits on peaks during winter as well as the presence of typical alpine taxa at lower elevations led to the rejection of the possibility of distinct alpine flora (Marloth 1900). Based only on characteristic alpine growth forms, other scientists have described the flora of Cape mountain summits as alpine (Bews 1916). Results from a more recent study where alpine growth forms were found at lower elevations on the summit ridges of the Klein

Swartberg in the central Western Cape at an altitude of 2000 m supported Marloth's (1900) argument (McDonald *et al.* 1993). This resulted in the application of the 'sub-alpine' terminology to the high altitude flora of the CFK (Linder *et al.* 1993). Although the term 'alpine' has been used incorrectly in various studies, each alpine environment should be viewed as a whole including altitude, latitude, climate, soil type and nutrient availability and not solely on altitude. Carbutt and Edwards (2001) concluded that "any temperate environment which represents the summit region of a particular mountain formation, regardless of ceiling altitude; characterized by the absence of trees and the presence of an ericoid, schlerophyllous low shrubland with or without herbaceous components, representing a measure of structural conformity, and being distinctive from flora of lower elevations (physiognomically), might be considered 'alpine'."

An intensive plant ecological study done by Killick (1963) of Cathedral Peak in the Natal Drakensberg indicated three altitudinal belts, each which coincides with its own major physiographic features, namely the Montane Belt, the Subalpine Belt and the Alpine Belt.

The Montane Belt's altitude ranges between 1280 and 1830 m.a.s.l. and is characterized by deeply incised river valleys, which "cut back into the terrace known as the Little Berg which lies below the main Drakensberg escarpment"(Killick 1963). The climax community of the Montane Belt is characterized by *Podocarpus latifolius* Forest (which corresponds to the Montane Forest Belt as described by Hedberg (1951).The upper montane belt (also previously referred to as the Subalpine Belt) has an altitudinal range from 1830 to 2865 m.a.s.l. and can be found on the lower slopes of the main escarpment and the terrace of the Little Berg (Korner *et al*. 2011). Climax vegetation found in this belt is *Passerina–Philippia* (now *Erica*)–*Widdringtonia* Bushland which corresponds to the Ericaceous Belt described by Hedberg (1951). The Alpine Belt, ranging from 2865 to 3353 m.a.s.l., occupies the summit area of the Drakensberg and is characterized by climax heath communities dominated by low, woody species of *Erica* and *Helichrysum* with interspersed grassland communities, dominated by species of *Merxmuellera, Festuca* and *Pentameris* (Killick 1978).

As a result of these intensive vegetation studies done at the summit and/or upper slopes of the Drakensberg in the Cape and KwaZulu-Natal as well as the higher parts of Lesotho, the area above 1800 m on Mariepskop could quite possibly be classified previously as part of the Subalpine belt (generally a South African ecological term) and the Montane Belt in places (Killick 1963, Edwards 1967). However, according to more recent classifications, Mariepskop could quite possibly form part of both the lower montane and upper montane belt (Korner *et al*. 2011).

2.4. Soil and vegetation

Nutrient limitation in the soil is arguably one of the most important factors which affect the structure of plant communities (Grime *et al.* 1997). It has been shown that species richness tends to decline as nutrient availability increases, which would favour certain species that are more competitive in terms of resource capture and biomass accumulation (Al-Mufti *et al.* 1977, Grime 1979). Also, the differential limitation between species by different nutrients might influence the observed species composition (Koerselman and Meuleman 1996). Plants are dependent on soil and the mineral nutrients (elements) contained within it such as nitrogen (N), phosphorus (P), and potassium (K). Different nutrients can limit biomass production and thus directly influence the species composition and diversity. The amount of available nitrogen plays a major role (e.g. Mountford *et al.* 1993, Willems *et al.* 1993) with phosphorus also playing a vital role across a range of soil types (Janssens *et al.* 1998). Potassium (K) in the soil can limit growth and can do so in combination with phosphorus (P) and nitrogen (N) (Vermeer and Berendse 1983, Van der Woude *et al*. 1994, Oomes *et al.* 1996, Boeye *et al.* 1997, Roem and Berendse 2000). These nutrients, primarily obtained through the roots, are essential for plants as the nutrients form an intrinsic component in the structure or metabolism of a plant and the absence of these nutrients could cause severe abnormalities in development, growth or reproduction (Arnon and Stout 1939, Epstein 1972).

Essential mineral elements needed by plants can be divided into two categories based on their relative concentration in the plant tissue, namely macronutrients and micronutrients. The most important macronutrients needed by plants are N, K, calcium (Ca), magnesium (Mg) and P (Taiz and Zeiger 2006).

These different macronutrients all have different functions both biochemically and physiologically. Nitrogen generally forms part of carbon compounds such as amino acids, proteins and nucleic acids. Potassium is an important nutrient in energy storage and structural integrity while the remaining macronutrients play essential roles in enzymes (K, Ca, Mg and Na), cell wall (Ca) and the formation of chlorophyll (Mg) (Taiz and Zeiger 2006). The type of environment with its variety of external factors has the ability to force plants in one environment to utilize certain macronutrients quite differently to the same plant in a different environment (Taiz and Zeiger 2006). Therefore, as a result of the rather extreme environmental conditions found on the summit of Mariepskop and the potential interesting vegetation, knowledge of the soils would aid the discussion on where the specific vegetation is found.

2.5. Phytogeography

Patterns of plant distribution and an understanding of the historical factors that may have shaped these patterns, phytogeography, is one important diagnostic characteristic of a plant taxon which should be analysed together with other diagnostic characteristics such as morphology, anatomy and ecology (Van Wyk and Smith 2001). The three main patterns of plant distribution, which are widely recognized are cosmopolitan (very wide distribution), endemic (very narrow) and disjunct (widely separate). Specifically for plant geographers, endemic and disjunct distributions are of special importance (Van Wyk and Smith 2001).

Disjunct distribution refers to an extreme basic type of plant distribution where two or more populations of a taxon are exceptionally widely separated, but cannot necessarily be explained by only one specific reason (Van Wyk and Smith 2001). A good example of a disjunct distribution is the species *Protea dracomontana*, which is found at high elevations (above 1900 m) on the Drakensberg in KwaZulu-Natal as well as on Mt Nyagani in Zimbabwe (Van Wyk and Smith 2001). Another excellent example is the genus *Cunonia* where one species is found in South Africa with 16 other species found on the island of New Caledonia east of Australia (Thorne 1972). Even though these distribution patterns cannot be explained by only one reason, some obvious plausible explanations can exist for certain situations. If the distribution is short-range disjunct, it could be explained by habitat discontinuity, which means that some environmental variable has changed and the taxon or species adapted accordingly (Van Wyk and Smith 2001). If a taxon was previously wider distributed than at present, a drastic event such as climate change could have caused the species to undergo differential extinction which forced the taxon to survive in separate sites termed refuges (Van Wyk and Smith 2001). Another more obvious explanation is that exceptional long distance dispersal (known as jump dispersal) away from the founder population occurred where the taxon crossed major intervening barriers such as unfavourable climatic zones, mountain ranges or oceans (Van Wyk and Smith 2001). An excellent example of range disjunctions can be observed in many different and unrelated plant taxa on the 'islands' of Afromontane vegetation between the Cape and Ethiopia (Carbutt and Edwards 2001, Van Wyk and Smith 2001). Some African and African-Madagascan endemics also show disjunct distribution between arid areas of south-western and north-eastern Africa (De Winter 1971) while others are centred in the Cape and extend outside southern Africa mainly in temperate Afromontane areas (Levyns 1964).

An endemic taxon, although a scale-related concept, can be defined as "a taxon limited in its range to a specified geographical area, which can be as a result of historical, ecological or physiological reasons” (Van Wyk and Smith 2001). If the taxon in question is marginally present elsewhere, it is referred to as a near-endemic. The near-endemic concept is sometimes more useful for phytogeographical analysis as a specific vegetation may not occupy a single geographical area and sometimes includes an outlier or “distant enclaves or ‘islands’ of similar vegetation” (Van Wyk and Smith 2001). Three types of endemics can be distinguished based on their presumed origins namely neo-endemic (new or evolutionary young), paleoendemic (remnant of species with a former wider distribution) and holoendemic (can be either old or new and are sometimes referred to as a habitat specialist either because of restricted range or isolation) (Richardson 1978). Where a specialized habitat exists with special climatic conditions such as cool, wet conditions on a mountain peak (e.g. Afromontane Region) surrounded by hot, arid lowlands, holoendemics are generally found (Van Wyk and Smith 2001). On the other hand, most of the endemic taxa found within the Wolkberg Centre of Plant Endemism, of which Mariepskop forms part, appear to be paleoendemics (Van Wyk and Smith 2001).

In southern Africa, two Centres of Plant Endemism (CEs) fall completely within the Grassland Biome namely the Drakensberg Alpine CE and the Wolkberg CE (Figure 2.2), with Mariepskop falling within the latter (Van Wyk and Smith 2001). The Wolkberg Centre has been distinguished based on the geology of the rock outcrops, which form part of the Drakensberg Escarpment, and are classified as part of the Transvaal Supergroup in the south-east of Limpopo province and adjacent parts in Mpumalanga (Van Wyk and Smith 2001). Generally, the landscape characterizing the north-eastern side of the Wolkberg Centre is mountainous with very steep slopes and vertical cliffs with more rolling hills and less rugged terrain towards the west. Summers in the Wolkberg Centre are generally hot and wet while the winters are cool and dry with frequent frost at some of the high altitudes (Matthews *et al.* 1993). At high altitudes within the Wolkberg Centre, such as Mariepskop, the climate is more temperate and orographic rain (which is moisture from the Indian Ocean towards the east), mist, drizzle and thunderstorms are common (Van Wyk and Smith 2001). Regarding the Wolkberg CE, almost all endemics found there are associated with the grassland habitats, which are drier and more exposed to the elements compared to the adjacent forest habitats (Hilliard and Burtt 1987, Matthews*et al.* 1993). In the Mpumalanga province within the Blyde Canyon Nature Reserve, of which Mariepskop forms part, 12% of the area representing the Wolkberg CE is protected (Mucina *et al.* 2006).

Endemic plant taxa are generally more common on nutritionally peculiar or isolated substrata (Raven and Axelrod 1978, Hopper 1979, Matthews *et al.* 1993). Mariepskop falls within two types of quartzite formations namely the Wolkberg group and the Black Reef Formation, the latter which is a "very clean quartzite with layers of pebbles and conglomerate" (Matthews *et al.* 1993). The soils derived from these quartzite formations are generally lower in Ca and Mg compared to soils derived from dolomitic formations. It has also been hypothesized that the endemic plants occurring on these quartzite-derived soils either have a lower requirement for these elements or their uptake is more efficient (Matthews *et al.* 1993). Also, quartzite-derived soils are generally more acidic, sandy, low in fertility and low in phosphorus content compared to the dolomite-derived soils (Larcher 2003)**.** These extremely unfavourable conditions could quite possibly have been a reason as to why local endemics develop on quartzite-derived soils (Matthews *et al.* 1993). Previous phytosociological studies have shown that some endemics or near-endemics can be diagnostic species for certain plant communities and their environmental variables such as soils (Matthews *et al.* 1991). For example, *Helichrysum reflexum*, *H. rudolfi*, *Syncolostemon eriocephalus* and *Asparagus rigidus* are associated with large quartzitic rocky outcrops along the Transvaal escarpment while *Helichrysum mariepscopicum* is diagnostic of certain high elevation hygrophilous grassland communities (Matthews *et al.* 1992). Also, in the Wolkberg CE, 71% of the endemics occur on soils derived from nutrient-poor quartzites with the remainder being associated with soils derived from Ca - and Mg -rich dolomites (Matthews *et al.* 1993). Five families with the largest number of endemics associated with these quartzitic formations are Alliaceae, Asparagaceae, Asphodelaceae, Iridaceae and Asteraceae (all but Alliaceae occur on Mariepskop) with the genus *Helichrysum* having as much as ten endemics (Matthews *et al.* 1993). The only tree species showing narrow endemism and being only marginally Afromontane associated with the Black Reef formation and/or the Wolkberg group include the shrub/small trees *Combretum petrophilum* and *Dombeya autumnalis*, with no forest trees being endemic (Matthews *et al.* 1993). Other large woody quartzite endemics which are associated with Afromontane grasslands (such as those on the summit of Mariepskop), sparsely open woodlands, rocky outcrops or forest margins include *Protea rubropilosa*, *P. laetans* and *Searsia tumilicola*.

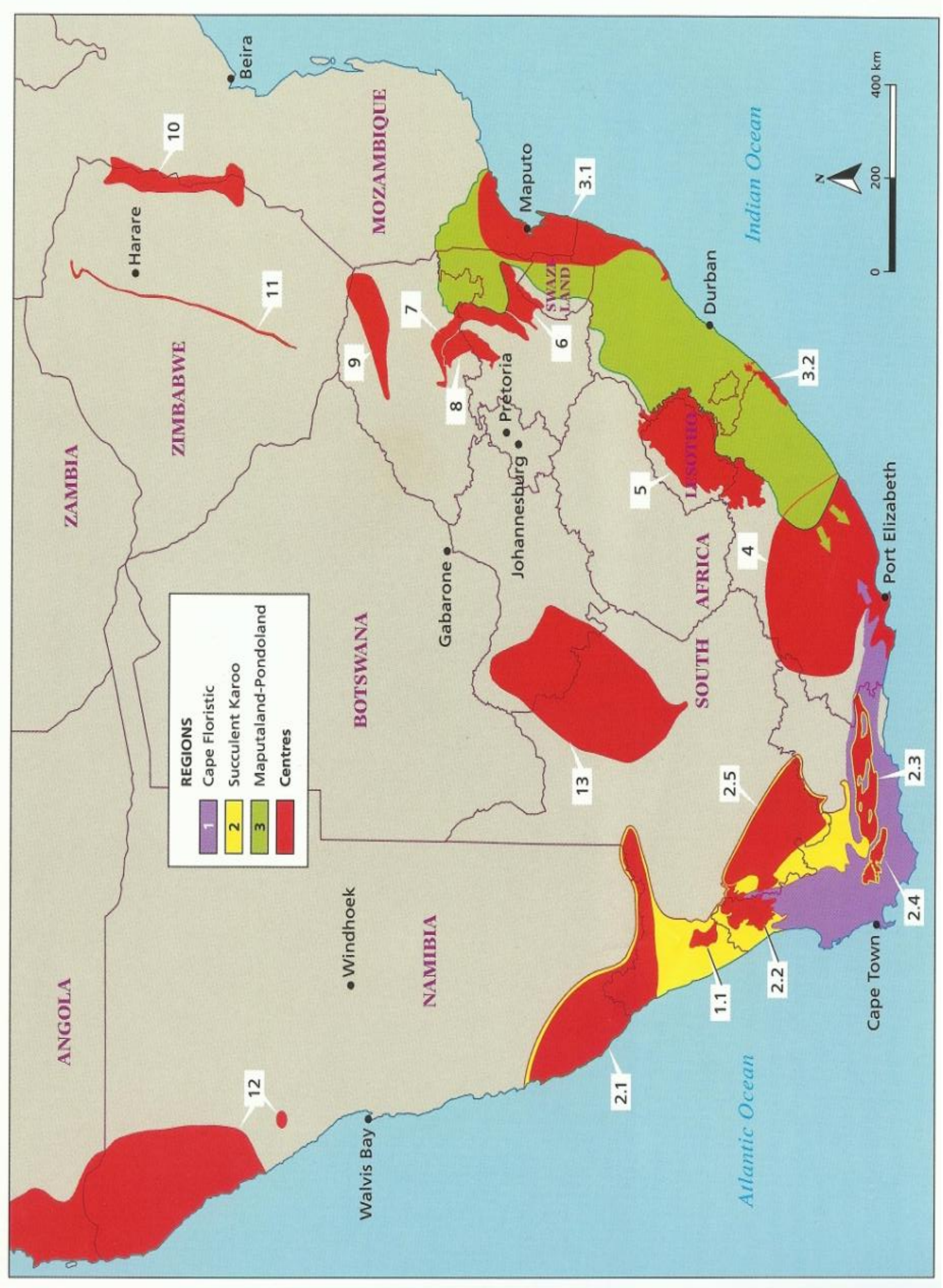

Figure 2.2. Centres of Plant Endemism (CEs) in southern Africa as mapped by Van Wyk and Smith (2001).The CE of interest which falls completely within the Grassland Biome is the Wolkberg CE (7), within which Mariepskop is located.

2.5.1. Afromontane Region

As previously mentioned, the mountainous landscape within which Mariepskop is located falls within the Afromontane Region (White 1983). The Afromontane and Afroalpine Region is not a discrete region such as the Karoo-Namib or Tongaland–Pondoland Regions but rather "a series of isolated areas forming an archipelago-like regional centre of endemism" (White 1983, Cowling *et al.*2004), which can be found scattered across Africa ranging from north-eastern Africa, along the East African uplands to south-eastern Africa and the Cape Peninsula (White 1983). The Afromontane Region is spread out over southern Africa mainly along the eastern escarpment, but also to the south reaching the coast. This region is known for its diverse flora, a number of endemics as well as affinities with a variety of regions namely the Sudano-Zambezian Region, the Guineo-Congolian Region as well as the CFR Flora (White 1978). The flora found predominantly in the Cape has been found to radiate northwards along the eastern escarpment (Drakensberg) and is found only at high elevations. Climate in this region is generally temperate with rainfall being more than 1000 mm annually even though freezing night temperatures and relative dryness have been recorded in 'alpine' zones above the forested belt of the high mountains (Cowling *et al.* 2004). Although plant communities within this region are usually located above 2000 m, further south as far as the Cape Region, Afromontane forest 'pockets' can also be found at sea level (Cowling *et al.* 2004). The Afromontane region in southern Africa is predominantly found in the Lesotho and KwaZulu-Natal Drakensberg with some outliers located to the north and south along the Great Escarpment (Cowling *et al.* 2004). Although endemism at regional level among forest trees might be as high as 75%, local endemism remains quite low. Local endemism among grassland herbs throughout the Afromontane region however can be rather high (as high as 50%) (Hilliard and Burtt 1987, Meadows and Linder 1989).

In a chorological sense, which refers to spatial distribution, the difference between the Afromontane and Afroalpine regions is minimal. Some differences arise regarding the total number of plant species and endemic genera of which the Afroalpine Region has few and none, respectively (White 1978). Ecologically speaking the Afroalpine Region differs markedly from most of the Afromontane Region and therefore the Afroalpine Region can be loosely defined as "an archipelago-like region of extreme floristic impoverishment" (White 1976a, as referenced in White 1978). Phytogeographically, however, it is preferable that these two regions should be considered together as some have named the Afroalpine region only as "an extreme variant of the Afromontane" (Weimarck 1941, as referenced in White 1978).

2.5.2. Migratory route of taxa

A variety of hypotheses exist concerning the origin of the 'Cape' taxa found in the Afromontane Regions throughout southern Africa (including Mariepskop) and the relationships shared between their source flora(s) (Levyns 1952, 1964; Goldblatt 1978, Taylor 1978, Linder *et al.* 1992). The two main suggestions include a southern migration from tropical Africa to the Cape region where the Cape Flora indicates a recent history with a more northerly origin; and northern migrations from the Cape which gives an explanation for an ancient Gondwanan history for the Cape Flora (Specht 1979, Goldblatt 1983). A study on the Cape elements on high altitude corridors and edaphic islands in southern Africa by Carbutt and Edwards (2001) found a correlation between these elements and distance from the CFR. With an increase in distance away from the CFR (along the SW-NE gradient across high-altitude regions in South Africa), increases in both altitude and rainfall and an overall decrease in temperature resulted in an increased number of Cape elements among these high altitude communities, compared to lower altitudes. This would suggest that factors such as climate and/or edaphic influences possibly play a major role in the observed patterns of Cape elements and that the Drakensberg Alpine Centre is "a historical high-altitude refugium for Cape elements" (Carbutt and Edwards 2001). For example, the low temperatures at high altitudes slow down the metabolic processes of plants such as nutrient uptake which could be explained by the nutrient-poor soils generally found at high altitudes. Thus Cape taxa, that possibly migrated northwards would have an added competitive advantage as these taxa have evolved in a nutrient-poor soil environment in the CFR (Linder *et al.* 1992, Carbutt & Edwards 2001). It is however uncertain as to whether the same scenario applies to high elevation areas extending into tropical East Africa as research focussing on phytogeography and possible migration routes due to climate change are lacking.

Regarding Mariepskop, Van der Schijff and Schoonraad (1971) suggested that vegetation found in this part of the Wolkberg Centre and in the Northern Drakensberg (Matthews *et al.* 1993), form close ties with both the CFR in the south and the Chimanimani Mountains in Zimbabwe towards the north, which could possibly point towards an eastern mountain migration route for fynbos from the Western Cape (Carbutt and Edwards 2001). There is, however closer ties between the forests found on Mariepskop and the forests of tropical Africa (e.g. evergreen forests in Malawi (Chapman and White 1970)) which could suggest that the Drakensberg Range is a migration route for both southern and tropical elements (Van der Schijff and Schoonraad 1971). Regardless of which hypothesis holds true, the Drakensberg Range plays a vital stepping-stone role in the spread of species through the Afrotemperate region (Galley *et al.* 2007), which could explain the ‘Cape’ elements found on Mariepskop.

CHAPTER 3

Study area

3.1. Topography

Mariepskop is situated in South Africa on the border between the Limpopo and Mpumalanga provinces on the eastern side of the Drakensberg Escarpment facing away from the Blyde River Canyon (30° 52’ E, 24° 30’ S) (Figure 3.1). The summit of Mariepskop (Figure 3.1) reaches a height of 1943 m above sea level (highest in the area) and is bordered by vertical cliffs with sheer drops of about 300 m and is characterized by an extremely rocky surface, very shallow soil and a highly fluctuating water table (Van der Schijff and Schoonraad 1971).

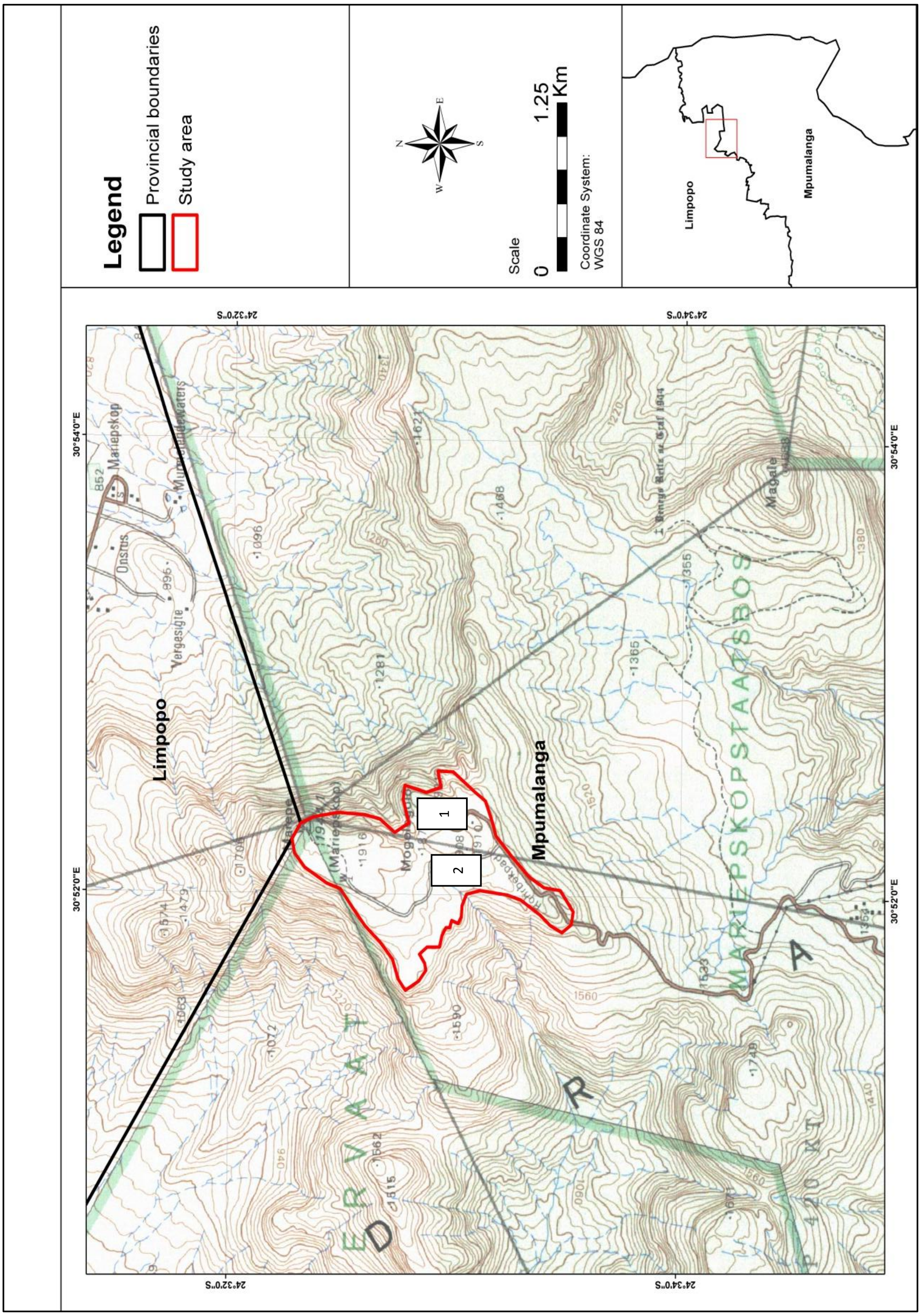

Figure 3.1. Summit of Mariepskop above 1800 m (indicated by the red outline). Also shown is the location of the eastern radar weather station (1) and the western fynbos weather station (2).

3.2. Climate

Specific climatic data, available from November 2011 to April 2014 for the summit of Mariepskop, was recorded at an altitude of 1924 m ((1) in Figure 3.1) on the eastern side, using an automated weather station. Variables recorded for each month were wind speed and direction, temperature, relative humidity, solar radiation, air pressure and rainfall, with the means shown in Table 3.1.Wind speed was relatively constant throughout the year (mean speed of 4.5 m.s^{-1}) with the wind direction varying between south-east and south-west. Relative humidity as well as solar radiation was higher during the summer months (November to March) compared to the rest of the year. During November to March, the mean rainfall was highest compared to the colder months (Table 3.1), with the Mean Annual Precipitation being 1224 mm. The Mean Annual Temperature (MAT) for the summit of Mariepskop was 13°C with definitive peaks in temperatures from November to March. The coldest months were June and July with mean temperatures below 10°C.

Table 3.1. Mean measured climatic variables at the eastern side weather station (labelled 1 on Figure 3.1) at the summit of Mariepskop at an altitude of 1924 m from 2011 to 2013 side.

	Wind Speed (m.s^{-1})	**Wind Direction (degrees)**	**Temperature (°C)**	**Relative Humidity (%)**	**Solar Radiation (watts.m^{2})**	**Air Pressure (mbar.hPa^{-1})**	**Rainfall (mm)**
January	4.9	153.8	15.4	91.7	201.1	809.7	441.2
February	4.1	168.3	15.5	91.6	201.8	809.8	107.9
March	4.5	172.0	14.5	90.6	168.8	811.7	74.4
April	4.4	197.7	12.4	79.4	163.6	813.0	43.7
May	3.8	194.5	12.0	66.2	143.8	814.0	12.0
June	5.1	206.0	10.5	55.7	133.6	813.7	11.1
July	4.3	187.2	9.5	66.3	129.9	814.0	28.4
August	4.8	190.3	11.5	55.2	179.3	812.3	29.4
September	5.2	185.9	12.9	68.3	186.4	812.6	75.9
October	4.2	176.4	12.8	81.3	185.1	811.9	100.4
November	4.7	192.0	14.5	81.2	226.5	811.2	106.1
December	3.8	163.5	14.6	90.0	198.0	810.8	193.4
Annual means (*annual total for rainfall*)	4.5	182.3	13.0	76.5	176.5	812.1	1223.9

3.3. Geology, land types and soils

3.3.1. Geology

Inselbergs such as Mariepskop are generally formed from sedimentary and volcanic rocks, capped by more resistant strata that form distinct flat-topped mesas, buttes or table mountains. Geomorphically, prominent landscape features are formed by "extensive subsurface decay along joints with the erosional detritus, rocks, boulders and gravel form the steep slopes to the inselbergs which are slowly buried in the rock debris" (Sarthou and Villiers 1998). Through the packing of the weathered material, a variety of ecological niches are formed, which create opportunities for the development of diverse plant communities which characterize inselbergs (Sarthou and Villiers 1998).

Mariepskop forms part of the Wolkberg Centre of Plant Endemism (Van Wyk and Smith 2001), located on the Drakensberg Escarpment, and is classified as part of the Transvaal Supergroup. The groups and formations particularly associated with the Wolkberg Centre include the Black Reef Formation, Wolkberg Group, Timeball Hill Formation and Chuniespoort Group (Van Wyk and Smith 2001). The geology on Mariepskop consists of shale, quartzite, conglomerate and basalt of the Wolkberg group, Transvaal sequence (Department Mineral and Energy Affairs 1986). Other geological formations which form part of Mariepskop are indicated in Table 3.2 (Department Mineral and Energy Affairs 1986). Two subcentres of the Wolkberg Centre of Plant Endemism (Van Wyk and Smith 2001), have been proposed namely the Blyde Subcentre, south of the Olifants River, and the Serala Subcentre, north of the Olifants River (Matthews *et al.* 1993).

Table 3.2. Geological formations found on and around Mariepskop (Department of Mineral and Energy Affairs 1986)

Formation	**Description**
Wolkberg Group	
Schelem Formation (Vwc)	White to grey reddish brown, medium- to fine-grained quartzite with coarse-grained and gritty layers, lenticular shale layers and conglomerate layers.
Selati Formation (Vwe)	Laminated micaceous and graphitic shale, locally interlayered with sandy shale, flagstone and quartzite.
Abel Erasmus Formation (Vwa)	Greenish grey intermediate lava, amygdaloidal in places, interbedded porphyritic layers and layers of shale and quartzite.
SekororoFormation (Vwk)	Grey to white quartzite, feldspar rich in places, interlayered with grit, conglomerate, tuff and limestone.

3.3.2. Land type and soils

Unique substrate factors such as geology and soil play a major role in the structuring of plant communities (Grime *et al.* 1997) and can lead to high levels of endemism in areas such as Mariepskop (Mucina and Rutherford 2006).

The dominant land type found on the summit of Mariepskop is Ib (land types with exposed rocks covering between 40% and 60% of the area and with generally sandy loam and shallow soils, but up to 900 mm deep in some places), with the soil depth at the summit being extremely shallow (less than 100 mm). The Ic land type (similar to Ib) is also present at the summit but more dominant further down the slopes outside the study area. This is evident from the difference in slope where the slope of Ic land type varies between 5 and 180 degrees while the slope of the Ib land type varies between 2 and 45 degrees. The dominant soil type for both land types is Mispah with the soil color varying from dark brown orthic soils to loamy fine sand (Southern African Agricultural Geo-referenced Information System (AGIS)). The dominant soil type found within the mistbelt forest in the sheltered kloofs is highly weathered, clayey deeper soils (up to 1000 mm in places) mainly of the Avalon and Hutton soil forms (Mucina and Geldenhuys 2006), while the land type is Ab which is characterized by red-yellow apedal, freely drained soils (AGIS).

Soils derived from the Black Reef Formation on Mariepskop possibly contain relatively low levels of Ca and Mg. It has been hypothesized that endemic plants occurring on these substrates with low levels of calcium and magnesium either have a lower requirement for these elements or their uptake is more efficient (Van Wyk and Smith 2001). Also, quartzite-derived soils such as those found on Mariepskop are generally acidic (pH lower than 5), sandy, highly leached, low in fertility (nutrients) and low in P content (Larcher 2003)**.**

With the limited soil information available specifically for Mariepskop, comparisons between the plant communities based on soil are extremely difficult. For more detailed analysis and to create a clearer picture of the possible relationship between soils and the plant species composition, soil samples were taken at various locations (Figure 4.1) and analysed for a variety of macronutrients.

3.4. Vegetation

According to the classification by Mucina and Rutherford (2006), Mariepskop now falls within the Grassland Biome and more specifically within the Mesic Highveld Grassland Bioregion. However, presently the majority of the summit of Mariepskop falls mainly within one vegetation type namely the Northern Escarpment Afromontane Fynbos vegetation type (Gm 24) with portions falling within the Northern Escarpment Quartzite Sourveld (Gm 23) and pockets of Afromontane Forest (Northern Mistbelt Forest (FOz 4)) confined to the slopes of the main escarpment (Figure 1) (Rutherford *et al.* 2006).

The Northern Escarpment Afromontane Fynbos vegetation type (Gm 24) is restricted mainly to the peaks of the Thabakgolo Mountains in the Limpopo province, southwards among the highest peaks only through Mariepskop as far south as Graskop (Mucina and Rutherford 2006). Fragments can also be found on the summits of the Blouberg and Soutpansberg with altitudes ranging from 1640 to 1900 m.a.s.l. The general landscape of this vegetation type is the high-lying fragmented quartzite patches, which are extremely rocky and experience frequent mist. The occurrence of fires in this vegetation type is very rare (Mucina *et al*. 2006), which is also true for Mariepskop. According to the Klaserie District Manager of Department of Water Affairs and Forestry, Harry Manoko, the last recorded fire incident in the forested areas (which form part of the Northern Mistbelt Forest vegetation type) was in 2003 with a large area of the pine plantation burnt (Parliamentary Monitoring Group (PMG), 2003). Although the fire threatened the radar station at the summit at times, the last record of a fire incident at the summit was in 1971 (Van der Schijff and Schoonraad 1971, Scriba 1976), which could explain the observed vegetation structure. The vegetation of this vegetation type is primarily shrubland "comprised of sclerophyllous shrubs and herbs, many with ericoid growth forms" (Mucina and Rutherford 2006). Some endemic taxa found in this vegetation type include the low shrub *Eumorphia davyi*, herb *Stachys reticulata* and geophytic herb *Gladiolus saxatilis*. Some phytogeographically important taxa found in this vegetation type (being northern sourveld endemics) include the small tree *Faurea galpinii*; low shrubs *Helichrysum rudolfii*, *Syncolostemon albiflorus* (Hemizygia albiflora), *Helichrysum mariepscopicum* and *Syncolostemon eriocephalus*; and the geophytic herb *Agapanthus inapertus* subsp. *pendulus* (Deall 1985, Deall *et al.* 1989, Matthews 1991).

Vegetation in the Northern Escarpment Quartzite Sourveld (Gm 23) is characterized by "short, closed grassland rich in forb species with scattered trees and shrubs" found on the slopes just below the fynbos (Mucina *et al*. 2006).This vegetation unit is known to be very rocky with nutrient-poor soils, which could imply lower biomass and more woody elements. Some endemic taxa found in this vegetation unit include the small trees *Protea laetans* and *Encephalartos brevifoliolatus*; low shrubs *Erica rivularis*, *Euclea dewinteri* and *Hemizygia rugosifolia*; graminoid *Schoenoxiphium schweickerdtii*; herbs *Senecio hederiformis*, *Monopsis kowynensis* and *Monsonia lanuginosa*; geophytic herbs *Cyrtanthus huttonii*, *Cyrtanthus junodii*, *Dierama adelphicum*, *Disa aristata* and *Watsonia strubeniae*; and the succulent herb *Aloe nubigena* (Deall 1985, Deall *et al.* 1989, Matthews 1991). There are also some phytogeographically important plant families and species forming part of the Wolkberg Centre of Endemism, which closely coincides with the Northern Escarpment Quartzite Sourveld. Two main families are distinguished as having a large number of endemics related to the quartzite and other related rock types namely Asteraceae and Iridaceae. Of these families, the genus *Helichrysum* (Asteraceae) has about 10 endemic species, which are all grassland species (Van Wyk and Smith 2001). A few species which are phytogeographically important (in terms of possible directionality of migrations to and from the Cape) include the low subtropical shrubs *Asparagus rigidus*, *Hemizygia rudolfii* and the succulent herb *Aloe thompsoniae* (Van Wyk and Smith 2001, Mucina *et al*. 2006).

The small Northern Mistbelt Forest (FOz 4) patches are characterized by the presence of tall, evergreen trees generally found in sub-ridge scarps and moist sheltered kloofs such as those found on Mariepskop. The most common canopy trees found in this vegetation type include

Podocarpus latifolius, Olea capensis subsp. *macrocarpa, Combretum kraussii*, *Cryptocarya transvaalensis* and *Xymalos monospora* (Mucina and Geldenhuys 2006).

CHAPTER 4

Materials and methods

4.1. Sampling techniques

4.1.1. Vegetation survey

Plant species composition and cover estimates were undertaken following the Braun-Blanquet approach (Becking 1957, Werger 1974). Firstly, satellite and aerial imagery together with spatial environmental data overlays of land type, topography and altitude (above 1800 m a.s.l.) of the study area were studied within ArcGIS to identify and visualize the study area as a whole. Thereafter relative homogeneous vegetation units were identified through stratification based on aerial photographs together with the abovementioned spatial environmental data. Based on the stratification, 61 plots were selected in an area of 160 ha with roughly 15 plots within each of the four designated homogeneous stratification units (Figure 4.1). The sampling plots were each placed within a homogeneous vegetation patch representative of the surrounding vegetation. A plot size of 10 m x 5 m was used to give a total plot surface area of 50 m^2, a plot size sufficiently large to cover both graminoid and shrubby vegetation (Westhoff and Van der Maarel 1980). Within each plot, a list of all the plant species was made, and the following noted: the cover-abundance values for each species, (following the modified Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974, Werger 1974); altitude, topography, total cover, rock cover as well as aspect and slope. Global Positioning System (GPS) coordinates were taken at each plot and used for determining altitude, aspect and slope, using the reference coordinate system namely WGS 1984 (World Geodetic System) through Garmin^{TM} software.

Table 4.1. Braun-Blanquet cover-abundance scale (Werger 1974)

Rating	Description
r	Very rare (less than 2 individuals)
+	Rare (less than 1% of plot area)
1	Not abundant (covering 1-5% of plot area)
2a	Covering ≥5-12% of plot area
2b	Covering ≥ 12-25% of plot area
3	Covering ≥ 25-50% of plot area
4	Covering ≥ 50-75% of plot area
5	Covering ≥ 75-100% of plot area

4.1.2. Soil sampling

Soil sampling was conducted in the identified plant communities in August 2013. A total of 20 soil samples, five within each perceived plant community (Figure 4.1), were taken at a depth of 0–20 cm. The soil samples were analysed for various macro-elements phosphorus (P), magnesium (Mg), calcium (Ca), potassium (K) as well as ammonium (NH_4), nitrate (NO_3) , particle size (sand, silt and clay) and pH (H_20).Soil analyses were conducted by the Department of Plant Production and Soil Science at the University of Pretoria (an Agri LASA certified laboratory). Samples were dried overnight at 50°C, crushed and passed through a 2 mm sieve before undergoing analysis. Phosphorus (P) concentration was determined using the Bray-1 method (Bray and Kurtz 1945) and cations (potassium [K], calcium [Ca], magnesium [Mg] and sodium [Na]) were determined through the *Ambic 1 method* using ammonium acetate (Black 1965). Extractable inorganic nitrogen (N) concentrations in the form of ammonium (NH_4^+) and nitrate (NO_3^-) were determined using potassium chloride extraction and steam distillation analysis (Bremner and Keeney 1966, Keeney and Nelson 1982). The pH (H_20) of each sample was determined (Black 1965) as well as the particle size distribution using Bouyoucos rapid method (Bouyoucos 1962).

Figure 4.1. Plots (indicated by ∆ and ●) within the study area where the solid dot (●) represents the plots where soil samples were taken, roughly five samples within each perceived plant community.

4.2. Data analysis

4.2.1. Vegetation classification

Identification of specimens was verified by comparison to herbarium specimens in the H.G.W.J. Schweickerdt Herbarium (PRU) at the University of Pretoria, supplemented with taxonomic literature. Analysis of the floristic data was conducted using the software TURBOVEG (Hennekens and Schaminee 2001), JUICE (Tichý 2002) and PC-ORD 6.0 (McCune and Mefford 2011). TURBOVEG was used to capture the species data from each plot. The modified TWINSPAN (Two-Way Indicator Species Analysis) algorithm of JUICE was used for divisive clustering in order to initially group plots (Roleček, et al. 2009). The pseudospecies cut levels used in the classification were 0, 5, 15, 25, 50 and 75. The phi coefficient of association (Chytrý*et al.* 2002) of each species was calculated, based on presence/absence data, to determine their fidelity to each plant community as an indication of their suitability as diagnostic species. The Fisher's exact test was also performed ($p<0.05$) simultaneously with the calculation of the phi coefficient to exclude species with non-significant fidelity from the groups of diagnostic species. Both the phi coefficient of association and the Fisher's exact test were calculated using JUICE. Thereafter, the percentage cover-abundance in JUICE were natural log-transformed in PC-ORD. Next, a cluster analysis using the Euclidean distance measure and Ward's linkage method was performed (McCune and Mefford 2011). A two-way cluster analysis was used to group and classify plots based on the Bray-Curtis dissimilarity index as well as to visualise the dissimilarity between individual plots. This cluster analysis was used as the basis for the ordering of columns (plots) in a synoptic ordination table of the data (Madeira and Oliviera 2004). Next, an indirect gradient analysis was used to visualise the similarity of plots independent of environmental factors. Using the distance-based technique PCoA (Principal Coordinates Analysis) and also the Bray-Curtis distance measure in the computer program PC-ORD, which uses linear correlation, the plots were arranged in such a way that their position in relation to each other is a direct reflection of the degree of dissimilarity to each other (Bray and Curtis 1957), based on species composition and environmental variables. To determine the relationship between the environmental variables (altitude, total cover, bare rock cover and measured soil variables) and the possible plant communities, a multivariate direct gradient ordination method, Canonical Correspondence Analysis (CCA; (Ter Braak 1986), was used using PC-ORD (version 6.0) (McCune and Mefford 2011).

The initial synoptic ordination table was further refined in JUICE based on the cluster and ordination results to obtain a hierarchical classification and finally to produce a synoptic table from which the communities and sub-communities were identified. Diagnostic, constant and dominant species were derived using JUICE (using fidelity, frequency and cover statistics, respectively). For the diagnostic, constant and dominant species, lower thresholds of 60, 60 and 50 and upper thresholds of 80, 80 and 60, respectively were used. Based on the synoptic table the initial classification of sample plots was adapted to reflect the communities and sub-communities. The final vegetation map illustrating both the communities and sub-communities was generated using ArcGIS 10 (ESRI 2011). The total area of each of the communities and sub-communities was also calculated using ArcGIS 10.

4.2.2. Life forms and biome affinities

After surveying the plots, each species within each plot was classified into a broad life form category following Raunkiaer's (1934) classification, as modified by Mueller-Dombois and Ellenberg (1974). Once all the species were assigned to a life form category, the total number of species per life form encountered in the 50 m^2 plots was expressed as a percentage of the total number of species to provide a measure of the relative contribution of each life form to species richness within a plot. Likewise, the relative contribution of each life form to total vegetation cover was calculated as a percentage of the total cover within a plot. The life form spectra based on species composition, thus number of species per life form, was used for comparison between communities on Mariepskop, in addition to life form spectra based on cover-abundance. Life form spectra based on cover/abundance was used for comparison with other similar research since this was the measure used in those studies. Using Principal Coordinate Analysis (PCoA), life form spectra based on cover/abundance was analysed for each plot (version 6) to produce an ordination plot in PC-ORD (McCune and Mefford 2011).

4.2.3. Phytogeography

In terms of the distribution of the identified plant taxa, the distribution data of each species across South Africa were obtained and analysed using SIBIS (www.sibis.sanbi.org).SIBIS (SANBI's Integrated Biodiversity Information System) focuses on species and specimen information for landscape and mapping information such as area checklists, distribution maps and general species details. These distributions were then assigned to one of three categories namely northern–southern distribution (CFR-Mariepskop distribution), north–eastern distribution (Drakensberg-Mariepskop distribution) and strictly northern distribution (strictly endemic or near-endemic distribution) (see (a), (b) and (c) in Figure 4.1). Plant taxa belonging to a northern-southern distribution (a) are those taxa found in a continuous range from the CFR along the Great Escarpment (Drakensberg) to Mariepskop (black arrow). Plant taxa with a north-eastern distribution (b) are those taxa found along the Drakensberg up to Mariepskop, while the strictly northern distribution (c) was assigned to those plant taxa only found on and around Mariepskop (thus endemic or near-endemic).

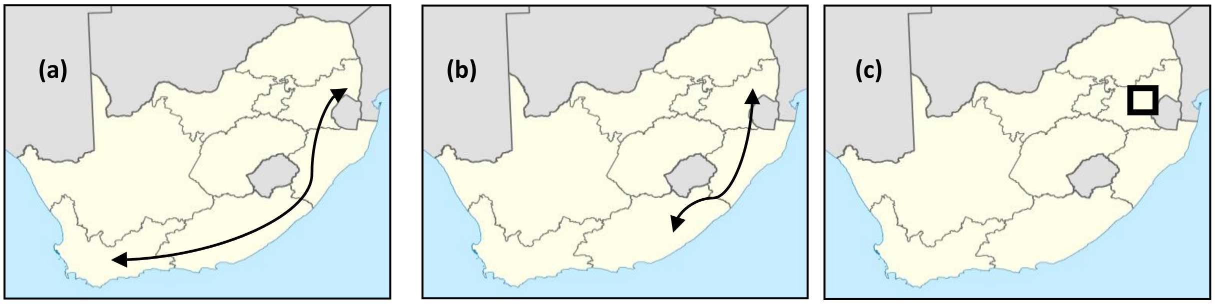

Figure 4.2. Distribution categories for plant taxa found at the summit of Mariepskop namely northern-southern (CFR-Mariepskop) (a), north-eastern (Drakensberg-Mariepskop) (b) and strictly endemic or near-endemic (c).

CHAPTER 5

Results

5.1. Introduction

A total of 62 species (APPENDICES A and D) were recorded in 61 sample plots. Overall, the mean species richness per sample plot was 11, ranging from 4 to 20 species.

5.2. Vegetation classification

The TWINSPAN analysis (Hill 1979) on the entire data set of 61 plots showed the presence of three main floristic communities and four sub-communities (Figure 5.1). The synoptic table indicating the communities and sub-communities as well as the species groups is shown in Appendix A. The following communities and sub-communities were identified:

1. *Panicum ecklonii–Watsonia* sp. Grassland
   1.1. *Panicum ecklonii–Watsonia* sp.–*Eragrostis curvula* Grassland
   1.2. *Panicum ecklonii–Watsonia* sp.–*Restio schoenoides* Shrubby Grassland
2. *Erica woodii–Passerina montana* Shrubland
   2.1. *Erica woodii–Passerina montana–Syncolostemon albiflorus* Shrubland
   2.2. *Erica woodii–Passerina montana–Myrsine africana* Tall Shrubland
3. *Dryopteris athamantica–Podocarpus latifolius* Forest

This identification of the communities and sub-communities was supported by Ward's method of agglomerative cluster analysis and principle coordinate analysis (PCoA).

Firstly, the cluster analysis using the Bray-Curtis dissimilarity produced a dendogram indicating three communities, shown by the grey line in Figure 5.1, and four sub-communities, shown by the broken grey line. The clustering explained 66% of the total information of the data set.

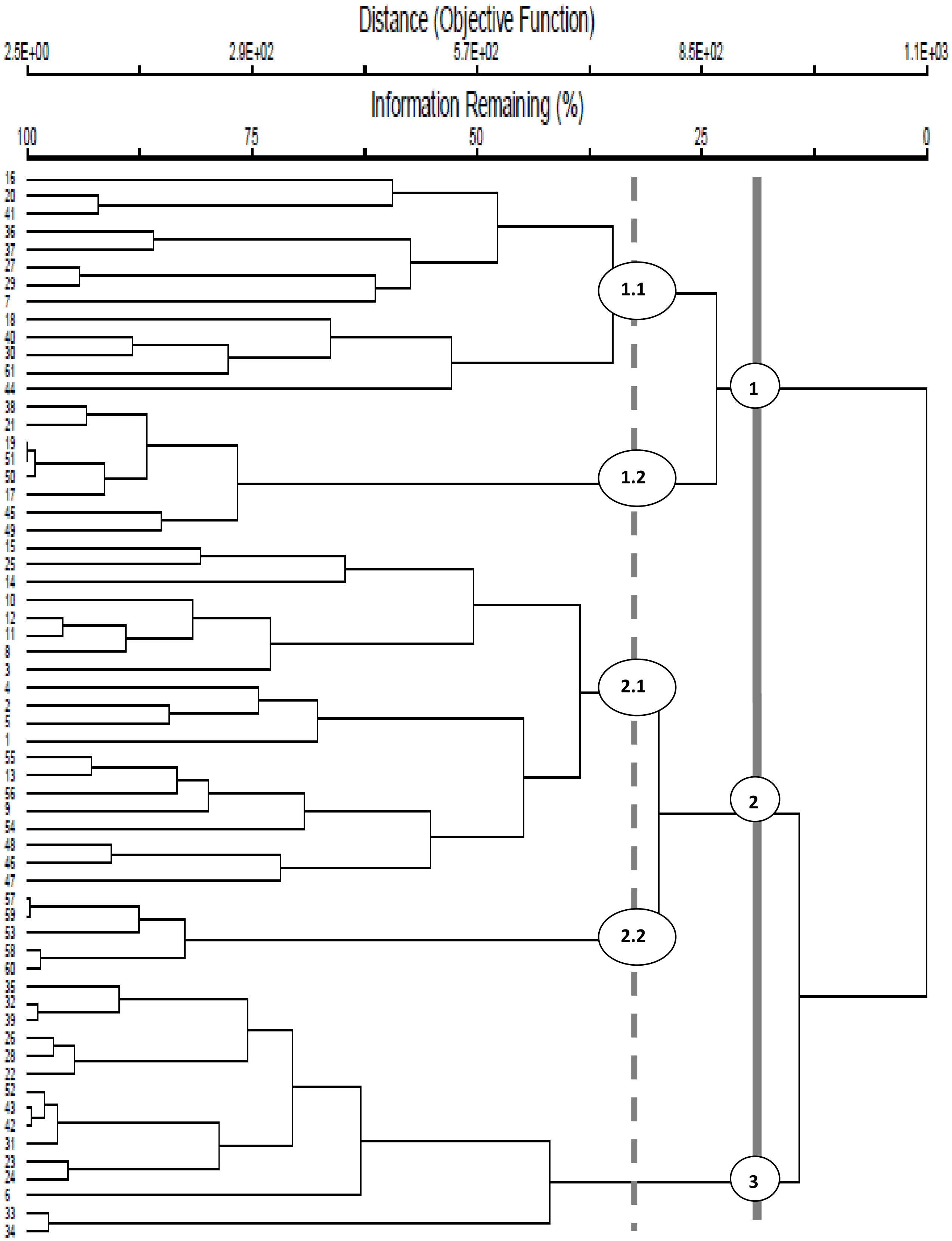

Figure 5.1. Agglomerative cluster analysis dendogram using the Bray-Curtis dissimilarity index indicated three communities (solid grey line) and four sub-communities (grey broken line) with their corresponding plots.

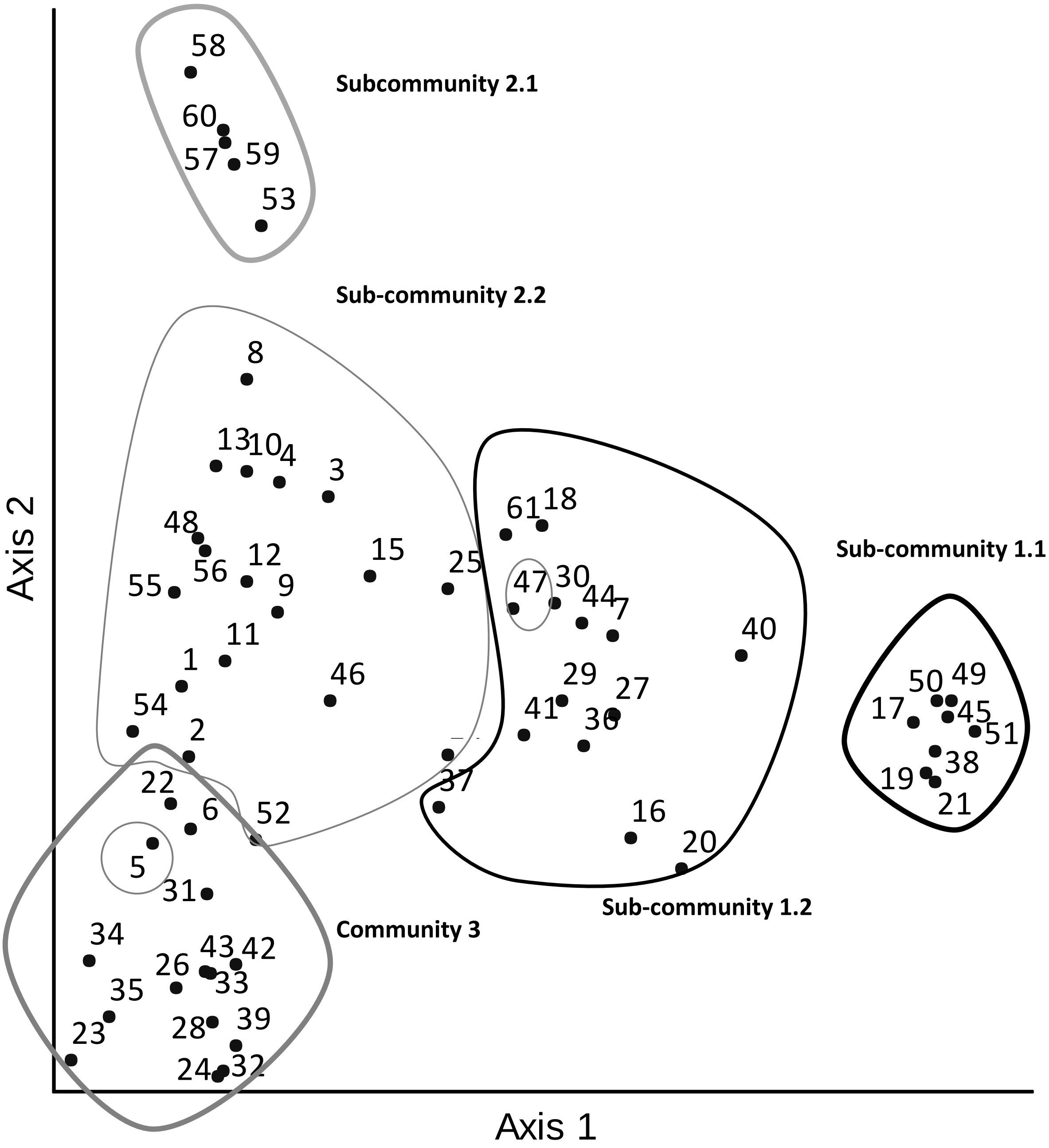

Figure 5.2. Indirect gradient distance-based analysis: PCoA (Principal Coordinates Analysis) ordination diagram. The three communities with four sub-communities are indicated.

5.3. Life forms

Based on presence of life forms, the vegetation studied on Mariepskop above 1800 m was co-dominated by phanerophytes, chamaephytes and hemicryptophytes (APPENDIX A). With all three communities combined, the dominant species within each life form category were: *Cliffortia serpyllifolia* (nanophanerophyte), *Aloe arborescens* (chamaephyte), *Panicum ecklonii* (hemicryptophyte), and *Watsonia* sp. (geophytes). However, analysing the three communities individually, each community had different dominant species within each life form category and different combinations of life forms compared to both the combined spectrum. Although the mean percentage vegetation cover contribution of species per life form were not the principal determinant in structuring the communities and sub-communities, results from the principal coordinate analysis (PCoA) confirmed the most important life form characteristics of each community (Figure 5.11, Tables 5.5.1, Table 5.3.2).

The diagnostic life form of community 1 (*Panicum ecklonii – Watsonia sp.* Grassland) in terms of species composition was hemicryptophytes (*Panicum ecklonii* and *Eragrostis curvula*), with chamaephytes (Species Group J) and geophytes (*Watsonia sp.*) also being present. Based on cover, the dominant life form (73%) for this community was hemicryptophytes (i.e. *Panicum ecklonii, Miscanthus junceus* and *Eragrostis curvula*). The PCoA characterised this community by a large presence of hemicryptophytes and few phanerophytes (Table 5.2).

The diagnostic life form of community 2 (*Erica woodii – Passerina montana* Shrubland) in terms of species composition was chamaephytes (*Erica woodii, Cliffortia serpyllifolia* and *Passerina montana*).The dominant life forms (cover > 60%) within this community were chamaephytes (*Cliffortia serpyllifolia*) as well as hemicryptophytes (*Eragrostis curvula*) (APPENDIX A). Based on cover, the dominant life forms for this community were phanerophytes, more particularly nanophanerophytes, (43%), chamaephytes (33%) and hemicryptophytes (21%). The PCoA characterised this community by a large contribution of geophytes (Table 5.2).

Lastly, the diagnostic life forms (fidelity > 60%) for community 3 (*Dryopteris athamantica–Podocarpus latifolius* Forest) in terms of species composition,were phanerophytes (*Podocarpus latifolius*), hemicryptophytes (*Dryopteris athamantica*) and geophytes (*Asparagus rigidus* and *Cyrtanthus huttonii*). The dominant life forms within this community were also phanerophytes (*Podocarpus latifolius*), hemicryptophytes (*Dryopteris athamantica*) and geophytes (*Cyrtanthus huttonii*). Based on cover, the dominant life form for this community was phanerophytes (42%) with chamaephytes (22%) and hemicryptophytes (21%) also present. The PCoA characterised this community by the low occurrence of chamaephytes and the presence of phanerophytes (Table 5.2)

Table 5.1.1. Mean percentage contribution based on species composition within plots per life form in three plant communities and four sub-communities and three broad vegetation groups present above 1800 m on Mariepskop.

Plant community	**Broad vegetation type**	**No. of plots**	**Mean percentage contribution by species**				
			P	Ch	H	G	Th
1. *Panicum ecklonii* –*Watsonia* sp. Grassland	Northern Escarpment Quartzite Sourveld (Gm 23)	21	14.6	30.9	39.6	13.8	1.2
1.1. *Panicum ecklonii*–*Watsonia* sp. – *Eragrostis curvula* Grassland		8	6.8	33.8	42.4	17.1	0.0
1.2. *Panicum ecklonii*–*Watsonia* sp. – *Restioschoenoides*Shrubby Grassland		13	19.5	29.1	37.9	11.7	1.9
2. *Erica woodii* – *Cliffortia serpyllifolia* Shrubland	Northern Escarpment Afromontane Fynbos (Gm 24)	25	35.7	31.3	27.5	5.4	0.5
2.1. *Erica woodii*–*Passerina montana*–*Syncolostemon albiflorus* Shrubland		5	43.3	33.2	19.1	4.3	0.0
2.2. *Erica woodii*–*Passerina montana*–*Myrsine africana* Tall Shrubland		20	33.7	30.8	29.6	5.4	0.5
3. *Dryopterisathamantica* – *Podocarpus latifolius* Forest	Northern Mistbelt Forest (FOz 4)	15	36.4	24.4	25.0	14.1	0.0
Combined spectrum for area above 1800m		61	28.9	28.9	30.7	11	0.5

Key: P-phanerophyte, Ch-chamaephyte, H-hemicryptophyte, G-geophyte and Th-therophyte.

Table 5.1.2. Mean percentage vegetation cover contribution of species per life form in three plant communities and four sub-communities and three broad vegetation groups present above 1800 m on Mariepskop.

Plant community	**Broad vegetation type**	**No. of plots**	**Mean percentage cover contribution by species**				
			P	Ch	H	G	Th
1. *Panicum ecklonii* –*Watsonia* sp. Grassland	Northern Escarpment Quartzite Sourveld (Gm 23)	21	8.5	11.8	73.0	6.7	0.3
1.1. *Panicum ecklonii*–*Watsonia* sp. – *Eragrostis curvula* Grassland		8	1.1	6.0	87.0	5.8	0.0
1.2. *Panicum ecklonii*–*Watsonia* sp. – *Restio schoenoides* Shrubby Grassland		13	13.0	15.3	64.1	7.2	0.4
2. *Erica woodii* – *Cliffortia serpyllifolia* Shrubland	Northern Escarpment Afromontane Fynbos (Gm 24)	25	42.9	33.3	21.1	2.6	0.1
2.1. *Erica woodii*–*Passerina montana*–*Syncolostemon albiflorus* Shrubland		5	50.4	38.5	10.6	0.6	0.0
2.2. *Erica woodii*–*Passerina montana*–*Myrsine africana* Tall Shrubland		20	41.0	32.0	23.7	3.2	0.1
3. *Dryopterisathamantica* – *Podocarpus latifolius* Forest	Northern Mistbelt Forest (FOz 4)	15	42.5	21.8	21.2	14.5	0.0
Combined spectrum for area above 1800m		61	31.3	22.3	38.4	7.9	0.1

Key: P-phanerophyte, Ch-chamaephyte, H-hemicryptophyte, G-geophyte and Th-therophyte.

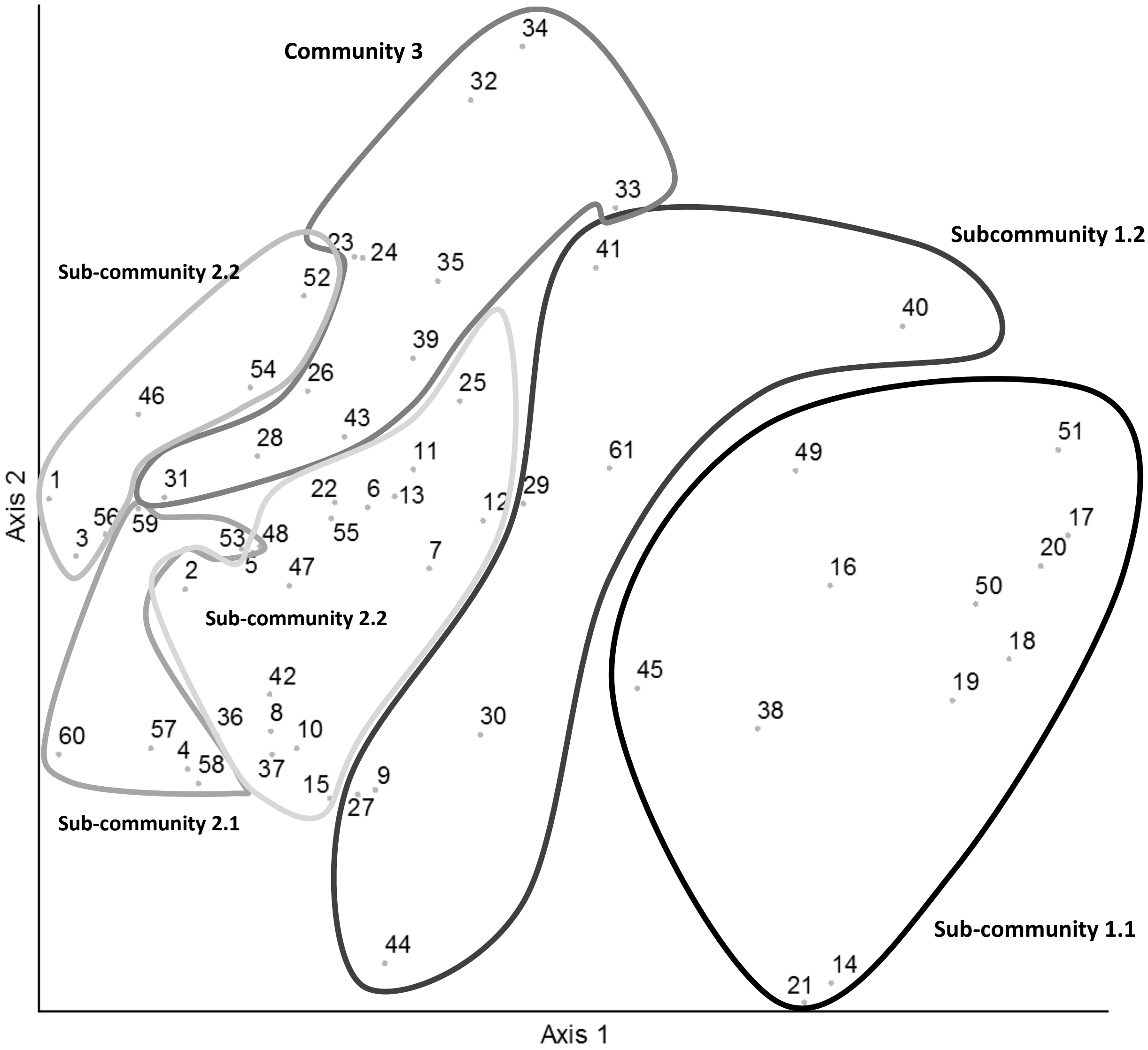

Figure 5.3. Principal coordinate analysis (PCoA) ordination diagram. The three communities with four sub-communities are indicated and were generated using life forms.

Table 5.2. **(a)** Axis summary statistics for the Principal Coordinate Analysis (PCoA). The majority of the variance within the community matrix was attributed to axis 1 (eigenvalue of 1.99).

	Axis 1	**Axis 2**	**Axis 3**
Eigenvalue	1.99	1.07	0.71
% variance	49.86	26.65	17.65
Cumulative % variance	49.86	76.51	94.16

Table 5.2. (b) Eigenvectors for the Principal Coordinate Analysis (PCoA). These vectors report on the correlation coefficients between plots and life forms. Phanerophytes had a strong negative correlation with axis 1 (-0.89) while hemicryptophytes were strongly correlated with axis 1 (0.87).

Life form	Axis 1	Axis 2	Axis 3
Phanerophytes	-0.89	0.24	0.19
Chamaephytes	-0.60	-0.42	-0.68
Hemicryptophytes	0.87	-0.33	-0.14
Geophytes	0.28	0.85	-0.44

5.4. Description of plant communities

Appendix A presents the synoptic table of species and sample plots while Appendix B presents the vegetation map of the identified plant communities. Below follows a description of the vegetation communities identified.

1. *Panicum ecklonii–Watsonia* sp. Grassland

This plant community was located almost exclusively at the highest elevation (1885 to 1943 m a.s.l.) towards the northern side on Mariepskop's plateau and covered an area of about 23.4 ha (APPENDIX B). The vegetation was characterized by open grassland, dominated by tussock grasses with scattered herbs (Figure 5.4). Geologically the community was found predominantly on quartzite of the Black Reef Formation as well as on shale, conglomerate and basalt of the Wolkberg Group. The major land types found in this community were Ib (rocky areas with miscellaneous soils) and Ic (rock with little or no soil) which also occurs locally with the soils being primarily shallow and rocky of the Mispah form. The soils were acidic (mean pH of4.8), sandy (mean percentage sand of 89%) with the lowest mean concentrations of almost all the macronutrients (Ca, K, Mg and Na), except for P which was intermediate. It was also in this community were the highest amount of N bound in NO_3^- was found (Table 5.3).

The diagnostic and dominant species of this community with a fidelity of 60% and with cover > 60% which formed Species group A was *Panicum ecklonii* (APPENDIX A). The constant species (frequency > 60%) in this group were *Panicum ecklonii* and *Watsonia* cf. *pulchra* * (both in Species Group A). The species belonging to this plant community were predominantly chamaephytes and hemicryptophytes with phanerophytes (predominantly nanophanerophytes) and geophytes (Table 5.1.1). Based on cover, the dominant life form was hemicryptophytes (Table 5.1.2). Within this community, a total of 46 species were recorded with a mean of nine species per plot.

**Note: Watsonia* sp. could not be identified as it was never in full bloom at the times of conducting fieldwork

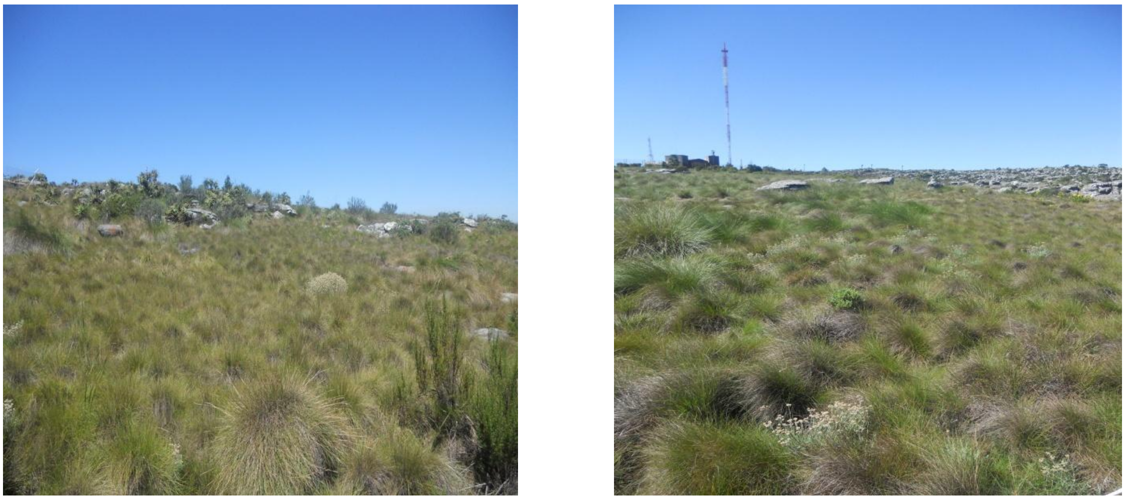

Figure 5.4. Photographs of Community 1 (showing characteristic plots namely 19 and 21).The vegetation was characterized by open grassland, which was dominated by graminoids with scattered herbs.

1.1 *Panicum ecklonii–Watsonia sp.–Eragrostis curvula* Grassland

The *Panicum ecklonii–Watsonia sp.–Eragrostis curvula* sub-community was located towards the northern side on Mariepskop’s summit and covered an area of 10.4 ha (APPENDIX B).The vegetation was open grassland, dominated by graminoids with scattered herbs and geophytes (Figure 5.5); the altitude within this sub-community ranged from 1911 to 1943 m a.s.l. With regards to geology and land types, this sub-community was identical to community 1.

Figure 5.5. Photographs of sub-community 1.1 with characteristic plots namely 45 and 49. The vegetation is open grassland which was dominated by graminoids with scattered herbs and geophytes also being present.

There were no diagnostic species for this sub-community with a fidelity higher than 60% (APPENDIX A). There were no dominant species within this sub-community with a cover higher than 60%, while the constant species with a frequency higher than 60% in this sub-community was *Eragrostis curvula* (Species Group F). The species of this plant sub-community were predominantly hemicryptophytes and chamaephytes with geophytes (Table 5.1.1). Based on cover, the dominant life form in this sub-community was hemicryptophytes (Table 5.1.2).Within this sub-community, a total of 24 species were recorded with an average of 7 species per plot.

1.2 Panicum ecklonii–Watsonia sp.–Restio schoenoides Shrubby Grassland

The *Panicum ecklonii–Watsonia* sp.–*Restio schoenoides* sub-community was located towards the northern side on Mariepskop's plateau and covered an area of 13 ha (APPENDIX B).The vegetation was very rocky with short, closed grassland, rich in forb species with scattered trees and shrubs (Figure 5.6); the altitude within this sub-community ranged from 1849 to 1943 m a.s.l. With regards to geology and land types, this sub-community was identical to community 1.

Figure 5.6. Photographs of sub-community 1.2 with characteristic plots namely 40 and 41.The vegetation is rugged with short, closed grassland rich in forb species with scattered trees and shrubs.

There were no diagnostic species for this community with a fidelity higher than 60% (APPENDIX A). The dominant species within this sub-community (cover > 60%) were *Miscanthus junceus* (Species Group A) and *Eragrostis curvula* (Species Group F) while there were no constant species with a frequency higher than 60% in this sub-community. The species belonging to this plant sub-community were predominantly hemicryptophytes and chamaephytes with phanerophytes (predominantly nanophanerophytes) and geophytes (Table 5.1.1).Based on cover, the dominant life form was hemicryptophytes (Table 5.1.2). Within this sub-community, a total of 45 species were recorded with a mean of 10 species per plot.

2. *Erica woodii–Passerina montana* Shrubland

This plant community was located almost exclusively on the southern side of the plateau of Mariepskop with some scattered patches in between boulders towards the northern side and covered an area of about 57.8 ha (APPENDIX B). The landscape was dominated by rocky sheets and the vegetation was a dense shrubland with interspersed grassy patches (Figure 5.7). Altitude in this community ranged from 1805 to 1940 m a.s.l. The dominant geology found here was quartzite of the Black Reef Formation as well as shale, conglomerate and basalt of the Wolkberg Group. The major land types found in this community were Ib (rocky areas with miscellaneous soils) with Ic (rock with little or no soil) also occurring locally. The soils were acidic (mean pH of4.6), sandy (mean percentage sand of 86%) with relatively intermediate concentrations of almost all the macronutrients (Ca, K, Mg and Na). However, the mean concentration for P was the lowest of all the plant communities with the highest amount of N bound in NH_4 found in this community (Table 5.3).

Figure 5.7. Photographs of community 2 with characteristic plots namely 55 and 57.The landscape was dominated by rocky sheets and the vegetation was a dense shrubland with interspersed grassy patches.

The diagnostic species of this community with a fidelity higher than 60%, forming Species group C, was *Erica woodii* (APPENDIX A). The dominant species within this community (with cover > 60%) were *Eragrostis curvula* (Species Group F) and *Cliffortia serpyllifolia* (Species Group J). The constant species (frequency >60%) in this group were *Eragrostis* *curvula* (Species Group F), *Passerina montana* (Species Group I), *Syncolostemon albiflorus* (Species Group I) and *Cliffortia serpyllifolia* (Species Group J). The species belonging to this plant community were predominantly chamaephytes with scattered hemicryptophytes, phanerophytes (predominantly nanophanerophytes) and geophytes in between (Table 5.1.1). Based on cover, the dominant life forms were phanerophytes and chamaephytes with hemicryptophytes also largely present (Table 5.1.2). Within this community, a total of 47 species were recorded with a mean of 12 species per plot.

2.1. Erica woodii–Passerina montana–Syncolostemon albiflorus Shrubland

This sub-community was located almost exclusively on the south-eastern side of Mariepskop's plateau and covered an area of about 5.2 ha (APPENDIX B). Altitude in this sub-community ranged from 1881 to 1905 m above sea level and the vegetation was mainly dominated by phanerophytes (specifically nanophanerophytes) with grasses (Figure 5.8). The geology and land types within this sub-community were identical to the entire community 2.

Figure 5.8.Photographs of sub-community 2.1 with characteristic plots namely 57 and 60. The vegetation was mainly dominated by shrubs with grasses and was interspersed by rocky sheet patches.

The diagnostic species of this sub-community with a fidelity higher than 60% were *Erica woodii* (80%; Species group C) and *Helichrysum mariepscopicum* (60%; Species Group J). The dominant species of this sub-community were *Cliffortia serpyllifolia* (Species Group J), *Erica woodii* (Species Group C), *Helichrysum mariepscopicum* (Species Group J) and *Passerina montana* (Species Group I). Species with a complete constancy (100% frequency) in this subcommunity were *Erica woodii, Cliffortia serpyllifolia, Eragrostis curvula* (Species

Group F), *Passerina montana*, *Syncolostemon albiflorus* and *Helichrysum mariepscopicum*. The species belonging to this plant sub-community were predominantly phanerophytes (predominantly nanophanerophytes) with scattered hemicryptophytes and chamaephytes and a few geophytes present in between the large shrubs (Table 5.1.1). Based on cover, the dominant life forms were phanerophytes and chamaephytes (Table 5.1.2).Within this sub-community, a total of 15 species were recorded with a mean of eight species per plot.

2.2. Erica woodii–Passerina montana–Myrsine africana Tall Shrubland

This sub-community was located almost exclusively on the south-western side of Mariepkop's plateau with some scattered patches between boulders towards the northern side and covered an area of approximately52.6 ha (APPENDIX B). Altitude in this sub-community ranged from 1805 to 1940 m a.s.l. and the vegetation was dominated by nanophanerophytes (mean height of 1.5 m) with sheets of rocks interspersing (Figure 5.9). The geology and land types within this sub-community were identical to the entire community 2.

Figure 5.9. Photographs of sub-community 2.2 with characteristic plots namely 25 and 15. The vegetation was dominated by tall shrubs (mean height of 1.5 m) interspersed with sheets of rock.

There were no diagnostic species for this sub-community with a fidelity higher than 60%. The dominant species within this community (with cover > 60%) were *Eragrostis curvula* (Species Group F) and *Cliffortia serpyllifolia* (Species Group J). The constant species in this group was also *Cliffortia serpyllifolia* (frequency > 85%) as well as *Eragrostis curvula, Helichrysum lepidissimum* (Species Group J), *Passerina montana* and *Aloe arborescens* (Species Group J) (frequency > 60%). The species belonging to this plant sub-community were predominantly nanophanerophytes with scattered chamaephytes, hemicryptophytes and geophytes present (Table5.5.1). Based on cover, the dominant life forms were phanerophytes, chamaephytes and hemicryptophytes (Table 5.1.2). Within this sub-community, 46 species were recorded with a mean of 13 species per plot.

3. *Dryopteris athamantica–Podocarpus latifolius* Forest

This plant community was found scattered around the summit of Mariepskop between large boulders, in sheltered gorges and covered an area of approximately 28.9 ha (APPENDIX B). The landscape was dominated by huge boulders and vegetation was comprised by a mixture of trees, shrubs and smaller hemicryptophytes and geophytes scattered underneath (Figure 5.10). The dominant geology found here was quartzite of the Black Reef Formation as well as shale, conglomerate and basalt of the Wolkberg Group .The dominant land type in this community was Ic (rock with little or no soil) with Ib (rock areas with miscellaneous soils) also being secondarily present. Soils in this vegetation unit were acidic, loamy sand (mean pH of 5; mean percentage sand of 67%) with the highest relative levels of all the macronutrients (Ca, K, Mg, Na and P) (Table 5.3). The mean concentration of N, bound in NH_4^+, was also the highest within this community. Altitude within this community ranged from 1878 m to 1943m a.s.l. Community 3 also had the lowest amount of N bound in both NO_3^- and NH_4^+, thus lowest mean µg of NO_3^- and NH_4^+ per gram of soil, compared to the other communities.

The diagnostic species of this community with fidelity higher than 80%, forming part of Species group H, was *Podocarpus latifolius* (APPENDIX A). Other diagnostic species in this group (fidelity>60%) included *Asparagus rigidus* (Species Group H), *Dryopteris athamantica* (Species Group I) and *Robsonodendron eucleiforme* (Species Group H).The dominant species within this community were also *Podocarpus latifolius* as well as *Dryopteris athamantica, Robsonodendron eucleiforme* and *Cyrtanthus huttonii* (Species Group H). The constant species (frequency > 90%) in this group were also *Podocarpus latifolius* and *Dryopteris athamantica* as well as *Aloe arborescens, Plectranthus fruticosus, Asparagus rigidus, Robsonodendron eucleiforme, Cyrtanthus huttonii* and *Helichrysum lepidissimum* (Species Group J) (frequency > 60%).The species belonging to this plant community were fairly evenly divided between all life forms (Table 5.1.1). Based on cover, the dominant life form was phanerophytes with chamaephytes and hemicryptophytes also present (Table 5.1.2).Within this community, a total of 34 species were recorded with a mean of 12 species per plot.

Figure 5.10. Photographs of community 3 with characteristic plots namely 26 and 52.The landscape was dominated by huge boulders with trees and smaller geophytes scattered underneath.

5.4.1 Soil differences on the summit of Mariepskop

Results from the analysis of soil samples are presented in Table 5.3 while Figure 5.11 shows a bi-plot from a Canonical Correspondence Analysis (CCA), indicating the relationships between the measured environmental variables (measured soil variables) and each of the identified communities. The total variance in the species data was 4.15 with the variance attributed to the various axes as well as the standard correlation coefficients for each axis shown in Table 5.4 (a). The results from the multiple regression (canonical coefficients), shown in Table 5.4 (b), reports on the effectiveness of the measured environmental variables in structuring the ordination and describe the relationships of the environmental variables to the ordination axes.

Although the soil nutrients were not the principal determining factor in the structuring of the communities, the CCA did to a lesser extent confirm the distinction between the communities. Community 1 was associated with high levels of (P, high pH to a certain degree as well as low levels of Mg and K. It was also in this community were the highest amount of N bound in NO_3^- were found (thus highest mean µg of NO_3^- per gram of soil) compared to the other communities. Community 2 was associated with high levels of Mg, intermediate levels of K, low levels of P as well as the highest amount of N bound in NH_4^+ compared to the other communities (Table 5.1). Community 3 was associated with high Mg levels and low

P as well as low pH levels. Community 3 also had the lowest amount of N bound in both NO_{3-} and NH_4^+, thus lowest mean µg of NO_3^- and NH_4^+ per gram of soil, compared to the other communities. (Although soil samples from plots 35 and 43 were also analysed, values for all macronutrients were extreme (see Table 5.3) and were therefore excluded from the CCA analysis for clearer results.).

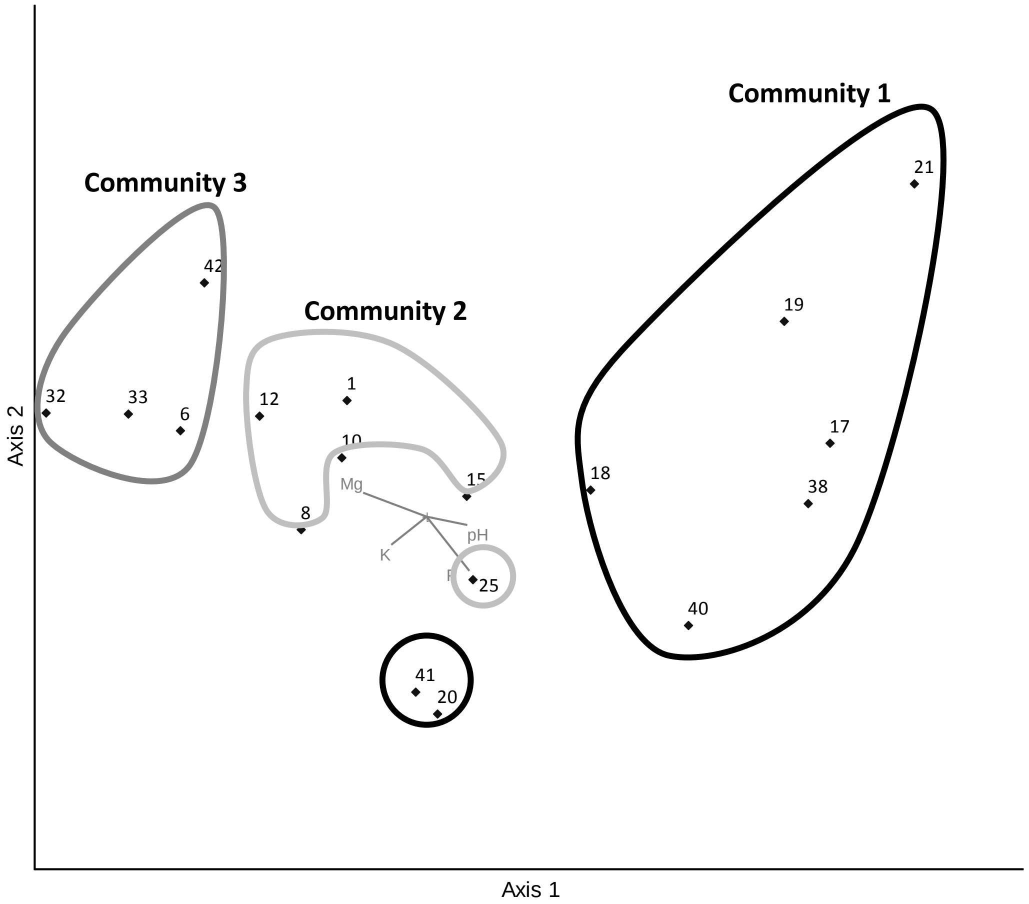

Figure 5.11. Canonical Correspondence Analysis bi-plot showing the relationship between the measured soil variables and the identified plant communities. The respective communities are indicated. As the length of environmental variable line indicates strength of relationship, a longer line equals stronger relationship. Thus, soil nutrients at the summit of Mariepskop were not the principal determining factor in the structuring of the communities.

Table 5.3. Measured soil variables of 20 soil samples within the three identified communities at the summit of Mariepskop.

Plot number	% Sand	% Clay	% Silt	pH (H_20)	Ca (mg/kg)	K (mg/kg)	Mg (mg/kg)	Na (mg/kg)	P (mg/kg)	N in NH_4^+ (μg/gram of soil)	N in NO_3^- (μg/gram of soil)
Grassland community											
38	92.08	2.00	5.92	5.17	290.12	23.83	20.57	12.49	8.71	0.62	3.59
18	89.60	0.00	10.40	4.51	341.52	31.75	30.75	13.77	6.35	0.94	7.88
21	91.52	4.00	4.48	4.60	75.65	27.79	21.24	18.34	5.86	1.69	6.30
19	82.18	0.00	17.82	4.68	305.52	51.53	30.47	20.51	5.30	1.23	5.25
17	90.76	0.00	9.24	5.34	123.62	16.57	11.14	11.84	5.72	0.68	5.69
20	89.40	0.00	10.60	4.62	234.22	55.42	40.12	15.17	7.96	1.26	7.35
40	88.14	0.00	11.86	5.00	44.25	24.58	8.935	9.27	9.48	1.09	9.98
41	91.10	2.00	6.90	4.40	85.08	64.37	26.06	8.34	4.89	0.89	4.38
Shrubland community											
25	88.54	0.00	11.46	5.26	1205.62	42.52	68.68	16.97	2.21	1.29	9.19
15	79.04	0.00	20.96	5.09	1285.62	59.28	102.20	15.25	2.28	2.42	10.24
12	87.58	2.00	10.42	4.73	857.42	75.76	95.58	30.78	3.50	1.23	0.00
8	89.74	2.00	8.26	3.92	67.68	53.22	38.30	10.37	3.97	1.68	9.98
10	226.42	0.00	0.00	4.68	335.82	46.77	89.30	11.29	3.79	1.03	7.44
1	86.84	0.00	13.16	4.18	203.72	47.70	49.66	13.74	3.89	0.42	1.49
Forest community											
6	90.40	0.00	9.60	4.92	457.52	18.61	81.98	7.37	2.29	0.55	2.19
32	78.78	0.00	21.22	3.75	711.02	83.96	97.78	32.31	5.80	2.13	8.84
42	77.30	0.00	22.70	4.51	225.42	39.31	42.6	16.40	3.74	0.66	6.48
33	84.02	0.00	15.98	4.68	963.62	39.36	98.2	12.77	2.34	0.61	2.45
35	75.90	0.00	24.10	6.67	4784.62	244.30	160.8	31.80	1.78	0.51	0.00

Table 5.4 (a). Axis summary statistics for the Canonical Correspondence Analysis (CCA). The majority of the variance within the community matrix was attributed to axis 1 (eigenvalue of 0.580), while there was a strong positive species-environment correlation for all three axes (Pearson Correlation, Spp-Envt).

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.580	0.331	0.311
Variance in species data **% of variance explained**	16.9	9.7	9.1
Cumulative % explained	16.9	26.6	35.6
Pearson Correlation, Spp-Envt*	0.987	0.967	0.975
Kendall (Rank) Correlation, Spp-Envt*	0.869	0.765	0.895

*Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables.

Table 5.4 (b). Canonical coefficients for multiple regression analysis. These coefficients report on the effectiveness of the environmental variables in structuring the ordination and describe the relationships of the environmental variables to the ordination axes. The variables that were critical to this structuring were Mg, P, pH and K.

Variable	**Axis 1**	**Axis 2**	**Axis 3**
% Sand	1.129	0.780	0.029
% Clay	-0.344	0.225	0.196
% Silt	0.176	0.709	-0.391
pH	-0.197	-0.404	0.220
Ca	1.515	0.175	-0.197
K	-0.773	-0.976	0.814
Mg	-2.793	-0.537	-0.453
Na	-0.063	0.444	-0.534
P	0.138	-0.404	-0.831
N in NH_4^+	1.835	0.545	0.375
N in NO_3^-	-1.593	-0.643	-0.232

5.4.2 Climate differences on the summit of Mariepskop

Climate data were available for the eastern and western weather stations at the summit of Mariepskop (Figure 3.1). As previously mentioned, the data available for the eastern weather station were for the time period November 2011 to April 2014 (1 in Figure 3.1). Limited climatic data with various gaps, available only from October 2011 to mid-March 2012, was recorded by a second weather station positioned on the western side of the summit (2 in Figure 3.1) at an altitude of 1870 m a.s.l. (Table 5.5). Thereafter, where possible, climate data were compared on a monthly average over the same time period between the two weather stations (Table 5.6).

Table 5.5. Mean measured climatic variables on the western side at the summit of Mariepskop at an altitude of 1870 m.

	Wind Speed ($m.s^{-1}$)	Temperature (°C)	Relative Humidity (%)	Solar Radiation ($watts.m^{2}$)	Air Pressure ($mbar.hPa^{-1}$)	Rainfall (mm)
October 2011	0.121	19.281	55.551	256.551	810.673	51.06
November 2011	1.509	18.649	77.531	289.755	816.371	12.19
December 2011	1.447	16.047	89.648	195.390	815.762	212.41
January 2012	1.616	15.932	94.379	198.840	814.534	651.36
February 2012	1.378	17.052	90.121	221.981	809.744	120.76
March 2012	1.664	15.501	89.342	210.801	810.648	21.54
Six month mean (total for rainfall)	**1.289**	**17.077**	**82.762**	**228.886**	**812.955**	**1069.320**

Table 5.6. Mean climatic comparison between the western (Fynbos) and eastern (Radar) weather stations across two months at the summit of Mariepskop

	January 2012		**February 2012**		**March 2012 (1-7 March)**	
	Fynbos (west)	**Radar (east)**	**Fynbos (west)**	**Radar (east)**	**Fynbos (west)**	**Radar (east)**
Wind Speed ($m.s^{-1}$)	1.614	4.557	1.378	3.747	1.664	7.038
Temperature (°C)	15.939	15.399	17.052	16.386	15.501	14.656
Relative Humidity (%)	94.368	91.603	90.121	87.791	89.342	87.576
Solar Radiation ($Watts/m^{2}$)	199.064	225.704	221.981	219.451	210.801	216.735
Air Pressure (Millibar / hPa)	814.537	809.141	813.7	809.744	811.8	808.155
Rainfall (mm)	651.36	643.50	120.76	111.70	21.54	13.7

Climate data during summer for the west-facing slope did not differ largely from those of the east-facing slope (Table 5.6). However, it can be seen that there was specifically a clear difference in wind speed at the two weather stations. For both January and February 2012, the wind speed at the western station was at least 2 $m.s^{-1}$ faster compared to the eastern station (Table 5.6). In terms of temperature, it was slightly warmer on the western side compared to the eastern side of the summit, although the difference was a mere 0.5 °C. Relative humidity was slightly higher at the western station compared to the eastern station (only 3% higher) while air pressure was also slightly higher at the western station. In terms of rainfall, there were small differences between the two weather stations ranging between seven and nine mm more for the western weather station. This suggests a slightly wetter and warmer climate on the western slope than on the east-facing slope. Field observations suggest that this is largely due to a higher frequency of mist on the west-facing slope. However, this was a short-term data comparison and longer term data should be collected before conclusions about longer term climate differences can be drawn to explain the vegetation observed on the western and eastern side of the summit.

5.5. Phytogeography

Out of a total of 61 species found at the summit of Mariepskop, 23 species (38%) had CFR-Mariepskop distribution (i.e. the biggest group), 17 species (28%) had a Drakensberg-Mariepskop distribution and 21 species (34%) were strictly endemic or near-endemics of Mariepskop.

Two of the dominant species within community 1 namely *Miscanthus junceus* and *Watsonia* sp., had a strictly northern distribution while *Panicum ecklonii* had a north-eastern distribution. Other species of phytogeographical interest within this community include *Restio schoenoides* (CFR-Mariepskop distribution), *Protea rubropilosa* and *Euryops pedunculatus* (both with Drakensberg-Mariepskop distributions).

In community 2, the diagnostic species *Erica woodii* had a Drakensberg-Mariepskop distribution while the other dominant species such as *Eragrostis curvula, Passerina montana* and *Cliffortia serpyllifolia* all had CFR-Mariepskop distributions. It is also noteworthy that the majority of species which were strictly endemic or near-endemics of Mariepskop was dominant within this community such as *Syncolostemon albiflorus, Helichrysum mariepscopicum* and *Eumorphia davyi*.

In community 3, the diagnostic species (fidelity > 80%) *Podocarpus latifolius* had a CFR-Mariepskop distribution while other diagnostic species (with fidelity >60%) had

Drakensberg-Mariepskop (*Dryopteris athamantica*), CFR-Mariepskop (*Robsonodendron eucleiforme*), as well as strictly endemic or near-endemic to Mariepskop (*Asparagus rigidus* and *Cyrtanthus huttonii*). Other high frequency species within this community such as *Aloe arborescens* and *Plectranthus fruticosus* had CFR-Mariepskop distributions.

Species found in the CFR, Drakensberg and Mariepskop (CFR-Mariepskop distribution*:* 23 species) were: *Restio schoenoides* (Kunth), *Verbena bonariense* L., *Ficinia gracilis* Schrad., *Myrsine africana* L., *Eragrostis curvula* (Schrad.) Nees., *Cliffortia linearifolia* Eckl. & Zeyh., *Cyperus fastigiatus* Rottb., *Widdringtonia nodiflora* (L.) Powrie, *Psoralea arborea* Sims, *Robsonodendron eucleiforme* (Eckl. & Zeyh.) R.H.Archer, *Podocarpus latifolius* (Thunb.) R.Br. ex. Mirb., *Anthospermum herbaceum* L.f., *Passerina montana* Thoday, *Plectranthus fruticosus* L'Hér., *Melinis nerviglumis* (Franch.) Zizka, *Cliffortia serpyllifolia* Cham. & Schltdl., *Aloe arborescens* Mill., *Hebenstretia dura* Choisy, *Seriphium plumosum* Levyns, *Kniphofia linearifolia* Baker., *Wahlenbergia undulata* (L.f.) A.DC., *Stachys aethiopica* L. and *Cussonia spicata* Thunb.

Species found in the Drakensberg and Mariepskop (Drakensberg-Mariepskop distribution: 17 species) were: *Panicum ecklonii* Nees, *Brunsvigia natalensis* Baker, *Euryops pedunculatus* N.E.Br., *Monocymbium ceresiiforme* (Nees) Stapf., *Erica woodii* Bolus var. *woodii, Mohria rigida* J.P. Roux, *Muraltia flanaganii* Bolus, *Carex zuluensis* C.B.Clarke, *Hypericum revolutum* Vahl subsp. *revolutum*, *Crassula sarcocaulis* Eckl. & Zeyh. subsp. *sarcocaulis*, *Dryopteris athamantica* (Kunze) Kuntze, *Helichrysum lepidissimum* S.Moore, *Helichrysum polycladum* Klatt, *Polygala virgata* Thunb. var. *decora* (Sond.) Harv, *Helichrysum acutatum* DC., *Lobelia flaccida* (C.Presl) A.DC. subsp. *flaccida* and *Silene burchelli* Otth var. *angustifolia* Sond.

Species found only on and around Mariepskop (strictly endemic or near-endemics of Mariepskop: 21 species) were: *Watsonia* cf. *pulchra* N.E.Br. ex Goldblatt, *Miscanthus junceus* (Stapf) Pilg., *Protea rubropilosa* Beard, *Tetraselago wilmsii* (Rolfe) Hilliard & B.L.Burtt, *Olinia rochetiana* Juss., *Syncolostemon eriocephalus* I.Verd., *Macowania tenuifolia* M.D.Hend., *Helichrysum obductum* Bolus, *Cyrtanthus huttonii* Baker, *Asparagus rigidus* Jessop., *Clivia caulescens* R.A.Dyer, *Syncolostemon albiflorus* (N.E.Br.) D.F. Otieno, *Senecio hederiformis* Cron, *Searsia tumilicola* (S.Moore) Moffett var. *tumilicola, Otiophora cupheoides* N.E.Br., *Helichrysum mariepscopicum* Hilliard, *Eumorphia davyi* Bolus, *Senecio junodii* Hutch. & Burtt Davy, *Craterostigma wilmsii* Engl. ex Diels., *Vernonia wollastonii* S.Moore. and *Hesperantha schlechteri* (Baker) R.C.Foster.

CHAPTER 6
Discussion

6.1. Introduction

This project had three main objectives: (1) describe and map the plant communities above 1800 m a.s.l. at Mariepskop and determine the possible environmental gradients that may give rise to these communities; (2) analyse the life forms in each community using Raunkiaer's (1934) classification as modified by Mueller-Dombois and Ellenberg (1974) in order to assess similarities with the Cape fynbos vegetation and; (3) investigate the geographic distribution of the identified plant species and their association with the Cape Floristic Region.

6.2. The different plant communities

The study identified three different plant communities with two communities being further subdivided (Figure 5.1). Although the communities and sub-communities were not determined based on mean percentage cover/abundance per life form per plot (NMS ordination), percentage cover per life form did support the structuring based on the PCoA analysis (Figure 5.11).

The *Panicum ecklonii–Watsonia sp.* Grassland (Community 1) was dominated by graminoids, a variety of forbs and scattered trees and shrubs closely resembling the Northern Escarpment Quartzite Sourveld (Gm 23) in terms of similar composition of vegetation features (i.e. short grassland with scattered trees and shrubs) (Mucina and Rutherford 2006).

The *Erica woodii–Passerina montana* Shrubland (Community 2) was characterized by the co-dominance of shrubs (nanophanerophytes and chamaephytes) and hemicryptophytes, with the two sub-communities representing both a shrubland sub-community and a transitional sub-community between forest and shrubland (APPENDIX A). The tall shrubland sub-community closely resembles the Northern Escarpment Afromontane Fynbos vegetation type (Gm 24) as the dominant vegetation was sclerophyllous shrubs and herbs (Mucina *et al.* 2006). On Mariepskop the tall shrubland sub-community forms an ecotone between the forest and the surrounding vegetation and contains elements of both the Northern Escarpment Afromontane Fynbos vegetation type (Gm 24) and the Northern Mistbelt Forest vegetation type (FOz 4) (Mucina and Geldenhuys 2006, Mucina *et al.* 2006). Similar results were observed for other studies focussing on inselbergs such as Platberg where the forest edge at high elevation also contained fynbos-like vegetation (Brand *et al.* 2009).

The *Dryopteris athamantica–Podocarpus latifolius* Forest (Community 3) was characterized by the even distribution of all life forms. However, compared to the other communities, the percentage of phanerophytes and geophytes are considerably higher (Table 5.2). With the dominance of the canopy tree *Podocarpus latifolius*, herbs *Plectranthus fruticosus* and *Stachys aethiopica,* and fern *Mohria rigida,* this community closely resembles the Northern Mistbelt Forest vegetation unit, FOz 4, which falls within the Forest Biome (Mucina and Geldenhuys 2006).

6.3 Ecological factors giving rise to the different communities.

6.3.1 Correlation between soil and vegetation communities

The importance of soils in community structure has been observed in other plant ecological studies at high elevations. Normally at the highest elevations, graminoids only become dominant where the soils are either shallow, have impeded drainage or the natural vegetation was removed as a result of fire (White 1978). Although the soil properties of the individual communities on the summit of Mariepskop were not the principal determining factor in the observed community structure, there were quantifiable effects of soil on Mariepskop, as on other inselbergs.

High percentage sand is important in relatively high altitude areas (from 1800 to 2100 m) where woody plants such as trees and shrubs tend to co-dominate (White 1978). In general, both communities 1 (grassland) and 2 (shrubland) on Mariepskop, covering the majority of the summit, the soils were acidic and sandy (Table 5.1), which was similar to the soils in the shrubland on Platberg at 2000 m.a.s.l. (well-drained sandy grassland soils) as well as the ericaceous communities on the Chimamimani mountains (nutrient poor, sandy acidic soils) (Phipps and Goodier 1962, Brand *et al.* 2008). In terms of land types, the soils of the grassland and the shrubland communities correspond to the Ib land type where soils were generally shallow and sandy while the soils of the forest community corresponded with the Ab land type which were slightly deeper, loamy sand and freely drained (Department of Minerals and Energy 1986).

It is also possible that one of the major reasons for the dominance of physiognomically similar shrubs in this community (i.e. *Erica woodii* as well as other species namely *Passerina montana* and *Cliffortia serpyllifolia*) could be as a result of soil depth. The *Erica* communities on the Chimanimani Mountains, where various *Erica* species (such as *Erica eylesii*, *E. pleiotricha*, *E. gazensis* and *E. johnstoniana*) reached heights of about 0.5 m, are generally found on the quartzite soils which are too shallow for larger competing plants (Phipps and Goodier 1962). Similarly, the co-dominance of shrubs and trees coincided with the highest percentage sand (community 2). In extremely rocky areas providing a physical barrier from fires, many shrubland species can behave as forest precursors (i.e. *Aloe arborescens, Cliffortia linearifolia, Erica woodii, Passerina montana*) when secondary grasslands are protected from fire (Masson and Moll 1987).

Although the soil nutrients were not the principal determining factor in the structuring of the communities, certain nutrients such as N (bound in either NO_3^- or NH_4^+) were more evident in certain communities (Table 5.1). In the Drakensberg Alpine Centre (DAC), the supply of soil inorganic N to plants is extremely limited at higher elevations (>1860 m.a.s.l.), where temperatures are lower (Carbutt *et al.* 2013). Despite an intrinsically N-rich soil (total soil N of 4.0 µg. g^{-1}), temperature played a more important role in plant growth as low temperatures limited microbial activity and thus limited N mineralisation by plants (Carbutt *et al.* 2013). Slightly higher levels of total N on Mariepskop (total soil N of 6.8 µg. g^{-1}: 1.1 µg. g^{-1} (NH_4) and 5.7 µg. g^{-1} (NO_3)) compared to the DAC (total soil N of 4.0 µg. g^{-1}) could be explained by the low temperatures. The grassland community had the highest mean average N concentration bound in NO_3^-. The shrubland community was associated with the highest mean amount of N bound in NH_4^+ while the forest community had the lowest mean amount of N bound in both NO_3^- and NH_4^+. High levels of NO_3^- possibly tend to favour the growth of grasses whereas high levels of NH_4^+ are possibly more favoured by shrubby plants (Nordin *et al.* 2006). A possible explanation for this could be that grasses utilize NO_3^- much more effectively in resource allocation (flowering, shoot and root growth) and are able to effectively take up nitrogen in the form of NO_3^- compared to shrubby plants (McKane *et al.* 2002, Miller and Bowman 2002). Greater N availability also tends to intensify above-ground competition for light and favours woody plants in competition with grasses (e.g. Tilman and Pacala 1993, Wilson 1993, Grace 1995, Li and Wilson 1998, Wilson 1998), as observed in community 2 where high mean levels for both NO_3^- and NH_4^+ was found. Soil pH also plays a vital role in the availability of nutrient elements in organic soils as mineral elements form less-soluble compounds when the pH is lower than 6 (Taiz and Zeiger 2006), compared to alkaline soils. Potentially, the higher mean pH in the forest community could lead to less efficient uptake and higher levels of nutrients present in the soils (Table 5.1).

6.3.2. Effects of climate.

Although the climatic data from the two weather stations above 1800 m on Mariepskop were short-term, qualified conclusions and predictions could be made. Increased moisture content [i.e. humidity (92%) and rainfall (650 mm) on western side] could favour the presence and/or dominance of more woody plants (shrubland and forest communities) whereas decreased levels of water availability (possibly on the eastern side) could be favoured by the more water-use efficient grasses of the grassland community (Taiz and Zeiger 2006). The absence of larger shrubs and trees on the eastern side of the mountain could possibly be explained by the marked difference in wind speed (speed on eastern side a mean speed of 2.5 $m.s^{-1}$ faster) compared to the western side (Table 5.4) as grasses would be better adapted to high wind speeds compared to shrubs [i.e. in terms of resistance or leaf surface area being reduced affecting photosynthesis ability (e.g. Whitehead 1962, Sinoquet *et al.* 2001, Smith and Ennos 2003)]. As a result the shrubs and larger trees were almost only found among large boulders which acted as partial wind barriers and had relatively thick branches and leaves, probably as an adaptation to wind (Watt *et al.* 2005). Thus climate could to a certain degree explain the characteristics and the combination of life forms of the communities on Mariepskop, but further research is needed to qualify this preliminary observation.

6.4 Life forms and biome affinities

The area above 1800 m a.s.l. on Mariepskop has been classified as falling within the Grassland Biome (Mucina *et al.* 2006). However, the life form spectra in terms of cover contribution did not show similarity with the Grassland Biome spectrum (dominated by hemicryptophytes) (Table 5.5.2) (Rutherford 1997). The ratio of the combined life form spectrum of the three communities on Mariepskop did however show similarities to the ratio of the life forms present in the Fynbos Biome spectrum (Table 2.1)*. The co-dominant life forms in terms of cover contribution for the Fynbos Biome are phanerophytes (35.2%), chamaephytes (33.5%) and hemicryptophytes (28.1%) (Rutherford *et al.* 1994), while the co-dominant life forms on Mariepskop were also phanerophytes (31.3%), chamaephytes (22.3%) and hemicryptophytes (38.4%) (Table 5.5.2), confirming that there might be possible strong life form similarities with the Fynbos Biome. However, the individual plant communities showed similarities with different biomes.

**This does not necessarily indicate an outlier of the Fynbos Biome, but rather a possible expansion of woody vegetation due to minimum disturbances such as fire.*

6.4.1 Grassland Biome Affinities

The Grassland Biome is characterized by hemicryptophytes (more than 95%), generally graminoids of the families Poacaeae, Cyperaceae and Restionaceae. The other life forms present in the Grassland Biome include geophytes (less than 3%), chamaephytes and therophytes (both less than 1%). Mariepskop, which falls within the Mesic Highveld Grassland Bioregion, is co-dominated by phanerophytes, hemicryptophytes and chamaephytes with geophytes having a substantially higher percentage compared to the conventional life form composition for the Grassland Biome (Table 5.2). Although specific life form spectra were not conducted during other studies on inselbergs, similar co-dominance by grasses (hemicryptophytes), shrubs (chamephytes) and tall shrubs (nanophanerophytes) were found for the summits of Chimanimani Mountains and Platberg (Phipps and Goodier 1962, Brand *et al.* 2010). Community 1 shows definite affinities with the Grassland Biome (Rutherford*et al.* 1994), as were the case for parts of the Platberg (Brand *et al.* 2010), the DAC (Carbutt and Edwards 2004), as well as the Chimanimani mountains in Zimbabwe (Phipps and Goodier 1962).

The grasslands on the Chimanimani Mountains are dominated by grasses (i.e. hemicryptophytes) (Phipps and Goodier 1962) including *Loudetia simplex*, *Trachypogon spicatus* and *Themeda triandra* as well as chamaephytes (e.g. *Blaeria friesii*, *Otiophora inyanga* var. *parivolia* and *Protea enervis*) and geophytes (e.g. *Eriospermum* sp.), with certain microhabitats being dominated by *Restio* spp. (Phipps and Goodier 1962). Similar life form dominance was also found in the hygrophilous grasslands at high elevations in the Wolkberg Centre (Matthews *et al.* 1992). These hygrophilous grasslands, of which Community 1 on Mariepskop forms part, is characterized by the dominance of grass (hemicryptophyte) species such as *Alloteropsis semialata*, *Andropogon schirensis*, *Themeda triandra*, *Plectranthus calycinus* and the therophyte *Lobelia flaccida*.

6.4.2. Forest Biome Affinities

The entire Forest Biome in South Africa is composed of forest patches. What was possibly once a wide distribution of the Afrotemperate Forests, has become relictual elements found as refugia on inselbergs, relictual scarp on elevated ranges or in ravines (Von Maltitz *et al.* 2003, Mucina and Rutherford 2006, Brand *et al.* 2009).

One such patch is Mariepskop where Northern Mistbelt Forest (FOz 4) can be found in the ravines and lower slopes (not within the current study area) of the mountain as well as slightly above 1800 m. Community 3 closely resembles a forest edge of a Northern Mistbelt

Forest as it is characterized by the dominance of the canopy tree *Podocarpus latifolius*, other phanerophytes such as *Robsonodendron eucleiforme* and *Searsia tumulicola,* and various other hemicryptophytes (*Plectranthus fruticosus, Senecio hederiformis* and *Dryopteris athamantica*) and geophytes (*Cyrtanthus huttonii* and *Asparagus rigidus*). However in terms of cover contribution of life forms, Community 3 does not closely resemble the Forest Biome (Table 2.1) where phanerophytes are dominant (86.9%) (Table 2.1) (Rutherford 1997), compared to Community 3 where phanerophytes were not dominant (42.5%). Community 3 closely resembles (not in terms of cover but in terms of species composition) the forest of the Afromontane Region.

6.4.3. Fynbos Biome Affinities

The vegetation of the Cape Fynbos Biome is characterized by the co-dominance of fine-leaved, sclerophyllous, evergreen shrubs and dwarf shrubs together with hemicryptophytes (Rutherford and Westfall 1994). The dominant life forms in terms of cover contribution by which the Cape Fynbos Biome is characterized are phanerophytes (35.2%), chamaephytes (33.5%) hemicryptophytes (28.1%) and geophytes (3.2%) (Table 2.1). The shrubland communities on Mariepskop, are co-dominated by phanerophytes (specifically nanophanerophytes), chamaephytes, hemicryptophytes and geophytes (Table 5.2.2), similar to that of the Fynbos Biome.

Regarding the specific life forms and genera, both the life forms (chamaephytes, hemicryptophytes and geophytes) and the genera found on Mariepskop such as *Passerina, Cliffortia, Erica, Euryops, Muraltia, Pentameris, Restio* and *Watsonia* (known to be typical Cape-centred plant taxa) are all southern African endemic taxa typical of the Cape Floristic Region (Goldblatt and Manning 2000), and have also been found on Platberg (Brand*et al.* 2008, 2009), on a steep remote hillside (altitude of 1800 m) in the Tendele area in the Royal Natal National Park in the northern KwaZulu-Natal Drakensberg (Carbutt and Edwards 2001), and the Chimanimani Mountains (Phipps and Goodier 1962). The grass-like genus *Restio*, which is a major component of the Cape flora and vegetation, is also found on Mariepskop, Platberg, other inselbergs in the Free State and the broader Drakensberg, namely *Restio schoenoides* (formerly known as *Ischyrolepsis schoenoides*). Mariepskop fynbos is not well matched to the Mesic Highveld Grassland Bioregion in terms of life forms as well as species composition, as has been suggested by Mucina *et al*. (2006) and Rutherford *et al.* (1994; 2006).

6.5. Phytogeography

Mariepskop shares many biotic, edaphic and climatic similarities not only with both the Drakensberg Alpine Centre (DAC) and the Wolkberg Centre (WC) but also with the CFR (Carbutt and Edwards 2001).

6.5.1. Migratory route of taxa found on Mariepskop

Phytogeographically, Mariepskop falls within the Wolkberg Centre of Plant Endemism with many palaeo-endemics, i.e. species with a former wider distribution (Van Wyk and Smith 2001), suggesting phytogeographic links with other mountains to the south and to the north. Floristically and phytogeographically at higher elevations, the Wolkberg Centre and Mariepskop have strong floristic links further north [the Chimanimani Mountains in eastern Zimbabwe as well as Mulanje Mountains in south-eastern Malawi (Chapman 1962)] and south (Northern Drakensberg and the CFR (Matthews *et al.* 1993)) with similar floristic 'islands' with these 'islands' known to also contain Cape floristic elements namely Ericaceae, Proteaceae and Restionaceae (Van der Schijff and Schoonraad 1971, Carbutt and Edwards 2001, Van Wyk and Smith 2001). This could point towards an eastern mountain migration route for fynbos from the Western Cape (Phipps and Goodier 1962, Chapman and White 1970).

6.5.2 Island effects on mountain biodiversity

A high diversity of certain Cape plant families and genera has been commonly observed in the DAC, the Wolkberg Centre as well as the CFR (Goldblatt and Manning 2000, Carbutt and Edwards 2004). An example of such a diverse family present in both centres and CFR is Asteraceae (65 genera and 430 species in the DAC), which was also the largest family present on Mariepskop (7 genera, 12 species, 20% of total flora). Other similarities in terms of families and genera on Mariepskop with the Wolkberg Centre and the DAC include Iridaceae (*Gladiolus*), Amaryllidaceae (*Brunsvigia*, *Clivia* and *Cyrtanthus*), Asphodelaceae (*Aloe* and *Kniphofia*), Poaceae (*Eragrostis*, *Melinis* and *Panicum*), Cyperaceae (*Carex*, *Cyperus* and *Ficinia*) and Crassulaceae (Matthews *et al.* 1993, Van Wyk and Smith 2001, Brand *et al.* 2008). In contrast with the species composition of the Cape flora, both Poaceae and Cyperaceae (which are poorly represented in the Cape flora) were the second and fourth richest families on Platberg (DAC) (Brand *et al.* 2008), inselbergs in Ivory Coast (Porembski *et al.* 1996) and Mariepskop. The environmental and floristic position of Poaceae (in terms of cover) in the Cape flora is filled by Restionaceae, a distinctive feature of fynbos graminoids, (Goldblatt and Manning 2000, Brand *et al.* 2008), which was also present on Mariepskop in places by a single species namely *Restio schoenoides*. Based only on presence, genera in both centres and the CFR as well as Mariepskop and Afromontane Regions further north (Zimbabwe and Malawi) include *Restio, Watsonia, Protea, Cliffortia, Muraltia, Widdringtonia, Passerina* and *Erica* (White 1978). Particular species present on Mariepskop as well as forests and inselbergs (Chimanimani Mountains) in tropical Africa include *Cliffortia nitidula, Myrsine africana* and *Passerina montana* (Phipps and Goodier 1962, Van der Schijff and Schoonraad 1971).

African mountain tops (which act as an island) generally show low species richness in terms of fauna and flora, which can also be said for Mariepskop (Kingdon 1990, Linder 2003). The size of the inselberg in question also plays a major role in the species turnover as seen on small size inselbergs in West African rain forests (only 66 plant species in 29 families), with the numbers showing good correlation with inselberg size (Porembski *et al.* 1996). Species richness on the summit of Mariepskop was also rather low (only 61 species from 30 families) compared to the high species richness on Platberg (670 taxa and 27 endemics) but the surface area was more than ten times larger (3000 ha) compared to the Mariepskop study area (only 160 ha). Although the species richness on Mariepskop is low (mean of 11 per 50 m^2) compared to other similar studies (Platberg had a mean of 28 species per 30 m^2 (Brand *et al.* 2008)), a few species are either endemic or near-endemic to the Wolkberg Group (Matthews *et al.* 1993) of which Mariepskop forms part. Even though the species richness of these fynbos taxa decreases to the east and the north of the Cape; their contribution to floras of the Afromontane Regions is substantial (Cowling 1983, Carbutt and Edwards 2001, Linder 2003). This again could imply that the Drakensberg Range is a migration route for both southern and tropical elements (Van der Schijff and Schoonraad 1971), which plays a vital stepping-stone role in the spread of species through the Afrotemperate region (Galley *et al.* 2007). Therefore, both the Wolkberg Centre and the DAC have been referred to as migratory routes for taxa of diverse regions and biomes (Killick 1963, 1978; Hilliard and Burtt 1987, Carbutt and Edwards 2004, Mucina and Rutherford 2006).

6.6. Floristic affinities associated with Afromontane Regions

Even though the communities at summit of Mariepskop might have affinities with certain biomes in terms of cover contribution, the vegetation in terms of species composition conforms to the Afromontane Phytochorion (within the Grassland Biome specifically) such as the summit and/or upper slopes of the Drakensberg in the Eastern Cape and KwaZulu-Natal as well as the higher parts of Lesotho (Killick 1963, Edwards 1967). Previous literature could have classified Mariepskop as forming part of the Ericaceous Belt (Hedberg 1951) (both alpine grasslands and dwarf shrub communities are found above 1800 m), but as two of the three communities contain Afromontane Forest elements (tree species such as *Widdringtonia nodiflora*) and the locality for this belt is much further north in the true Afroalpine region of tropical Africa; Mariepskop cannot conform to the Ericaceous Belt (Killick 1963). However, according to more recent classifications Mariepskop could have possibly form part of of both the lower montane and upper montane belt (Körner *et al*. 2011).

Community 1 (grassland) shows similarity to the Alpine Belt (dominated by low, woody species (*Erica* and *Helichrysum*) and interspersed grassland communities (dominated by the genera *Merxmuellera*, *Festuca* and *Pentameris*) (Killick 1978) while community 2 (shrubland) resembles the upper montane belt of the Drakensberg (characterized by *Passerina–Erica–Widdringtonia* shrubland) (Körner *et al*. 2011). Lastly, Community 3 (forest) shows similarity to the Montane Belt found on the Little Berg (deeply incised river valleys and a climax community dominated by *Podocarpus latifolius* forest).

CHAPTER 7
Conclusion

Taking into account all the environmental information as well as the lack of an up-to-date phytosociological study for the potentially interesting and biogeographically important plant species and vegetation on Mariepskop, a need exists for a detailed phytosociological and phytogeographical study to define the species composition and to elucidate the geographical affinities of the fynbos on Mariepskop. The aims of the study were to:

- describe and map the plant communities above 1800 m at Mariepskop;
- analyse the life forms in each community using Raunkiaer's (1934) classification as modified by Mueller-Dombois and Ellenberg (1974) in order to assess similarities with the Cape fynbos vegetation structure;
- investigate the geographic distribution of the identified plant species and their association with the flora of the CFR, as the typical genera which characterize summer rainfall montane environments structurally resemble the Cape fynbos structure found in the CFR (which include genera such as *Leucospermum* (Proteaceae), *Restio* (Restionaceae) and *Erica* (Ericaceae) (Linder 2003).

After conducting the phytosociological study on the summit of Mariepskop, three plant communities namely a grassland community, shrubland community and a forest community were identified and mapped.

The life form spectra for the three communities combined did not show similarity with Grassland Biome spectra but did however show vague similarities to the Fynbos Biome spectrum at Swartboskloof, where the ratio of contribution of the life forms was similar compared to the present study area. It is very important to note that in recent times, biomes have been distinguished based on positive feedbacks of growth forms on the relevant disturbance regime and not necessarily climate and soil alone. Thus, although the life form spectra of the three identified communities might vaguely resemble different biomes, another factor other than climate could have been responsible, such as the absence of fire. The Mariepskop vegetation complex seems an excellent example of three distinct biomes, fynbos, forest, grassland, occurring in the same landscape (sharing the same macroclimate). Fire intervals appear to be strongly controlled by rockiness and you could argue that the topographic effects on fire return intervals are responsible for the three biomes. However, more research is required regarding fire and the effect the absence and presence thereof has on specifically the summit of Mariepskop.

Out of a total of 61 species found at the summit of Mariepskop, 23 species had a CFR-Mariepskop distribution, 17 species had a Drakensberg-Mariepskop distribution and 21 species were strictly endemic or near-endemics on and around Mariepskop. Specifically for the Cape elements, there are strong ties between the Northern Drakensberg flora found on Mariepskop (forms part of the Wolkberg Centre), the CFR, the Chimanimani Mountains in eastern Zimbabwe as well as Mulanje Mountains in south-eastern Malawi.

Prior to this in-depth phytosociological classification and phytogeographical study, the only in-depth floristic study documenting the plant species at Mariepskop was by Van der Schijff and Schoonraad (1971). Other phytosociological studies, where Mariepskop was included were studies done on grassland-associated vegetation of the Black Reef Quartzite formation (Matthews *et al.* 1991), high altitude hygrophilous vegetation regions (Matthews *et al.* 1992), the complete phytosociological study on the north-eastern mountain sourveld (Matthews 1991) and forested fragments below 1800 m (Lötter and Beck 2004). A complete and up-to-date phytosociological and phytogeographical was needed as a pilot study for better understanding of the plant communities as well as a platform for possible future ecological studies such as adding to the discussion of directionality of the ‘Cape taxa’ migration (either from or to the Cape) as well as the ecology of mountain summits scattered along southern Africa.

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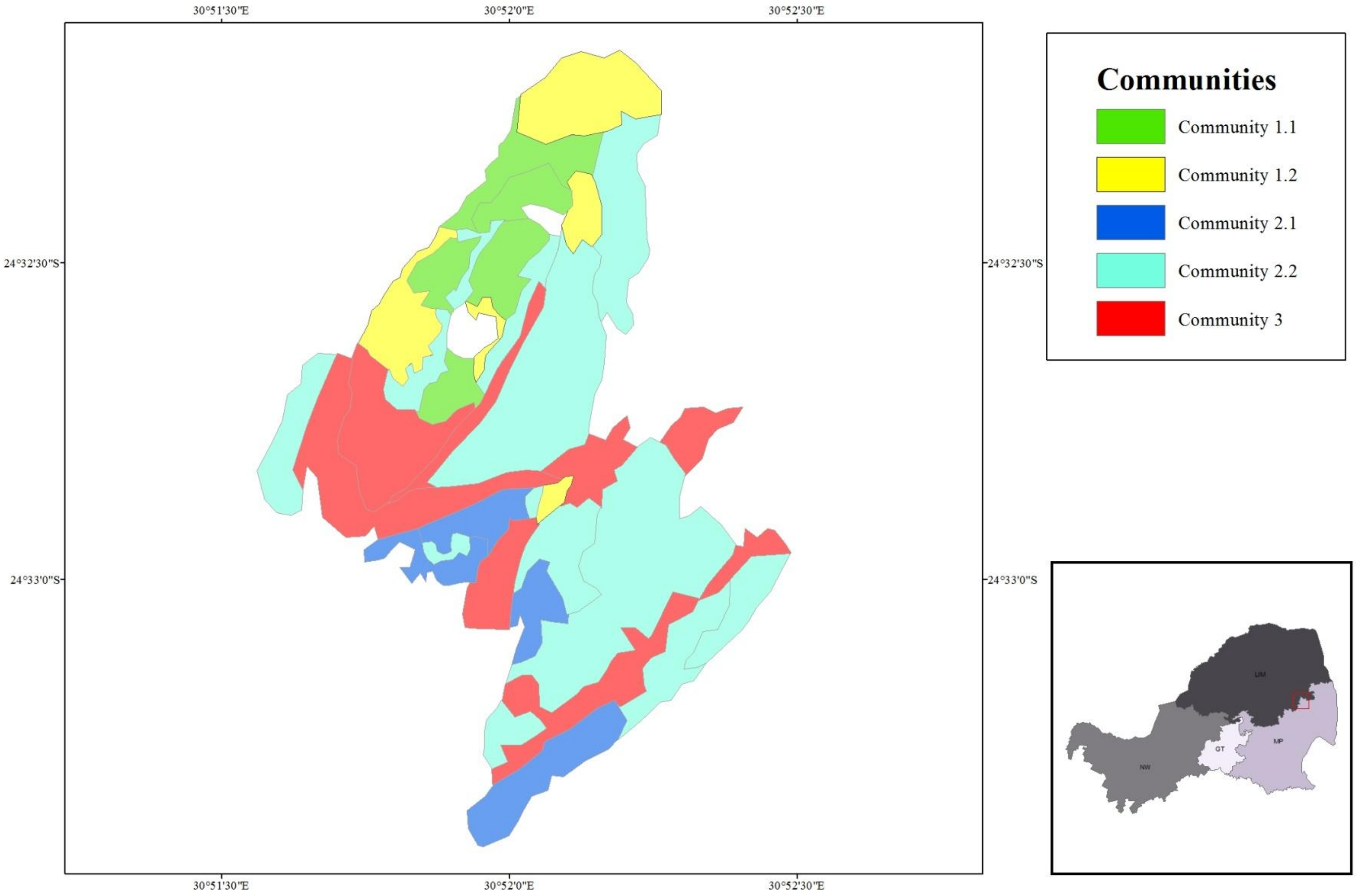
Appendix A. Phytosociological table.

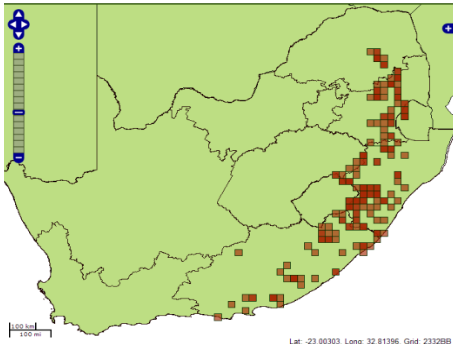
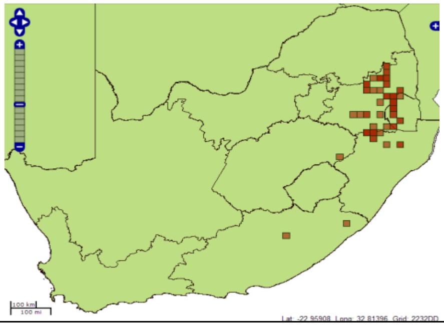
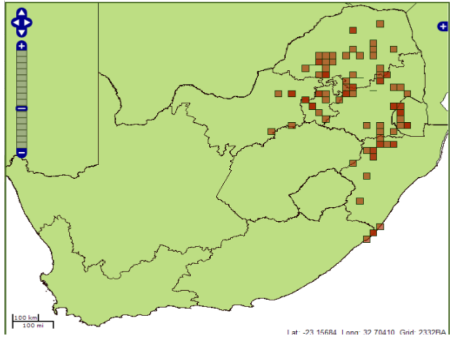
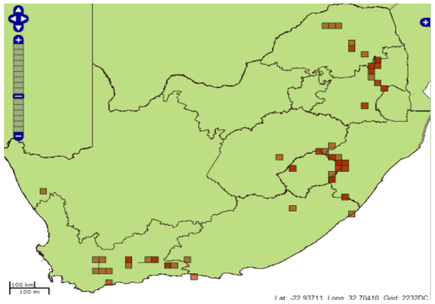
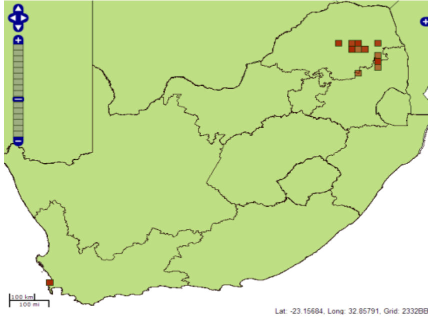
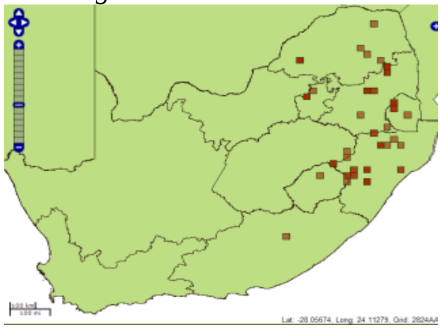
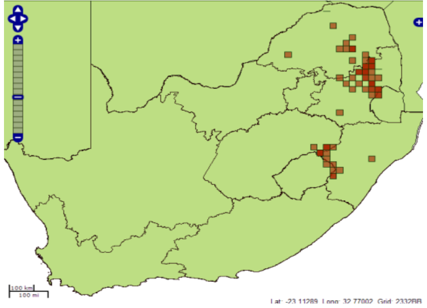
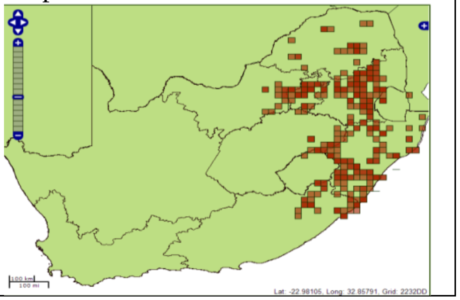
Relevé number	Life form	38	19	45	50	49	17	21	51	16	36	20	41	37	40	44	61	30	18	27	7	29	57	58	59	53	60	15	14	25	10	4	2	8	1	5	56	54	48	55	12	3	11	47	13	9	46	35	33	32	39	52	34	43	6	26	31	28	23	42	24	22
Species Group A																																																														
Panicum ecklonii	H	4	4	4	4	3	3	4	4	1	1	+			1	+		2		2	2	1				+																		2																		
Watsonia sp.	G	+	+	+	+	2	+		2			+	+		2		2		+			1			+					2														+																		
Miscanthus junceus	H			+		2		+				4	2																																																	
Species Group B																																																														
Restio schoenoides	H													1	2	2	3	2																																												
Protea rubripilosa	P										+			1		+																																														
Brunsvigia natalensis	G				+					+		+			+																																															
Euryops pedunculatus	Ch	2									2			+		2																																														
Monocymbium ceresiiforme	H									3			+																																																	
Tetraselago wilmsii	Ch									+																				+																												+				
Verbena bonariense	T									+	+																																																			
Species Group C																																																														
Erica woodii	Ch																						2	2	2	2	2					2	+			1	2	1		1					1																	
Species Group D																																																														
Ficinia gracilis	H																+							+		1																																				
Species Group E																																																														
Myrsine africana	NP																															r	+			+	+	+	+																							
Mohria rigida	H																														+			+																												
Muraltia flanaganii	NP																																+		+																											
Olinia rochetiana	P																														+												+																			
Species Group F																																																														
Eragrostis curvula	H		+	1	+	1	1		1						2	3	+	1	4			1	2	2	1	+	1	+	4	2	2	+		1		+	1	1	1	1	1	+	1	+	2	1	+								+							
Cliffortia linearifolia	Ch										+			+		+	1		+			+		2			2	2		2			2									+																				
Syncolostemon eriocephalus	NP			1							1			2		+				+										+									+					+			2															
Cyperus fastigiatus	H	+										+		+		+												+			+								2			+	+			+	+															
Macowania tenuifolia	Ch			+												2																												1			2															
Widdringtonia nodiflora	P			+												1																				+		2																								
Helichrysum obductum	Ch	+						+			+	+	+		+													1	+	+																																
Carex zuluensis	H			+			2												+	2		1						+												1					+																	
Species Group G																																																														
Hypericum revolutum	NP									+																																						1	2				3							+		
Psoralea arborea	NP																																																	1			+									

Relevé number	Life form	38	19	45	50	49	17	21	51	16	36	20	41	37	40	44	61	30	18	27	7	29	57	58	59	53	60	15	14	25	10	4	2	8	1	5	56	54	48	55	12	3	11	47	13	9	46	35	33	32	39	52	34	43	6	26	31	28	23	42	24	22
Species Group H																																																														
Robsondendron eucleiforme	P																														+		1		+	1					+		+					2		1	1		+	1		1	1	1	+	+		+
Cyrtanthus huttonii	G																									+							+		+	+				+			+					1		1	+		1	+	+	1		+	2		2	+
Podocarpus latifolius	P																																			+	1	1						+				+	1	1	1	+	+	1	+	1	1	1	2	1	2	
Asparagus rigidus	G																																				+	+	+	+					+		1	+	1	2	+	+	1		+	+	+	+	+			+
Crassula sarcocaulis	Ch																														+		+		+																				+			+	+			
Clivia caulescens	G																																					+														+							1			
Anthospermum herbaceum	H																											+						+							+					+			+				+		1							
Species Group I																																																														
Syncolostemon albiflorus	NP																+	+		1	1		2	+	2	+	2	1			2	+		+	+		2		+	+	+				+	+	+								+				+			+
Senecio hederiformis	H										+	1		+		+												+	+	+	+			+				+			+			+	1			+	1		+		1		+			+				+
Passerina montana	NP																1	+			1		2	2	2	2	2				1		+	2	1		1	1	1	1	+		+	+	1	1						+	+	+		+	+		1			
Dryopteris athamantica	H											+		+														+	+	+	+	+	+			1		+		+	+		+					2	2	1	+	+	2	1	1	1		+	2	1	1	+
Plectranthus fruticosus	H																	+				+								+			1		+	+				+			+		+	+		+	+	+	+			+		+	+	+	+	+	+	+
Searsia tumilicola	NP										1					+									+												+	2	+		1			+	+		+					+		+	1		+	+	+	+	2	+
Otiophora cupheoides	Ch															+	+			+		+							+						1				+					+			+				+					1	1	+	1		+	+
Melinis nerviglumis	H						+			1									+	+								+																		1											+		+			
Species Group J																																																														
Cliffortia serpyllifolia	NP	+				+					+		1					1		1		+	2	2	2	2	2	1		1	1	+		2	2	1		1	2	1	2	4	2	2	1	+	1	2	1			+	2		1		+			+		1
Helichrysum mariepscopicum	Ch			+	+			+													+		2	+	2	1	2		+		1	2	1	1						+			+	+	+											+						+
Eumorphia davyi	NP			+										+		+		+				+				+						1	1			+	1	+	2	+					+	+	+		+		+			+			+					
Helichrysum lepidissimum	Ch				+	1			+					+		1	+	+		+	+	+								+	+	+	+	+	2	+	+	+	+					+	+	+	1					+		+	+	+	+	+	+	+	+	+
Senecio junodii	Ch			+				+						1		+	+			1		1				+							+	+	+		+		+																+	+		+	+			+
Helichrysum polycladum	Ch		+	+		+		1								+	+												+								1		+	1				+			2									+	+	+				+
Aloe arborescens	Ch		+	+												+		+		+		+							+				1		1	2	1	+	1	2			+	+	+	2	+	+		+	+	+		+	+	1	1	1	1	1	+	2
Species Group K																																																														
Hebenstretia dura	H																																												+										+							
Stoebe vulgaris	Ch															+																												+											2							
Craterostigma wilmsii	H																				2																																									1
Veronia wollastonii	H																																													+		+								+						
Kniphofia linearifolia	G												1																																+																	
Polygala virgata	Ch																																									+						+														
Helichrysum sp.	Ch							+																																																						
Helichrysum acutatum	Ch															+																																														
Wahlenbergia undulata	H																		+																																											
Crassula sp.	Ch																				1																																									
Hesperantha schlectheri	G																				+																																									
Stachys aethiopica	H																															+																														
Lobelia flaccida	T																															+																														
Silene burchelli	H																																																		+											
Cussonia spicata	P																																																							+						

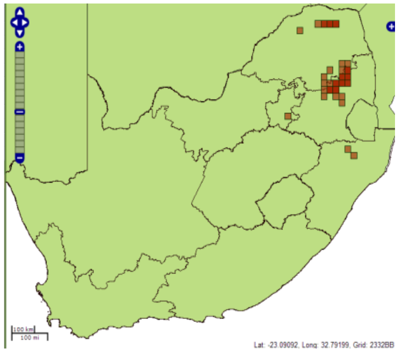
APPENDIX B. Vegetation map of the summit of Mariepskop



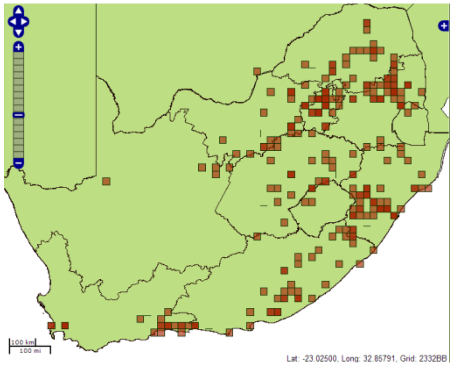
APPENDIX C. Distribution maps of identified species on the summit of Mariepskop.

Panicum ecklonii Nees  	*Watsonia* cf. *pulchra* N.E.Br. ex Goldblatt  	*Miscanthus junceus* (Stapf) Pilg.  	*Restio schoenoides* (Kunth) H.P.Linder. 
Protea rubripilosa Beard  	*Brunsvigia natalensis* Baker  	*Euryops pedunculatus* N.E.Br.  	*Monocymbium ceresiiforme* (Nees) Stapf 

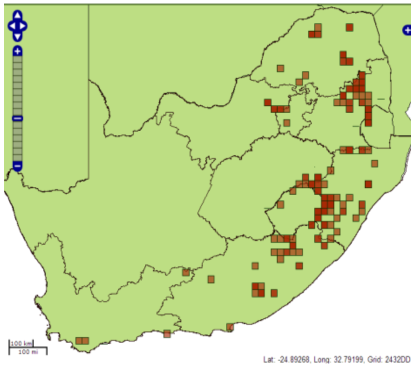
Tetraselago wilmsii (Rolfe) Hilliard & B.L.Burtt



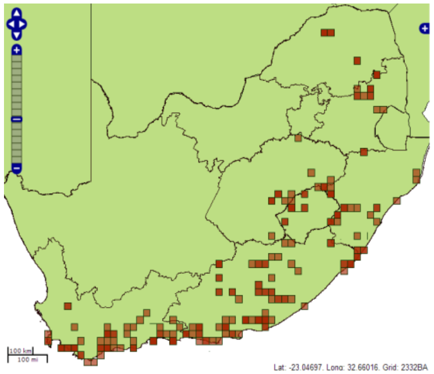
Verbena bonariense L.



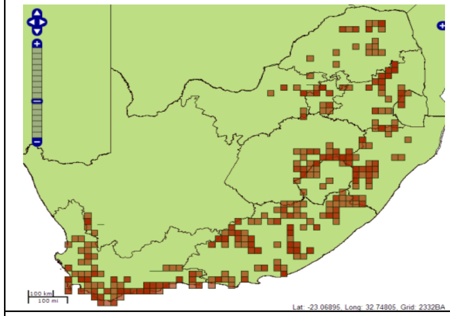
Erica woodii Bolus var. woodii



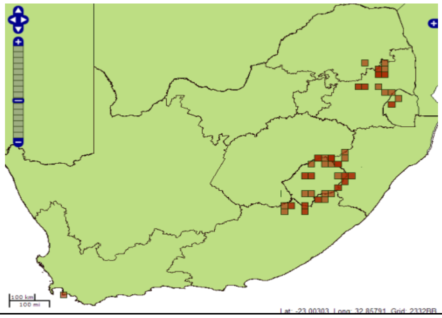
Ficinia gracilis Schrad.



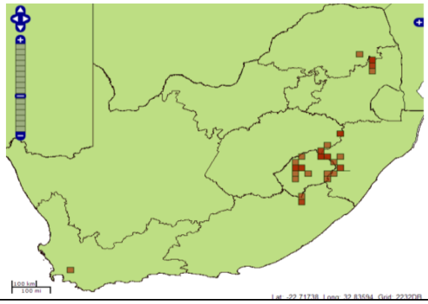
Myrsine africana L.



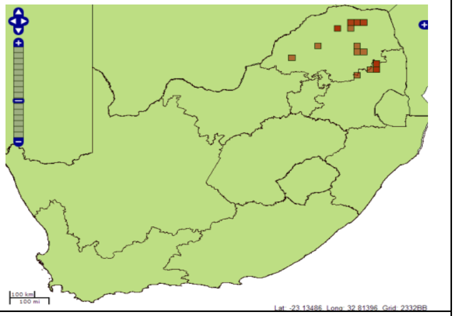
Mohria rigida J.P.Roux



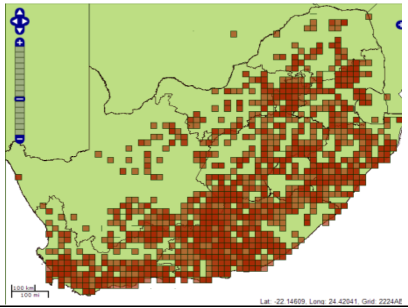
Muraltia flanaganii Bolus



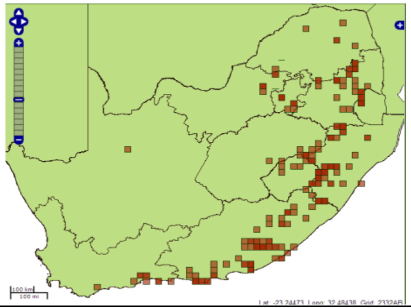
Olinia rochetiana Juss.



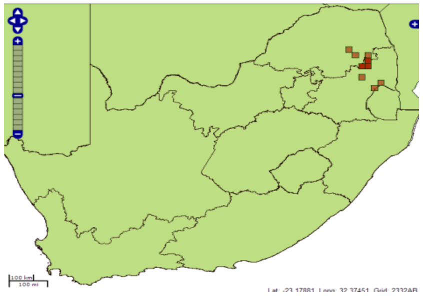
Eragrostis curvula (Schrad.) Nees



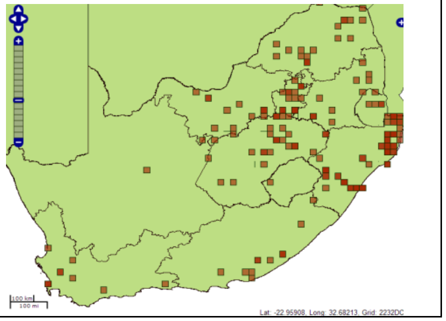
Cliffortia linearifolia Eckl. & Zeyh.

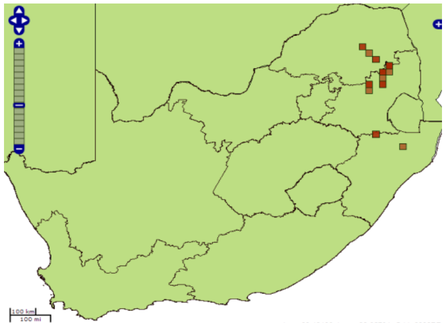
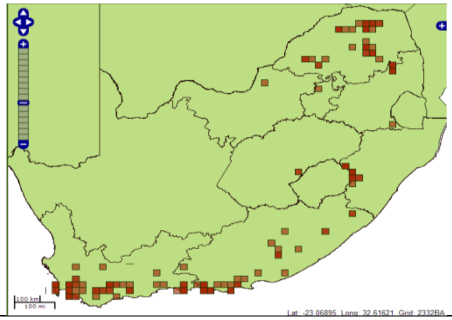
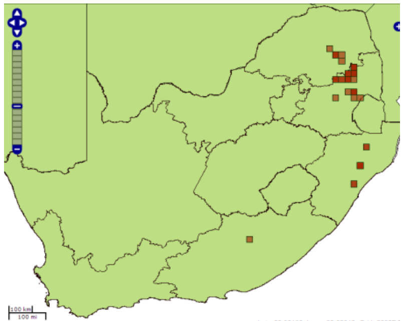
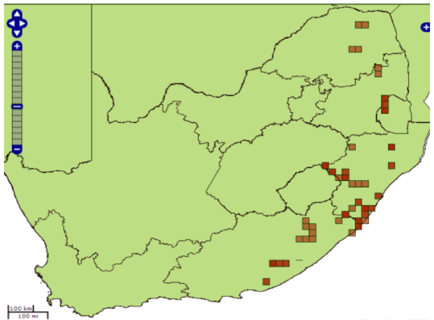
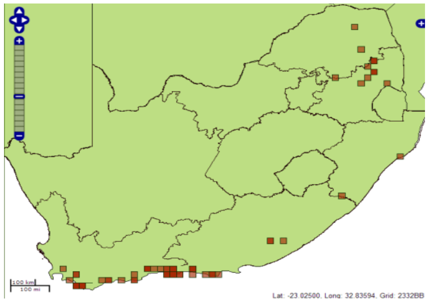
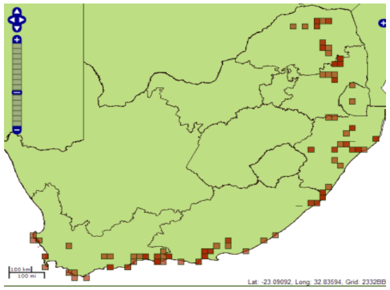
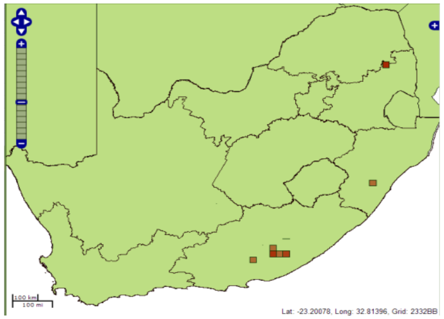


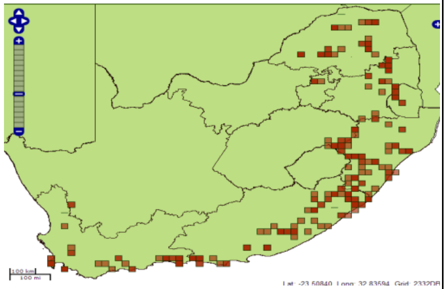
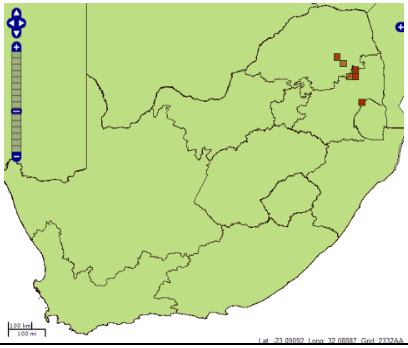
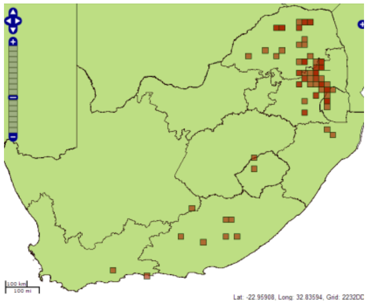
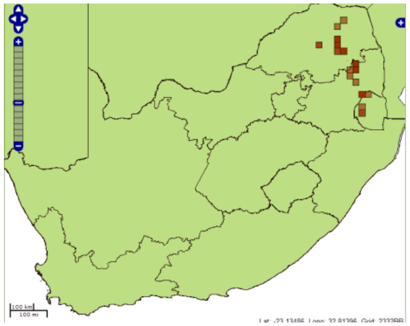
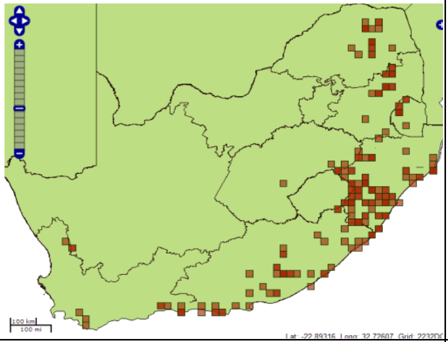
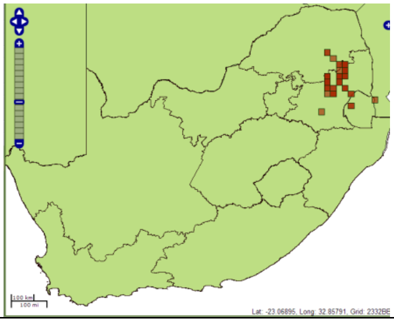
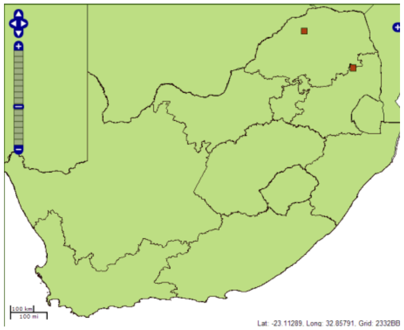
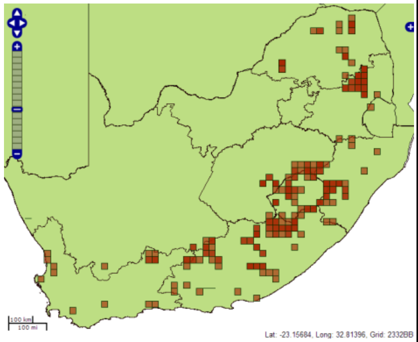
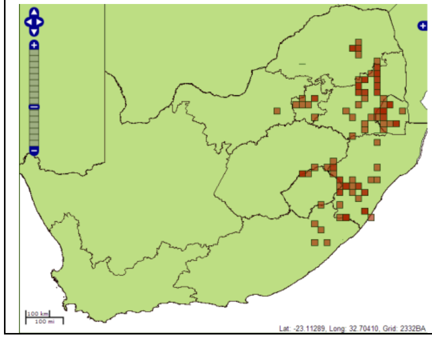
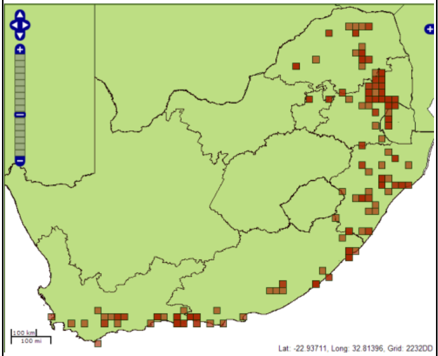
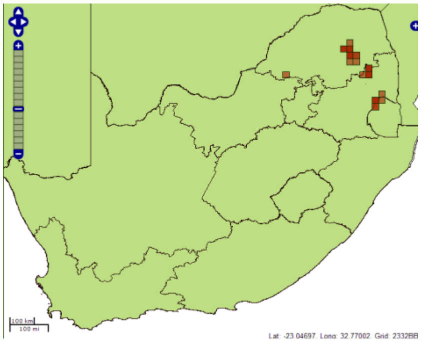
Syncolostemon eriocephalus I.Verd.



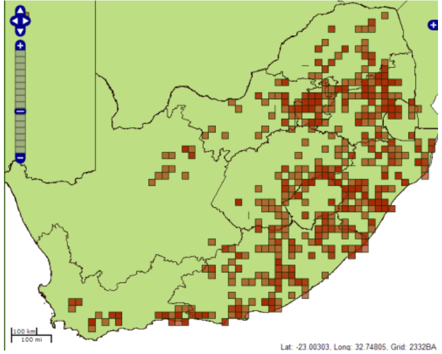
Cyperus fastigiatus Rottb.



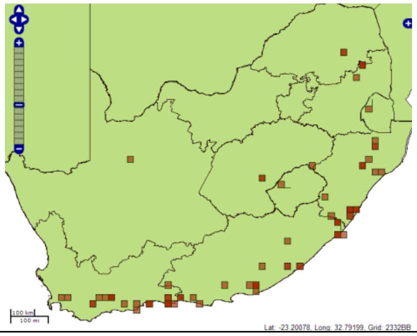
Macowania tenuifolia M.D.Hend.  	*Widdringtonia nodiflora* (L.) Powrie  	*Helichrysum obductum* Bolus  	*Carex zuluensis* C.B.Clarke 
Hypericum revolutum Vahl subsp. *revolutum* ***NO DATA AVAILABLE ON SIBIS***	*Psoralea arborea* Sims  	*Robsonodendron eucleiforme* (Eckl. & Zeyh.) R.H.Archer  	*Cyrtanthus huttonii* Baker 

Podocarpus latifolius (Thunb.) R.Br. ex Mirb 	*Asparagus rigidus* Jessop 	*Crassula sarcocaulis* Eckl. & Zeyh. subsp. *sarcocaulis* 	*Clivia caulescens* R.A.Dyer 
Anthospermum herbaceum L.f. 	*Syncolostemon albiflorus* (N.E.Br.) D.F.Otieno 	*Senecio hederiformis* Cron 	*Passerina montana* Thoday 
Dryopteris athamantica (Kunze) Kuntze 	*Plectranthus fruticosus* L'Hér. 	*Searsia tumilicola* (S.Moore) Moffett var. *tumilicola* ***NO DATA AVAILABLE ON SIBIS***	*Otiophora cupheoides* N.E.Br. 

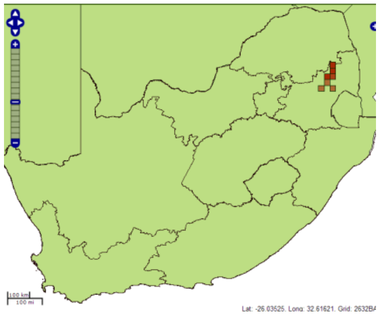
Melinis nerviglumis (Franch) Zizka



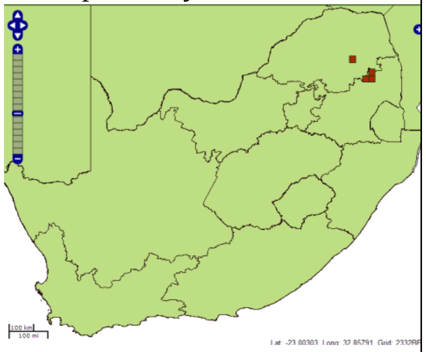
Cliffortia serpyllifolia Cham. & Schltdl.



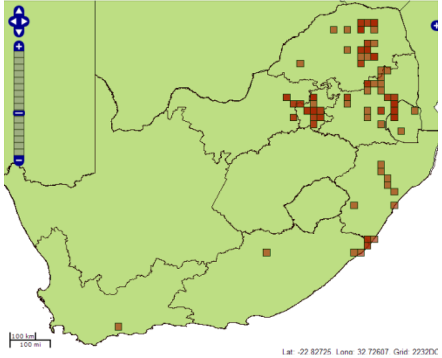
Helichrysum mariepscopicum Hilliard



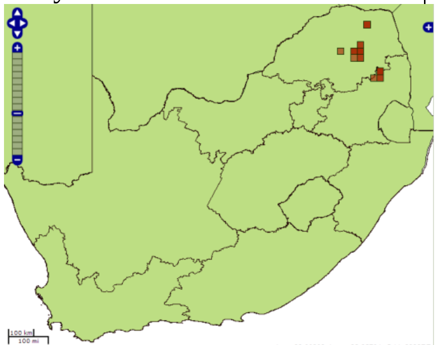
Eumorphia davyi Bolus



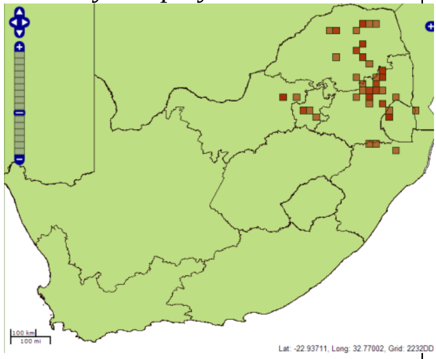
Helichrysum lepidissimum S.Moore



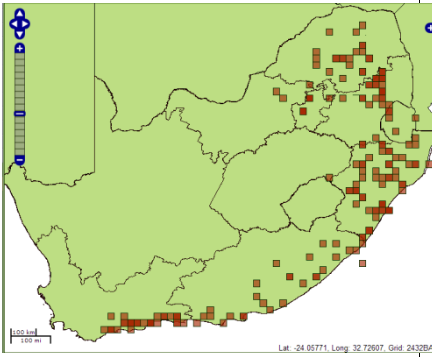
Senecio junodii Hutch. & Burtt Davy



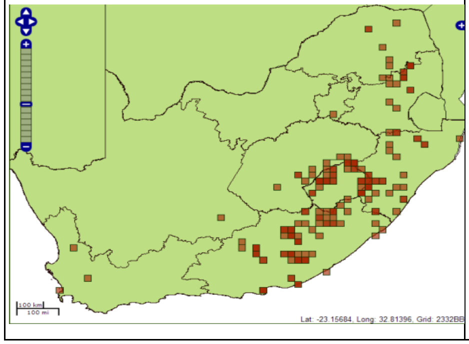
Helichrysum polycladum Klatt



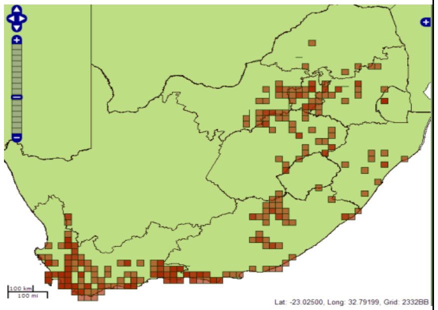
Aloe arborescens Mill.



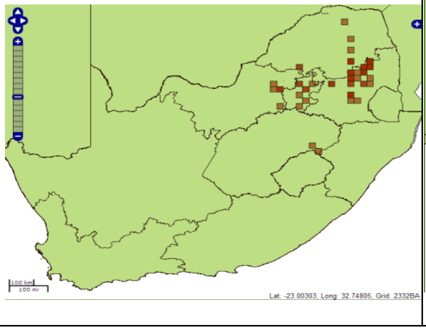
Hebenstretia dura Choisy



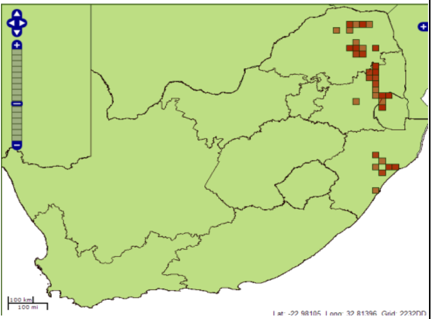
Seriphium plumosum Levyns



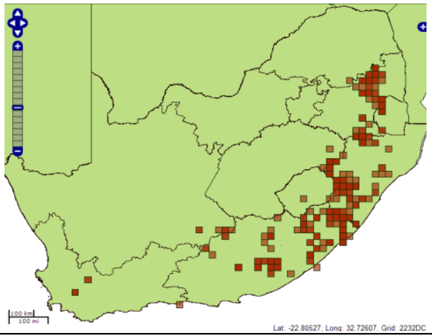
Craterostigma wilmsii Engl. ex Diels



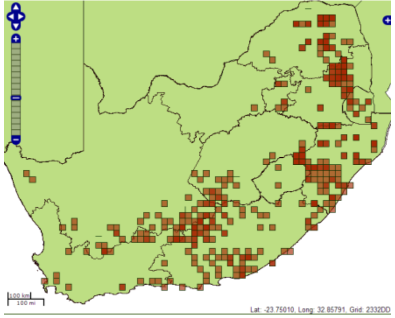
Veronia wollastonii S.Moore



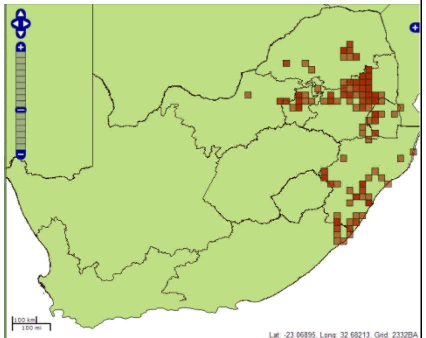
Kniphofia linearifolia Baker



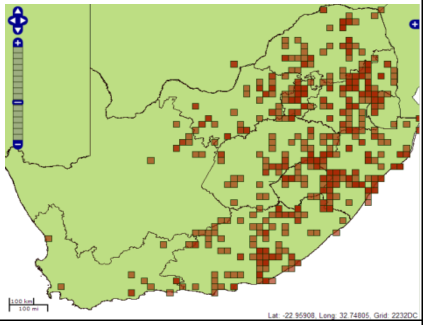
Polygala virgata Thunb. var. *decora* (Sond.) Harv.



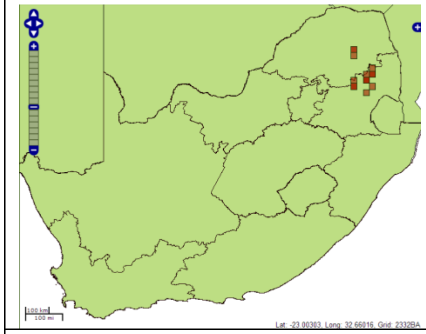
Helichrysum acutatum DC.



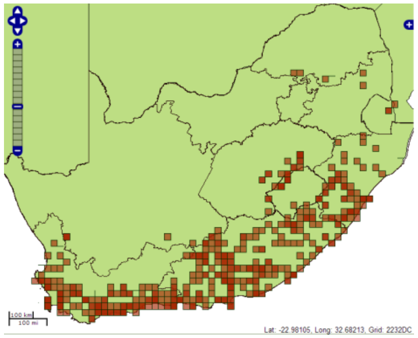
Wahlenbergia undulata (L.f.) A.DC.



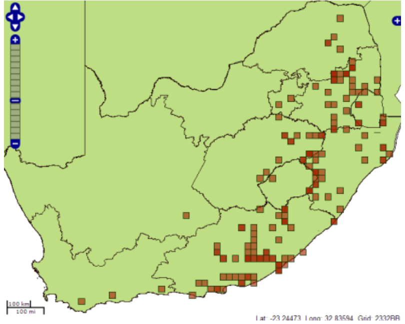
Hesperantha schlectheri (Baker) R.C.Foster



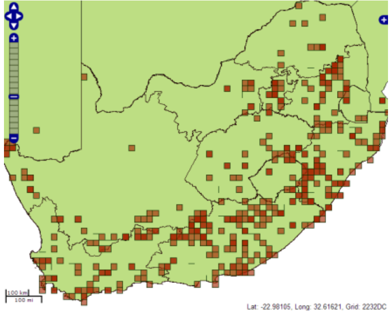
Stachys aethiopica L.



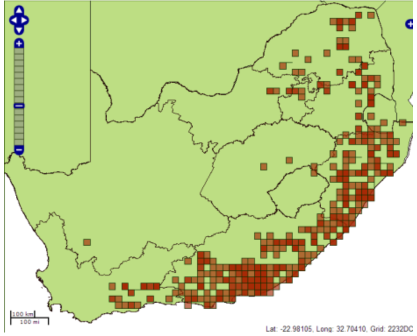
Lobelia flaccida (C.Presl) A.DC. subsp. *flaccida*



Silene burchelli Otth var. *angustifolia* Sond.



Cussonia spicata Thunb.



APPENDIX D. Species list

Panicum ecklonii Nees

Watsonia cf. *pulchra* N.E.Br. ex Goldblatt

Miscanthus junceus (Stapf) Pilg.

Restio schoenoides (Kunth) H.P.Linder

Protea rubripilosa Beard

Brunsvigia natalensis Baker

Euryops pedunculatus N.E.Br.

Monocymbium ceresiiforme (Nees) Stapf.

Tetraselago wilmsii (Rolfe) Hilliard & B.L.Burtt

Verbena bonariense L.

Erica woodii Bolus var. woodii

Ficinia gracilis Schrad.

Myrsine africana L.

Mohria rigida J.P. Roux

Muraltia flanaganii Bolus

Olinia rochetiana Juss.

Eragrostis curvula (Schrad.) Nees.

Cliffortia linearifolia Eckl. & Zeyh.

Syncolostemon eriocephalus I.Verd.

Cyperus fastigiatus Rottb.

Macowania tenuifolia M.D.Hend.

Widdringtonia nodiflora (L.) Powrie

Helichrysum obductum Bolus

Carex zuluensis C.B.Clarke

Hypericum revolutum Vahl subsp. *revolutum*

Psoralea arborea Sims.

Robsonodendron eucleiforme (Eckl. & Zeyh.) R.H.Archer

Cyrtanthus huttonii Baker

Podocarpus latifolius (Thunb.) R.Br. ex. Mirb.

Asparagus rigidus Jessop.

Crassula sarcocaulis Eckl. & Zeyh. subsp. *sarcocaulis*

Clivia caulescens R.A.Dyer

Anthospermum herbaceum L.f.

Syncolostemon albiflorus (N.E.Br.) D.F. Otieno.

Senecio hederiformis Cron.

Passerina montana Thoday

Dryopteris athamantica (Kunze) Kuntze

Plectranthus fruticosus L'Hér.

Searsia tumilicola (S.Moore) Moffett var. *tumilicola*

Otiophora cupheoides N.E.Br.

Melinis nerviglumis (Franch.) Zizka.

Cliffortia serpyllifolia Cham. & Schltdl.

Helichrysum mariepscopicum Hilliard