

CHAPTER 11

FLORISTIC ANALYSES

Abstract

Eighty plant species of the Sekhukhuneland Centre of Plant Endemism were assessed according to the 2000 IUCN categories of threat. Twenty-six of these taxa met the criteria. This analysis together with the level of endemism supports the listing of the region as an important Centre of Plant Endemism that contains a high diversity of plants requiring conservation attention. A first division of the Centre into sub-centres is presented to aid future conservation actions. Endemic plant species are listed, as well as the near-endemic and disjunct taxa that are shared between the Centre and other centres or floristic regions. Major threats to the floristic diversity of Sekhukhuneland are considered and a probable conservation solution is presented. Approximately 2 000 of the plant taxa occurring in the 4 000 km² of the Sekhukhuneland Centre of Plant Endemism are listed. Taxa in the checklist are arranged alphabetically by family, with the genera and species listed alphabetically within the families.

11.1 Introduction

Locating the world's 'hotspots' of biodiversity has long been advocated as one of the primary tactics in conservation (Wilson 1992). South Africa has a rich vascular plant flora and harbours prominent foci of plant diversity and endemism (Cowling & Hilton-Taylor 1994; Van Wyk & Van Wyk 1997), several of which are recognised internationally (Davis *et al.* 1994; Myers *et al.* 2000). What still remains to be done, is to identify smaller, lesser known 'hotspots', some of which are often located within already depleted floristic regions, and to investigate the rare and endemic species they contain. Van Wyk & Van Wyk (1997) proposed Sekhukhuneland as a micro-regional centre of plant endemism, which was subsequently investigated (Siebert 2000).

Prior to the democratisation of South Africa in 1994, floristic surveys of the SCPE were lacking. Large areas north of the Steelpoort River used to be part of the former self-governing homeland of Lebowa (Botha 1983). Although the geology of Sekhukhuneland has been thoroughly studied and mining possibilities in the region investigated for many years (Marlow 1976; Coetzee 1985; Blom 1989; Schürmann *et al.* 1998; Cawthorn 1999), the study of its biota has been largely neglected, despite the observation by Acocks (1953) that the vegetation of the Steelpoort region is unique and should receive further attention. Botanical surveys were conducted mainly on the periphery of this territory and focused on the floristic diversity of the adjacent Wolkberg Centre of Endemism (Ferrar *et al.* 1988; Deall *et al.* 1989; Matthews *et al.* 1993; Stalmans *et al.* 1997). These studies have contributed considerably to the knowledge of the rich plant diversity of the northeastern Drakensberg Escarpment and inspired an interest in the flora of the bordering Sekhukhuneland. This resulted in the first detailed floristic survey (Siebert 1998) and first comprehensive phytosociological study (Siebert *et al.* 2002a) of this botanically poorly known region.

In recent years the local flora of the Sekhukhuneland region has come under threat as a result of the rapid development and disturbance of the region. Surface outcrops of iron-rich chromite and vanadium (associated with titaniferous magnetite) is being removed at a rapid rate by strip or opencast mining, usually without any detailed knowledge of the flora on these sites. It has now become necessary to predict species' survival in the light of habitat loss and fragmentation. All over the world this has become one of the greatest challenges facing conservation biologists, particularly if disturbance could result in extinction (Mace & Hudson 1999; With & King 1999; Joubert & Dreyer 2000).

There are numerous techniques suitable for application to the particular situation in Sekhukhuneland. Some of these are the identification of conservation priorities and include *under-represented or rare ecosystems* and *distributions of rare or threatened plants* as focal areas (Lambeck 1997; Pfab & Witkowski 1997; Hoffmann & Welk 1999; Loomis & Echohawk 1999). However, before any conservation priorities can be identified, it is necessary to determine the Red List status of rare plants using the new IUCN categories and criteria (IUCN 1994).

The Red Data List of southern African plants (Hilton-Taylor 1996) is currently the most comprehensive and widely used list of threatened plants and their status. The criteria used for assessing conservation status have now been replaced by a new system. Consequently the status of all threatened species has to be re-evaluated, a process which is currently in progress (Golding 1999). The new method requires much more comprehensive field knowledge than the previous system, but the final result provides much more information to users such as the steps that should be taken to conserve a species. The new approach for determining the status of threatened plants was formally adopted by the Council of the International Union for Conservation of Nature (IUCN) in 1994. The study of Sekhukhuneland flora provided an ideal opportunity to gather data for these assessments, and in turn the assessments will provide much information for future conservation planning of the region.

Conservation related work in data-deficient countries should be fast tracked to identify threatened taxa (Golding 2001b). It is hoped that the updated list of the SCPE endemic plant taxa, defined boundaries of the SCPE, proposed Red Data List status for selected plant species, and discussions surrounding major threats and conservation strategies, will contribute towards this initiative.

11.2 Plant endemism, diversity, threatened taxa and conservation

11.2.1 Flora

About 2 000 species, but probably more, of vascular plants occur in the SCPE (Siebert 2000). Recently undescribed, endemic plant taxa have been discovered on a regular basis, for example *Plectranthus venteri* (Van Jaarsveld & Hankey 1997), *Gladiolus sekhukhuniensis* (Manning *et al.* 1999) and *Rhoicissus sekhukhuniensis* (Retief *et al.* 2001).

After the Serpentine of Barberton (Balkwill *et al.* 1995) and the Great Dyke of Zimbabwe (Wild 1965), Sekhukhuneland is the third richest in ultramafic-induced endemic plant species in southern Africa (Siebert 1998). The endemic taxa of the SCPE, and those shared with the Wolkberg Centre (near-endemics), are listed in Table 38. There are 57 endemic and approximately 58 near-endemic species/infraspecific taxa. These taxa belong to

36 families of which the Liliaceae (*sensu lato*) and the Euphorbiaceae are the largest. SCPE endemics and near-endemics represent a wide spectrum of growth forms, including trees, shrubs, suffrutices, succulents, forbs, geophytes and annual herbs (Siebert 1998).

The SCPE exhibits a percentage endemism of 5%. As a poorly collected region, its degree of endemism is thus comparable with the other Centres of Endemism in southern Africa. The Transvaal Drakensberg has an estimated endemism of 4% (Matthews *et al.* 1993), the KwaZulu-Natal Southern Drakensberg has an estimated endemism of 5% (Hilliard & Burt 1987), and the Great Dyke of Zimbabwe has an estimated endemism of 6% (Wild 1965). Most of the SCPE endemics appear to be palaeoendemics (e.g. *Rhus batophylla*). In addition, populations of many widespread species growing on ultramafic soils are morphologically slightly different from their counterparts on surrounding substrates, and these ecotypes may represent incipient species (neoendemics).

In southern Africa, centres of plant endemism and diversity are often associated with specific geological substrates (Wild 1963; Wild 1965; Matthews *et al.* 1993; Mustart *et al.* 1994; Van Wyk 1994; Balkwill *et al.* 1995). This is also the case in the SCPE, where the vegetation on ultramafics tends to have a distinct species composition which is rich in local endemics (Siebert 1998). Endemics on ultramafic substrates are of conservation value, mainly because they contain an important genepool that can be applied in the rehabilitation of 'problematic' substrates such as toxic mine dumps (Ellery & Walker 1986; Liston & Balkwill 1995; Howes *et al.* 1998). Furthermore, the SCPE is probably the region with the most extensive areas of surface-exposed chromitite in the world, thus providing unrivalled opportunities to study the possible effects of chrome on plants.

Many species adapted to ultramafic substrates are shared between, and are near-endemic to, the SCPE and mainly the dolomites of the adjacent Wolkberg Centre (Campbell-Young & Balkwill 2001). Most endemics and near-endemics are associated with one or more specific major plant communities (Siebert *et al.* 2002a). In view of the many species shared between the two regions (and endemic to the combined region), one may well ask whether the SCPE should be redefined so as to also include the western, more arid parts of the

Transvaal Supergroup, including the dolomites of the Chuniespoort Group (now treated as Wolkberg Centre).

There are also floristic links between the SCPE and the Waterberg (e.g. *Rhus keetii* and *Euclea linearis*), as well as the arid parts of the Soutpansberg, including the middle Limpopo River valley (e.g. *Sesamothamnus lugardii* and *Decorsea schlechteri*). Disjunct distributions of taxa, such as *Melhania randii*, between the SCPE, Barberton Centre of Endemism and the even more distant Great Dyke in Zimbabwe, are best explained by the mutual presence of ultramafic substrates in these three regions. Subtropical lowveld elements have entered the SCPE via the Olifants River valley (e.g. *Balanites maughamii*, *Diospyros mespiliformis*, *Merremia kentrocaulos*, *Ptaeroxylon obliquum*). The most intriguing disjunctions, however, are the satellite outlier populations in the SCPE of floristic elements otherwise found mainly in the Great Karoo and arid parts of the western Free State and North-West Province (e.g. *Amphiglossa triflora* (= *Pterothrix spinosa*), *Jamesbrittenia atropurpurea*, *Plinthus rehmannii* and *Rhigozum obovatum*). To this one can add disjunct distributions between the SCPE and the arid Griqualand West (e.g. *Gnidia polycephala*, *Nuxia gracilis*, *Phyllanthus parvulus* var. *garipensis*, *Polygala krumanina* and *Stipagrostis hirtigluma* var. *patula*). An ancient link between the SCPE and Pondoland is reflected by *Catha transvaalensis* [to be transferred to *Lydenburgia cassinoides*] (SCPE endemic) and its nearest relative, *C. abbottii* [to be transferred to *Lydenburgia*] (Pondoland endemic). A first record for South Africa was also recorded in that *Nemesia zimbabwensis*, a member of the Schrophulariaceae, occurs in the Afromontane forests on the summit of the Leolo Mountains. This species is usually restricted to damp forests of Mutare, Chibinga, Mt. Inyanga and Melsetter in the eastern highlands of Zimbabwe and Mt. Gorangosa west of Beira in Mozambique.

The flora of the SCPE is mainly of Zambezian extraction, with Afromontane elements, especially at higher altitudes. Afromontane links are to be expected as the region abuts on the northeastern Drakensberg Escarpment with its mainly Afromontane flora (Wolkberg Centre). The change from Afromontane to Zambezian is particularly noticeable as one descends from the high-lying, wetter, more temperate Steenkampsberg to the low-lying, much drier, subtropical Roosenekal-Steelpoort area.

The complete checklist of SCPE plant species is given in Appendix 5. Totals of species by family are given in Table 39. SCPE endemics and SCPE near-endemics, rare and threatened, and other noteworthy taxa are also indicated in Appendix 5. The ultramafic flora of the Great Dyke is seen as impoverished (Wild 1965). Sekhukhuneland can, however, be seen as extremely rich in taxa when compared with other regions in the world (see Chapter 1). On a national level the SCPE compares well with the southern Drakensberg (Bester 1998), both these areas harbouring approximately 2 000 vascular plant species on approximately 4 000 km².

Currently the Flora for the region stands at 172 families, 757 genera and 1957 species/infraspecific taxa. The Angiosperms represent 127 families, 677 genera and 1826 species/infraspecific taxa, the ferns and fern-allies 11 families, 17 genera and 31 species/infraspecific taxa, and the mosses 34 families, 63 genera and 100 species/infraspecific taxa. Most of the present flora (Appendix 5) originated from the surrounding flora and suggests that the ability to evolve resistance to ultramafic soils is a widespread attribute amongst angiosperm families. Approximately 20 species/infraspecific taxa are new to science and are currently being described, several in collaboration with staff of the National Botanical Institute (NBI), Pretoria. Based on PRECIS records, one out of every 15 plant specimens collected during this study was a new record for the region.

The species checklist is part of a specimen-label database that can assist conservationists and taxonomists alike during systematic, floristic and biogeographic studies in this region, and a high quality inventory will assist researchers in meeting their objectives when investigating and developing self-sustainable protected area strategies (Balmford & Gaston 1999; Soberon *et al.* 2000; Ter Steege 2000). The data presented here are linked to georeferenced herbarium specimens which can in future be integrated into a geographic information system for spatial analysis (Rhoads & Thompson 1992; Siebert & Willis 2000; Fish & Steyn 2001).

Plant collections were first made in the area at least 75 years ago and some of the earlier collections were by J.P.H. Acocks, W.G. Barnard, L.E.W. Codd, D.S. Hardy, R.O. Moffet, A.O.D. Mogg, N.J. van Warmelo, F. Wilms and R.G.N. Young. In the last decade

important collections were made by E. Retief, S.J. Siebert, F. Venter, A.E. van Wyk and P.J.D. Winter. A relatively high number of Bryophyte species collected in grid 2430 C is a result of a collecting trip to Sekhukhuneland by R.E. Magill in 1977 (Van Rooy 2000). Since 1997 extensive botanical work was conducted in the region, which include the discovery of many undescribed plant taxa.

11.2.1.1 Eleven largest families

- Only families with more than 15 genera and 30 species/infraspecific taxa were considered.
- Position determined by prioritising high numbers of genera in a family; the formula: $(n^1 \times 2) + n^2 = y$; the higher y , the more favourable the position, with n^1 = number of genera and n^2 = number of species/infraspecific taxa.

(1) POACEAE (70 genera/161 species)

The *Grass family* is the largest family in Sekhukhuneland, which is not surprising, for the dominant vegetation types of the region are bushveld and grassland. The family is well collected in the region and species are well represented at PRE.

(2) ASTERACEAE (59 genera/192 species)

Most habitats in Sekhukhuneland are characterised by the *Daisy family*, especially in the grasslands on rocky hillsides. Many taxa are shared with the adjacent Wolkberg- and Barberton Centres of Endemism and some are considered to be near-endemic to the SCPE (endemic to combined region).

(3) FABACEAE s.l. (46 genera/179 species)

Legumes are conspicuous in Sekhukhuneland and are characteristic of most vegetation types of the region. All three subfamilies of the *Pea family* are important: Caesalpinoideae 7 genera and 15 species; Mimosoideae 4 genera and 31 species; Papilionoideae 35 genera and 133 species.

(4) LILIACEAE s.l. (27 genera/111 species)

The *Lily family*, defined here in a broad sense, is very well represented in the region, as

it is elsewhere in southern Africa. There were surprisingly few undescribed species from Sekhukhuneland. Important subfamilies are: Asparagoideae 1 genus and 19 species; Asphodeloideae 4 genera and 31 species; Hyacinthoideae 11 genera and 35 species.

(5) ASCLEPIADACEAE (31 genera/67 species)

Individuals of the *Milkweed* family are prominent in most communities of the region. The family is, however, not well collected throughout the SCPE.

(6) LAMIACEAE (21 genera/66 species)

Mainly herbaceous plants of the *Mint* family are common throughout Sekhukhuneland. Taxa are abundant especially on rocky hillsides, ridges and outcrops. Although still poorly collected in the region, it is the fifth largest family in Sekhukhuneland.

(7) ACANTHACEAE (21 genera/60 species)

The *Acanthus* family is prominent in Sekhukhuneland; several species growing as dense stands in specific plant communities. Their large, colourful flowers draw attention in summer and autumn, and hence the family is well collected.

(8) SCHROPHULARIACEAE (25 genera/45 species)

Another family that is poorly collected in the region is the *Snapdragon* family. However, taxa of the family are conspicuous in all the plant communities of the region.

(9) EUPHORBIACEAE (17 genera/59 species)

Several succulents endemic/near-endemic to the region are represented in the *Euphorbia* family. These endemics grow in communities unique to the SCPE. Many non-succulents also occur.

(10) CYPERACEAE (18 genera/48 species)

The *Sedge* family is dominant in especially the wetland vegetation of the region, but also in the high rainfall grassland areas of the Roossenekal and Leolo Subcentres. The

group has been extensively collected.

(11) RUBIACEAE (22 genera/41 species)

Representatives of the *Coffee* family are noticeable in many of the more humid habitats, and also prefer the rocky outcrops and ridges of the region.

11.2.2 Subcentres of endemism

Three main subcentres were identified for the SCPE (Figure 32), based on the distribution of endemic/near-endemic and threatened plant taxa recorded for each of these areas (Siebert 1998) (Table 38):

- a) Roossenekal Subcentre (Roossenekal-Dwars River area). This is the most southern plant diversity ‘hotspot’ and is characterised by undulating norite hills. This 1 000 km² area is a unique ecotone between the Highveld and Lowveld of South Africa. A total of 67 (31/36) SCPE endemics/near-endemics and nine taxa recommended for Red Data List status occur in this subcentre (Table 38; 40). Six taxa are exclusively endemic to this subcentre.
- b) Leolo Mountain Subcentre. The subcentre is merely a geological extension of the former, but is isolated by broad, dry valleys. The Leolo Mountains harbour relict patches of Afromontane Forest and there are rare wetland systems on the summit. There are 39 (22/17) SCPE endemics/near-endemics and eight taxa worthy of Red Data List status in this 400 km² subcentre (Table 38; 40). Six taxa are endemic to this subcentre only.
- c) Steelpoort Subcentre (Steelpoort-Burgersfort area). It is located in the larger Steelpoort River valley, where it comprises undulating norite, pyroxenite and magnetitite outcrops and hills, and dongas (areas of weakly structured soils). This 2 600 km² is the core region of the SCPE and it is a unique *Kirkia wilmsii*-dominated mountain bushveld. There are 90 (42/48) SCPE endemics/near-endemics and 16 newly assessed Red Data List taxa in this subcentre (Table 38; 40). Twenty taxa are endemic to this centre only and occur nowhere else.

11.2.3 Red Data List

The Red Data List for southern African plants (Hilton-Taylor 1996) lists 37 species that were recorded in the study area. These species are listed in Table 2. Using the old IUCN Red Data List Categories, 1 species is considered Endangered (E), 1 Vulnerable (V), 8 Rare (R), 2 Indeterminate (I), 15 Insufficiently Known (K) and 10 Not Threatened in the SCPE, but in other provinces/countries of southern Africa (N). Of these, 12 can be considered as threatened (E, V, R and I), with the remainder (K and N) under no immediate threat. However, in the light of the development pressure on the SCPE, the plants of the region were once again assessed to try and identify additional threatened species.

Table 40 provides details of 26 taxa that *provisionally* met the criteria for a category of threat in the SABONET Red Data List Project (Golding 1999), along with the justification for assigning the status. Seven species that were listed in Hilton-Taylor (1996) as either indeterminate or insufficiently known have now been assigned a category of threat, and four that were listed as threatened still meet the criteria for a category of threat. In addition to these, 15 species, that have not been listed previously, have now been added to the Red Data List.

Table 41 includes taxa for which no category could be assigned owing to lack of necessary information, i.e. Data Deficient (DD), taxa not yet evaluated (NE), and those which have been evaluated but have not met the criteria for a category of threat. Data Deficient taxa should be treated as threatened unless proven otherwise, although most of these species are found to be not threatened according to the new IUCN categories and criteria. Species listed were assessed because of their endemism and in some cases because of their previous listing by Hilton-Taylor (1996).

11.2.4 Major threats

The SCPE has five major kinds of land ownership, namely communal land, mining property, commercial farmland, residential areas and a protected reserve (Botha 1983). No accurate figures were available on the percentage of the SCPE belonging to each of these land-uses.

A large population of mainly impoverished people inhabit the *communal lands* of the SCPE, a scenario typical for sub-Saharan Africa (Hackel 1999). It lies in rural South Africa, with the local inhabitants being a cultural people, known as the Pedi (Di Friuli 1998). For many of these people the only means of survival is subsistence farming and the sustainable use of natural resources (Crookes *et al.* 2000). Financial income is predominantly acquired from work on the mines and farms in the area. It is estimated that at least 35% of the SCPE is communal land. Overgrazing by domestic livestock has seriously degraded the vegetation in the densely populated areas in and around the Leolo Mountains, which is a threat to certain endemics of the region (Knowles & Witkowski 2000).

Approximately 15% of the SCPE belongs to *mining companies*. Mining property in the SCPE produces 75% of the world's platinum (Cowley 1998) and 35% of the world's chromium (Ringdahl & Oosterhuis 1998), all of which comes from the Bushveld Complex, more precisely the Critical Zone of the Rustenburg Layered Suite (Schürmann *et al.* 1998). Expansion of mining activities in these regions, including Sekhukhuneland, depends upon demand and future prices for these metals (Cawthorn 1999). This means that further mining pressure on the Sekhukhuneland Centre could arise if markets are favourable for the platinum group metals and chromium, which is being mined at present. Recently, dimension stone mining (norite) in the region has sparked an outcry from local interest groups in the region.

Commercial farming in the region is a small-scale venture, with cattle ranging and citrus production the major farming activities. These activities are restricted to about 30% of the land area of the SCPE. Owing to the ruggedness of the terrain, the mountainous parts of the SCPE are still fairly intact, with many private landowners keen to promote game farming and/or ecotourism because of the scenic beauty of the region (Joubert & Dreyer 2000).

Residential areas (towns and informal settlements) occupy some 15% of the SCPE. These areas are growing rapidly. Human population density in the 25 major hot spots of the world is 73 people/km², 71% more than in the world as a whole (Cincotta *et al.* 2000). Although the SCPE does not fall into one of these major regions, its current population density of approximately 40 people/km² (163 477 people on 4 000 km²), is an example of a

southern African plant diversity ‘hotspot’ that will increasingly come under pressure from human population impact.

Despite the region’s scenic landscapes, Potlake Nature Reserve is the only officially *protected area* in the SCPE. Together with the Pedi-cattle Breeding Station, Stellenbosch, less than one percent of the SCPE is protected. Potlake Nature Reserve is rather small and covers 2 800 ha of bushveld and mountain in the northern part of the SCPE, between the Olifants River and the Burgersfort-Pietersburg road. This reserve probably faces loss of plant species due to its small size and dense human population on its boundaries (Harcourt *et al.* 2001). Although prolonged settlement in the past has left its mark on parts of the reserve, the mountain range and its foothills harbour a wide variety of plant species typical to the Centre.

While conservationists are fighting to conserve government land in South Africa, communal land is continually being lost to commercial and residential development (Shackleton 1993; Knight 1999). This is due to a poor understanding of the complexity and diversity of rural livelihood systems, and because the products from communal lands are usually not measured in monetary terms. Settlements and mine dumps today cover large areas of the SCPE that used to be communal grazing land. As the mining industry expands and the infrastructure of the region improves, more and more people will move into the area, putting even more pressure on the already dwindling natural resources.

Rapid development in the SCPE is a threat not only to the common species that are used by the locals, but also to the endemics that are dependent on specific habitats. This is best illustrated by the fact that two of us (SJS & AVW) recently discovered new species of *Stylochaeton*, *Tragia* and *Tulbaghia* within densely populated residential areas.

11.2.5 Threatened status

A short analysis of the conservation status of each of the major vegetation types are given below (only those species that were recorded during the survey are included in the statistics):

- Among the 17 plant communities of the Grassland and Wetland Vegetation, 45 plant species/infraspecific taxa were identified as of conservation significance (Table 4). Sixteen are SCPE endemics and 19 SCPE near-endemics. Of these 17 were listed in the southern African Red Data List for plants. Nineteen of these taxa are restricted to this vegetation type in the SCPE. Norite mining and afforestation threaten these communities.
- Among the 17 plant communities of the Rock Outcrop Vegetation, 36 plant species/infraspecific taxa were identified as of conservation significance (Table 9). Sixteen are SCPE endemics and 18 SCPE near-endemics. Of these eight were listed in the southern African Red Data List for plants. Fifteen of these taxa are restricted to this vegetation type in the SCPE. Strip mining of magnetite and vanadium is a major threat.
- Among the 20 plant communities of the Open Mountain Bushveld, 48 plant species/infraspecific taxa were identified as of conservation significance (Table 15). Twenty-six are SCPE endemics and 21 SCPE near-endemics. Of these 12 were listed in the southern African Red Data List for plants. Five of these taxa are restricted to this vegetation type in the SCPE. Slimes dams and dumping sites pose a major threat.
- Among the 20 plant communities of the Closed Mountain Bushveld, 44 plant species/infraspecific taxa were identified as of conservation significance (Table 20). Twenty-two are SCPE endemics, 17 SCPE near-endemics and four were unique species. Of these six were listed in the southern African Red Data List for plants. Fourteen of these taxa are restricted to this vegetation type in the SCPE. Wood harvesting is responsible for the loss of large areas.
- Among the 8 plant communities of the Arid Northern Bushveld, 13 plant species/infraspecific taxa were identified as of conservation significance (Table 25). Four are SCPE endemics and 6 SCPE near-endemics. An additional six are listed in the southern African Red Data List for plants. Five of these taxa are restricted to this vegetation type in the SCPE. Overgrazing and chromium/platinum mining poses a threat.

For all 82 syntaxa that occur the SCPE region, 125 plant species/infraspecific taxa were identified as of conservation significance (Table 38). Fifty-eight are SCPE endemics and 67 SCPE near-endemics, of which 20 are Red Data List taxa according to Hilton-Taylor (1996). An additional 17 are listed in the southern African Red Data List for plants.

Obviously the 58 SCPE endemics are restricted to the plant communities of the SCPE. This numbers compare well with serpentineferous sites elsewhere in the world, namely 18 rare plants and endemics in central Queensland, Australia (Batianoff *et al.* 1995), 20 endemics on the Great Dyke, Zimbabwe (Wild 1965) and 22 endemics in southern Mpumalanga, South Africa (Balkwill *et al.* 1995).

The priority vegetation types of the Grassland and Wetland Vegetation are associations 2, 3, 4 and 5, of which sub-association 3.1, the *Brachiario serratae–Melhanietum randii helichrysetosum rugulosii*, a rocky grassland on the scarps and crests of norite hills, is probably the most important and threatened (Chapter 5). It should also be noted that the wetlands are sensitive systems that are easily disturbed and should be protected (Doust & Doust 1995; Van Wyk *et al.* 2000). Important wetlands to conserve are the seepage areas, namely the *Limosello maioris–Ranunculetum meyeri* and the *Fuireno pubescentis–Schoenietum nigricantis bulbostylietosum hispidulae*.

Certain plant communities, namely associations 2 and 6-10 (Chapter 6), are of conservation priority in the Rocky Outcrop Vegetation. These communities have large numbers of threatened taxa, which occur on specific chemical substrates that are not continuous, but interspersed as isolated islands within other major vegetation types. A good example is the *Commiphoro marlothii–Crotonetum gratissimi* with four taxa restricted to it.

Important communities of conservation value in the Open Mountain Bushveld are in associations 4, 5 and 7 (more specifically sub-associations 4.2, 4.3, 5.2, 7.1 and 7.2) (Chapter 7). Associations 1 and 6 should also be considered for they have high numbers of taxa with conservation value restricted to them. All the associations represent very unique plant communities that are restricted to the SCPE. This vegetation type has proven to contain the highest numbers of rare taxa and is threatened the most by development. The Open Mountain Bushveld is a vegetation type that is endemic to the SCPE. All the other vegetation types of the SCPE are more or less represented along the northeastern Escarpment (Grassland Vegetation Type), Pietersburg Plateau (Arid Northern Bushveld), Western Rustenburg Layered Suite (Closed Mountain Bushveld) and Bushveld Complex (Rock Outcrop Vegetation).

Important communities of conservation value in the Closed Mountain Bushveld are distributed across all the associations (Chapter 8). Important communities are subassociations 2.1, 2.2, 3.3 and most specifically sub-association 4.2, *Hippocrateo longipetiolatae–Euphorbietum tirucalli aristidetosum transvaalensis*. Sub-associations 3.4, 4.1 and 5.2 should also be considered for they are very unique plant communities.

The Arid Northern Bushveld does not harbour any specific communities in need of conservation when compared with the other major vegetation types of the SCPE. Its plant communities should remain conserved in the Potlake Nature Reserve.

The following associations and sub-associations of the SCPE are of conservation value (*the number of taxa of conservation value are in brackets*):

- Open Mountain Bushveld (O):

(30) Association 4 – *Tristachyo leucothricis–Cussonietum transvaalensis*

(25) Sub-association 4.2 – *Tristachyo leucothricis–Cussonietum transvaalensis melinetosum nerviglumis*

(23) Sub-association 4.3 – *Tristachyo leucothricis–Cussonietum transvaalensis argylobietosum wilmsii*

(16) Sub-association 4.4 – *Tristachyo leucothricis–Cussonietum transvaalensis combretetosum zeyheri*

(26) Association 7 – *Loudetio simplicis–Eucleetum linearis*

(23) Sub-association 7.1 – *Loudetio simplicis–Eucleetum linearis diheteropogonetosum amplectentis*

(21) Sub-association 7.2 – *Loudetio simplicis–Eucleetum linearis heteropogonetosum contorti*

(19) Sub-association 7.3 – *Loudetio simplicis–Eucleetum linearis andropogonetosum chinensis*

(24) Association 5 – *Eragrosti lehmannianae–Hippobrometum pauciflori*

(19) Sub-association 5.2 – *Eragrosti lehmannianae–Hippobrometum pauciflori sorgetosum bicoloris*

(21) Association 2 – *Enneapogono scoparii–Acacietum leiorachis*

(18) Sub-association 2.3 – *Enneapogono scoparii–Acacietum leiorachis brachylaenetosum*

ilicifoliae

- (21) Association 6 – *Aristido rhiniochloo–Gnidietum polycephalae*
 (19) Association 3 – *Phyllantho glaucophyllae–Brachylaenetum ilicifoli*
 (17) Sub-association 3.2 – *Phyllantho glaucophyllae–Brachylaenetum ilicifoli brachiarietosum serratae*
 (16) Sub-association 3.1 – *Phyllantho glaucophyllae–Brachylaenetum ilicifoli setarietosum sphacelatae*
 (19) Association 8 – *Petalidio oblongifolii–Raphionacmetum procumbentis*

● Grassland Vegetation (G):

- (23) Association 3 – *Brachiario serratae–Melhanietum randii*
 (18) Sub-association 3.1 – *Brachiario serratae–Melhanietum randii helichrysetosum rugulosii*
 (16) Sub-association 3.3 – *Brachiario serratae–Melhanietum randii gnidietosum capitatae*
 (16) Association 2 – *Zantedeschio pentlandii–Aloetum castaneae*
 (16) Association 5 – *Jamesbrittenio macranthae–Loudetietum simplicis*

● Closed Mountain Bushveld (C):

- (20) Association 1 – *Combreto apiculati–Kirkietum wilmsii*
 (20) Association 2 – *Panico deustii–Dichrostachetum cinereae*
 (20) Association 3 – *Fingerhuthio africanae–Boscietum foetidae*
 (18) Association 4 – *Hippocrateo longipetiolatae–Euphorbietum tirucalli*

From Table 42 it can be seen that of all the plant communities with conservation value, association O 4 is of the highest priority for conservation and association G 2 the lowest. On the sub-association level O 4.2 is of the highest priority and O 4.4 of the lowest. These communities of conservation value are also important on other levels. If endemics species are to be conserved plant communities O 4 to O 6 should be conserved (Table 42). If the focus is on near endemics, plant communities O 4, O 7, C 1 and C 2 must be considered. For Red List taxa G 3, G 3.1 and G 2 are the best options for maximum conservation. If taxa with restricted distributions are to be conserved, G 5, G 3 and C 1 should be seen as priority.

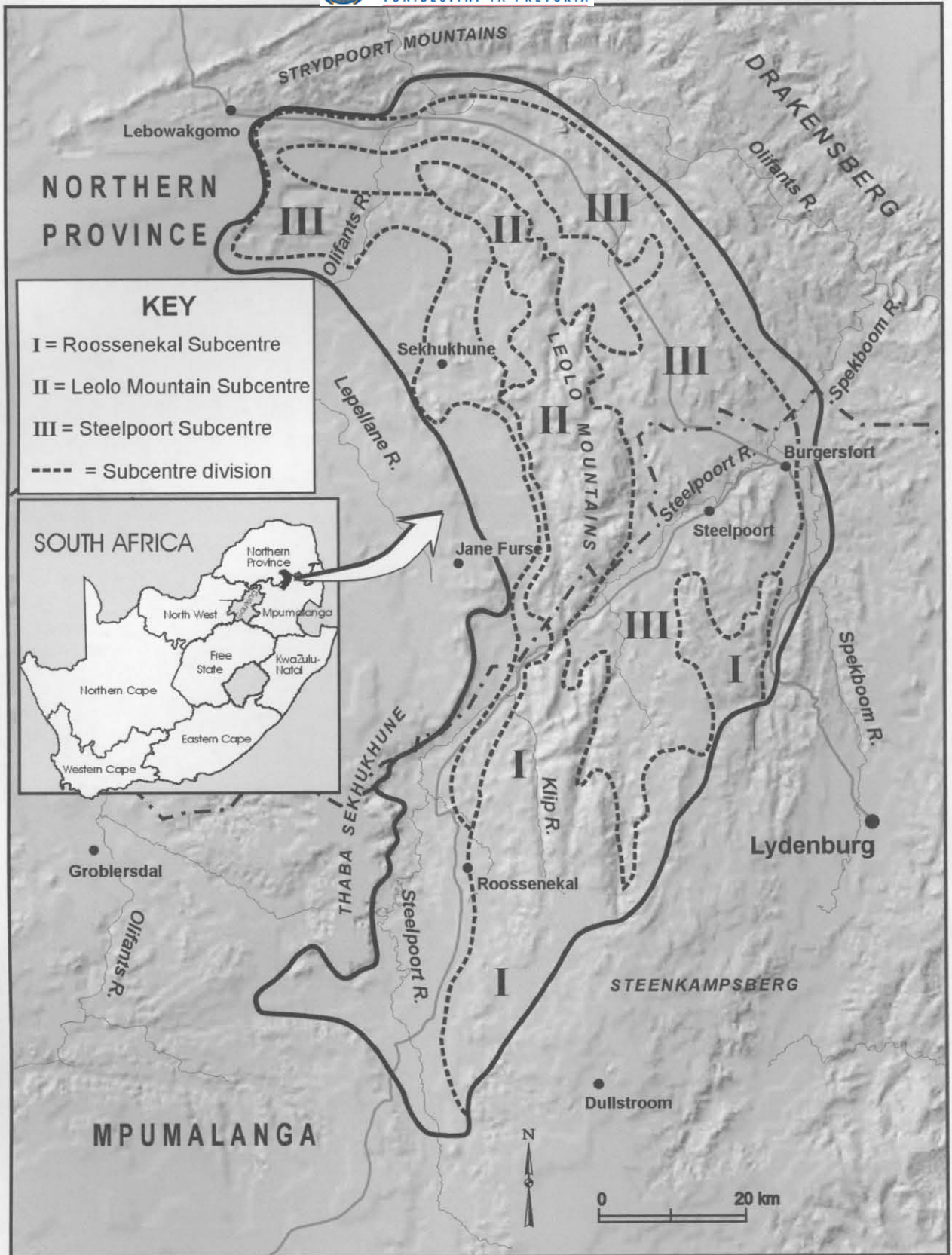


Figure 32 Subcentres of endemism of the Sekhukhuneland Centre of Plant Endemism (based on Siebert (1998)).

Table 38 List of the Sekhukhuneland Centre of Plant Endemism angiosperm endemics/near-endemics. Taxa are arranged in order of relative abundance in subcentres.

A = Roossenekal Subcentre; B = Leolo Mountain Subcentre; C = Steelpoort Subcentre; E = SCPE endemic; N-E = SCPE near-endemic;
 X = rare in subcentre; XX = frequent in subcentre; XXX = abundant in subcentre

Species	Family	E	N-E	A	B	C
<i>Melhamia randii</i> Baker f. [form] (Siebert 46)	STERCULIACEAE	✓	.	XXX	.	.
<i>Acacia karroo</i> Hayne [form] (Swartz 4)	FABACEAE	✓	.	XX	.	.
<i>Protea caffra</i> Meisn. Subsp. <i>caffra</i> [form] (Siebert 1382)	PROTEACEAE	✓	.	XX	.	.
<i>Rhoicissus</i> sp. nov. (Siebert 48)	VITACEAE	✓	.	XX	.	.
<i>Cyphostemma</i> sp. nov. C (Dednam FAA 4142)	VITACEAE	✓	.	X	.	.
<i>Schizoglossum</i> sp. nov. (Siebert 628)	ASCLEPIADACEAE	✓	.	X	.	.
<i>Zantedeschia jucunda</i> Letty	ARACEAE	✓	.	.	XXX	.
<i>Tulbaghia</i> sp. nov. (Siebert 1304)	LILIACEAE (Allioidea)	✓	.	.	XX	.
<i>Carissa</i> sp. nov. (Hurter pers. comm.)	APOCYNACEAE	✓	.	.	X	.
<i>Dioscorea</i> sp. nov. (Hurter pers. comm.)	DIOSCOREACEAE	✓	.	.	X	.
<i>Euphorbia</i> sp. nov. (Archer pers. comm.)	EUPHORBIACEAE	✓	.	.	X	.
<i>Psychotria</i> sp. nov. (Hurter pers. comm.)	RUBIACEAE	✓	.	.	X	.
<i>Gnidia caffra</i> (Meisn.) Gilg [form] (Van Wyk & Siebert 12975)	THYMELAEACEAE	✓	.	XX	XX	.
<i>Pavetta zeyheri</i> Sond. [form] (Siebert 22)	RUBIACEAE	✓	.	XX	XX	.
<i>Ledebouria</i> sp. nov. (Siebert 1865)	LILIACEAE (Hyacinthoidea)	✓	.	X	X	.
<i>Aloe burgersfortensis</i> Reynolds	LILIACEAE (Aloioidea)	✓	.	.	.	XXX
<i>Hibiscus barnardii</i> Exell	MALVACEAE	✓	.	.	.	XXX
<i>Asparagus sekukuniensis</i> (Oberm.) Fellingham & N.L. Mey.	LILIACEAE (Asparagoidea)	✓	.	.	.	XX
<i>Asparagus</i> sp. nov. (Van Wyk & Siebert 1358)	LILIACEAE (Asparagoidea)	✓	.	.	.	XX
<i>Premna mooiensis</i> (H. Pearson) W. Piep. [form] (Van Wyk & Siebert 13004)	VERBENACEAE	✓	.	.	.	XX

Table 38 continued.

Species	Family	E	N-E	A	B	C
<i>Rhus batophylla</i> Codd	ANACARDIACEAE	✓	.	.	.	XX
<i>Acacia</i> sp. nov. (Hurter pers. comm.)	FABACEAE	✓	.	.	.	X
<i>Albuca</i> sp. nov. (Siebert 856)	LILIACEAE (Hyacinthoidea)	✓	.	.	.	X
<i>Aloe</i> sp. nov. (Siebert 1419)	LILIACEAE (Alooidea)	✓	.	.	.	X
<i>Bauhinia tomentosa</i> L. [form] (Siebert 444)	FABACEAE	✓	.	.	.	X
<i>Ceropegia distincta</i> N.E. Br. subsp. <i>verruculosa</i> R.A. Dyer	ASCLEPIADACEAE	✓	.	.	.	X
<i>Clerodendrum suffruticosum</i> Gürke [form] (Siebert 1563)	VERBENACEAE	✓	.	.	.	X
<i>Euphorbia barnardii</i> C. White, R.H. Dyer & B.Sloane	EUPHORBIACEAE	✓	.	.	.	X
<i>Kleinia longiflora</i> DC. [form] (Van Wyk 13239)	ASTERACEAE	✓	.	.	.	X
<i>Orbeopsis gerstneri</i> (Letty) L.C. Leach subsp. <i>elongata</i> (R.A. Dyer) L.C. Leach	ASCLEPIADACEAE	✓	.	.	.	X
<i>Schotia latifolia</i> Jacq. [form] (Codd 9828 (PRE))	FABACEAE	✓	.	.	.	X
<i>Stylochaeton</i> sp. nov. A (Siebert 1845)	ARACEAE	✓	.	.	.	X
<i>Stylochaeton</i> sp. nov. B (Siebert 672)	ARACEAE	✓	.	.	.	X
<i>Tragia</i> sp. nov. (Siebert 1573)	EUPHORBIACEAE	✓	.	.	.	X
<i>Gladiolus sekhukhuniensis</i> P.J.D. Winter	IRIDACEAE	✓	.	.	X	X
<i>Plectranthus venterii</i> Van Jaarsv. & Hankey	LAMIACEAE	✓	.	.	X	X
<i>Euclea linearis</i> Zeyh. ex Hiern [form] (Siebert 937)	EBENACEAE	✓	.	X	.	XXX
<i>Euclea</i> sp. nov. (Van Wyk & Siebert 1686)	EBENACEAE	✓	.	X	.	XXX
<i>Brachylaena ilicifolia</i> (Lam.) E. Phillips & Schweick. [form] (Siebert 613)	ASTERACEAE	✓	.	X	.	XX
<i>Jamesbrittenia</i> sp. nov. (Van Wyk & Siebert 13026)	SCROPHULARIACEAE	✓	.	X	.	XX
<i>Polygala</i> sp. nov. (Van Wyk & Siebert 13311)	POLYGALACEAE	✓	.	X	.	XX

Table 38 continued.

Species	Family	E	N-E	A	B	C
<i>Rhoicissus sekhukhuniensis</i> Retief, Siebert & Van Wyk	VITACEAE	✓	.	X	.	XX
<i>Asclepias</i> sp. nov. (Kritzinger 110)	ASCLEPIADACEAE	✓	.	X	.	X
<i>Cyphostemma</i> sp. nov. B (Van Wyk & Siebert 1383)	VITACEAE	✓	.	X	.	X
<i>Gymnosporia</i> sp. nov. B (Siebert 458)	CELASTRACEAE	✓	.	X	.	X
<i>Hemizygia</i> sp. nov. (Siebert 615)	LAMIACEAE	✓	.	X	.	X
<i>Phyllanthus</i> sp. nov. (Siebert 470)	EUPHORBIACEAE	✓	.	X	.	X
<i>Berkheya insignis</i> (Harv.) Thell. [form] (Siebert 257)	ASTERACEAE	✓	.	XX	X	XX
<i>Catha transvaalensis</i> Codd	CELASTRACEAE	✓	.	XX	X	XX
<i>Elephantorrhiza praetermissa</i> J. H. Ross	FABACEAE	✓	.	XX	X	XX
<i>Euclea crispa</i> (Thunb.) Guerke subsp. <i>crispa</i> [form] (Van Wyk & Siebert 13205)	EBENACEAE	✓	.	XX	X	XX
<i>Jamesbrittenia macrantha</i> (Codd) Hilliard	SCROPHULARIACEAE	✓	.	XX	X	X
<i>Xerophyta retinervis</i> Baker [form] (Van Wyk 13208)	VELLOZIACEAE	✓	.	XX	X	X
<i>Cyphostemma</i> sp. nov. A (Van Wyk & Siebert 13389)	VITACEAE	✓	.	XX	X	.
<i>Rhus sekhukhuniensis</i> Moffett	ANACARDIACEAE	✓	.	XX	X	X
<i>Leucas capensis</i> (Benth.) Engl. [form] (Van Wyk 13007)	LAMIACEAE	✓	.	X	X	XX
<i>Orthosiphon fruticosus</i> Codd	LAMIACEAE	✓	.	X	X	XX
<i>Ipomoea bathycolpos</i> Hallier f. var. <i>sinuatodentata</i> Hallier f.	CONVOLVULACEAE	✓	.	X	X	X
<i>Zantedeschia pentlandii</i> (Watson) Wittm.	ARACEAE	.	✓	XXX	.	.
<i>Argyrolobium wilmsii</i> Harms	FABACEAE	.	✓	XX	.	.
<i>Helichrycum uninervium</i> Burt Davy	ASTERACEAE	.	✓	XX	.	.
<i>Hermannia antonii</i> I. Verd.	STERCULIACEAE	.	✓	XX	.	.

Table 38 continued.

Species	Family	E	N-E	A	B	C
<i>Jasminum quinatum</i> Schinz	OLEACEAE	.	✓	XX	.	.
<i>Aloe reitzii</i> Reynolds var. <i>reitzii</i>	LILIACEAE (Alooidea)	.	✓	X	.	.
<i>Argyrobium lancifolium</i> Burt Davy	FABACEAE	.	✓	X	.	.
<i>Berkheya densifolia</i> Bohnen ex Roessler	ASTERACEAE	.	✓	X	.	.
<i>Eucomis vandermerwei</i> I. Verd	LILIACEAE (Hyacinthoidea)	.	✓	X	.	.
<i>Pegolettia lanceolata</i> Harv.	ASTERACEAE	.	✓	X	.	.
<i>Gymnosporia</i> sp. nov. A (<i>Van Wyk & Siebert 13351</i>)	CELASTRACEAE	.	✓	.	XX	.
<i>Helichrysum albilanatum</i> Hilliard	ASTERACEAE	.	✓	XX	X	.
<i>Aloe pretoriensis</i> Pole Evans	LILIACEAE (Alooidea)	.	✓	X	X	.
<i>Rhus wilmsii</i> Diels	ANACARDIACEAE	.	✓	XX	X	.
<i>Jatropha latifolia</i> Pax var. <i>angustata</i> Prain	EUPHORBIACEAE	.	✓	X	X	.
<i>Jatropha zeyheri</i> Sond. var. <i>subsimplax</i> Prain	EUPHORBIACEAE	.	✓	X	X	.
<i>Rhus tumulicola</i> S. Moore var. <i>meeuseana</i> forma <i>pumila</i>	ANACARDIACEAE	.	✓	X	X	.
<i>Lotononis wilmsii</i> Dummer	FABACEAE	.	✓	X	X	.
<i>Tulbaghia coddii</i> Vosa & R.B. Burb.	LILIACEAE (Allioidea)	.	✓	X	X	.
<i>Petalidium oblongifolium</i> C.B. Clarke	ACANTHACEAE	.	✓	.	.	XXX
<i>Adenia fruticosa</i> Burt Davy subsp. <i>fruticosa</i>	PASSIFLORACEAE	.	✓	.	.	XX
<i>Aloe fosterii</i> Pillans	LILIACEAE (Alooidea)	.	✓	.	.	XX
<i>Dyschoriste erecta</i> C.B. Clarke	ACANTHACEAE	.	✓	.	.	XX
<i>Rhus engleri</i> Britten	ANACARDIACEAE	.	✓	.	.	XX
<i>Adenia wilmsii</i> Harms	PASSIFLORACEAE	.	✓	.	.	X
<i>Aloe immaculata</i> Pillans	LILIACEAE (Alooidea)	.	✓	.	.	X

Table 38 continued.

Species	Family	E	N-E	A	B	C
<i>Asparagus clareae</i> (Oberm.) Fellingham & N.L. Mey.	LILIACEAE (Asparagoidea)	.	✓	.	.	X
<i>Asparagus lynettiae</i> (Oberm.) Fellingham & N.L. Mey.	LILIACEAE (Asparagoidea)	.	✓	.	.	X
<i>Asparagus</i> sp. nov. (Van Wyk 13598)	LILIACEAE (Asparagoidea)	.	✓	.	.	X
<i>Boscia albitrunca</i> (Burch.) Gilg & Gilg-Ben. 'var. <i>macrophylla</i> Toelken' [form] (Van Wyk & Siebert 13182)	CAPPARACEAE	.	✓	.	.	X
<i>Ceropegia stapeliiformis</i> Haw. subsp. <i>serpentina</i> (E.A. Bruce) R.A. Dyer	ASCLEPIADACEAE	.	✓	.	.	X
<i>Combretum petrophilum</i> Retief	COMBRETACEAE	.	✓	.	.	X
<i>Cyphia transvaalensis</i> E. Phillips	LOBELIACEAE	.	✓	.	.	X
<i>Delosperma rileyii</i> L. Bolus	MESEMBRYANTHEMACEAE	.	✓	.	.	X
<i>Delosperma zeederbergii</i> L. Bolus	MESEMBRYANTIEMACEAE	.	✓	.	.	X
<i>Dicliptera fruticosa</i> K. Balkwill	ACANTHACEAE	.	✓	.	.	X
<i>Dombeya autumnalis</i> I. Verd.	STERCULIACEAE	.	✓	.	.	X
<i>Euphorbia enormis</i> N.E. Br.	EUPHORBIACEAE	.	✓	.	.	X
<i>Euphorbia lydenburgensis</i> Schweick. & Letty	EUPHORBIACEAE	.	✓	.	.	X
<i>Euphorbia maleolens</i> E. Phillips	EUPHORBIACEAE	.	✓	.	.	X
<i>Euphorbia schinzii</i> Pax [form] (Van Wyk & Siebert 13194)	EUPHORBIACEAE	.	✓	.	.	X
<i>Huernia insigniflora</i> C.A. Maass	ASCLEPIADACEAE	.	✓	.	.	X
<i>Huernia stapelioides</i> Schltr.	ASCLEPIADACEAE	.	✓	.	.	X
<i>Ledebouria dolomiticola</i> S. Venter	LILIACEAE (Hyacinthoidea)	.	✓	.	.	X
<i>Ozoroa albicans</i> R. & A. Fern.	ANACARDIACEAE	.	✓	.	.	X
<i>Pachycarphus transvaalensis</i> (Schltr.) N.E. Br.	ASCLEPIADACEAE	.	✓	.	.	X
<i>Plinthus rehmanni</i> G. Schellenb.	AIZOACEAE	.	✓	.	.	X

Table 38 continued.

Species	Family	E	N-E	A	B	C
<i>Rhynchosia spectabilis</i> Schinz	FABACEAE	.	✓	.	.	X
<i>Thesium multiramulosum</i> Pilg.	SANTALACEAE	.	✓	.	.	X
<i>Aloe castanea</i> Schönland	LILIACEAE (Alooidea)	.	✓	XXX	.	XX
<i>Solanum incanum</i> L. [form] (Van Wyk & Siebert 13013)	SOLANACEAE	.	✓	X	.	XX
<i>Plectranthus xerophilus</i> Codd	LAMIACEAE	.	✓	X	.	XX
<i>Rhus keetii</i> Schönland	ANACARDIACEAE	.	✓	X	.	XX
<i>Aneilema longirrhizum</i> Faden	COMMELINACEAE	.	✓	X	.	X
<i>Chlorophytum cyperaceum</i> Kies ex Oberm.	LILIACEAE (Anthericoidea)	.	✓	X	.	X
<i>Dyschoriste perrottetii</i> (Nees) Kuntze	ACANTHACEAE	.	✓	X	.	X
<i>Kleinia stapeliiformis</i> (E. Phillips) Stapf	ASTERACEAE	.	✓	X	.	X
<i>Nuxia gracilis</i> Engl.	LOGANIACEAE	.	✓	X	.	X
<i>Orthosiphon amabilis</i> (Bremek.) Codd	LAMIACEAE	.	✓	X	.	X
<i>Aloe cryptopoda</i> Baker [form] (Siebert 609)	LILIACEAE (Alooidea)	.	✓	XX	X	XX
<i>Indigofera lydenburgensis</i> N.E. Br.	FABACEAE	.	✓	XX	X	XX
<i>Triaspis glaucophylla</i> Engl.	MALPIGHIACEAE	.	✓	XX	X	XX
<i>Vitex obovata</i> E. Mey. subsp. <i>wilmsii</i> (Gürke) C.L. Bredenkamp & D.J. Botha	VERBENACEAE	.	✓	XX	X	XX
<i>Grewia vernicosa</i> Schinz	TILIACEAE	.	✓	X	X	XXX
<i>Karomia speciosa</i> (Hutch. & Corbishley) R. Fern. forma <i>speciosa</i>	VERBENACEAE	.	✓	X	X	XX
<i>Orthosiphon tubiformis</i> R.D. Good	LAMIACEAE	.	✓	X	X	XX
<i>Jatropha latifolia</i> Pax var. <i>latifolia</i>	EUPHORBIACEAE	.	✓	X	X	X
TOTAL		58	67	67	39	90
[E / N-E]				31/36	22/17	42/48

Specimens are housed in the H.G.W.J. Schweickerdt Herbarium (PRU), University of Pretoria; [form] = morphologically undifferentiated race of widespread species.

Table 39 Statistics of the families that are represented in the Sekhukhuneland Centre of Plant Endemism.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
AMARYLLIDACEAE		8	13	1	1	-	-	-	-
ARACEAE		2	9	2	-	2	-	3	1
COMMELINACEAE		3	12	-	3	-	-	-	1
CYPERACEAE		18	48	3	4	-	-	-	-
DIOSCOREACEAE		1	5	-	1	1	-	1	-
ERIOCAULACEAE		1	2	-	1	-	-	-	-
HYPOXIDACEAE		1	7	-	2	-	-	-	-
IRIDACEAE		9	25	4	3	-	-	1	-
JUNCACEAE		1	4	-	-	-	-	-	-
LILIACEAE s.l.	8*	27	112	9	10	4	2	7	13
Allioideae		2	6	1	-	1	-	1	1
Anthericoideae		2	8	-	1	-	-	-	1
Asparagoideae		1	19	1	6	1	1	2	3
Asphodeloideae		4	31	3	2	-	1	2	6
Colchicoideae		5	7	1	-	-	-	-	-
Dracaenoideae		1	3	-	-	-	-	-	-
Eriospermoideae		1	3	1	1	-	-	-	-
Hyacinthoideae		11	35	2	-	2	-	2	2
ORCHIDACEAE		11	36	6	5	-	-	-	-
POACEAE		70	161	14	9	-	-	-	-
POTAMOGETONACEAE		1	2	-	-	-	-	-	-
TYPHACEAE		1	1	-	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
VELLOZIACEAE		1	4	-	-	-	1	1	-
XYRIDACEAE		1	1	-	-	-	-	-	-
MONOCOTYLEDONAE	23	156	442	39	39	7	3	13	15
ACANTHACEAE		21	60	1	3	-	-	-	4
AIZOACEAE		8	15	2	7	-	-	-	1
AMARANTHACEAE		9	15	1	4	-	-	-	-
ANACARDIACEAE		4	28	2	6	-	-	2	5
ANNONACEAE		2	2	-	1	-	-	-	-
APIACEAE		9	14	1	5	-	-	-	-
APOCYNACEAE		5	6	2	-	-	-	1	-
AQUIFOLIACEAE		1	1	-	1	-	-	-	-
ARALIACEAE		3	6	1	-	-	-	-	-
ASCLEPIADACEAE		31	67	7	3	2	-	4	4
ASTERACEAE		59	192	19	6	-	3	3	5
BALANITACEAE		1	1	-	-	-	-	-	-
BALSAMINACEAE		1	1	1	-	-	-	-	-
BIGNONIACEAE		4	5	-	-	-	-	-	-
BORAGINACEAE		5	10	-	-	-	-	-	-
BRASSICACEAE		2	2	-	-	-	-	-	-
BURSERACEAE		1	7	-	-	-	-	-	-
BUXACEAE		1	1	-	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
CACTACEAE		1	1	-	-	-	-	-	-
CAMPANULACEAE		1	7	1	-	-	-	-	-
CAPPARACEAE		5	22	7	3	-	-	-	1
CARYOPHYLLACEAE		2	4	2	2	-	-	-	-
CELASTRACEAE		8	19	1	1	2	-	2	1
CHENOPODIACEAE		3	5	-	1	-	-	-	-
CLUSIACEAE		1	4	1	-	-	-	-	-
COMBRETACEAE		2	10	2	-	-	-	-	1
CONVOLVULACEAE		8	26	4	9	-	-	1	-
CRASSULACEAE		4	18	6	4	-	-	-	-
CUCURBITACEAE		10	22	1	1	-	-	-	-
DIPSACACEAE		2	2	-	-	-	-	-	-
DROSERACEAE		1	3	-	-	-	-	-	-
EBENACEAE		2	16	6	5	-	2	3	-
ERICACEAE		1	5	-	3	-	-	-	-
EUPHORBIACEAE		17	59	4	9	3	1	4	7
FABACEAE s.l.	3*	46	182	29	29	-	3	5	5
Caesalpinioidea		7	16	1	1	-	2	-	-
Mimosoidea		4	31	6	6	-	1	-	-
Papilionoideae		35	135	22	22	-	-	-	-
FLACOURTIACEAE		6	7	-	-	-	-	-	-
GENTIANACEAE		4	11	3	1	-	-	-	-
GERANIACEAE		3	9	1	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
GESNERIACEAE		1	3	-	-	-	-	-	-
GREYIACEAE		1	1	-	-	-	-	-	-
ICACINACEAE		3	3	1	-	-	-	-	-
ILLECEBRACEAE		1	1	-	-	-	-	-	-
LAMIACEAE		21	66	5	14	1	1	4	3
LINACEAE		1	1	-	-	-	-	-	-
LOBELIACEAE		3	7	1	2	-	-	-	1
LOGANIACEAE		4	8	-	-	-	-	-	1
LORANTHACEAE		4	9	-	-	-	-	-	-
LYTHRACEAE		1	2	-	1	-	-	-	-
MALPIGHIACEAE		2	4	3	-	-	-	-	1
MALVACEAE		5	34	1	2	-	-	1	-
MELASTOMATACEAE		1	1	-	-	-	-	-	-
MELIACEAE		3	3	-	-	-	-	-	-
MENISPERMACEAE		4	4	-	1	-	-	-	-
MESEMBRYANTHEMACEAE		2	5	-	-	-	-	-	2
MORACEAE		1	7	1	1	-	-	-	-
MYRICACEAE		1	1	-	-	-	-	-	-
MYROTHAMNACEAE		1	1	-	-	-	-	-	-
MYRSINACEAE		3	3	-	-	-	-	-	-
MYRTACEAE		2	3	-	-	-	-	-	-
NYCTAGINACEAE		2	7	-	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
OCHNACEAE		1	3	-	-	-	-	-	-
OLACACEAE		1	2	-	1	-	-	-	-
OLEACEAE		5	9	2	2	-	-	-	1
OLINIACEAE		1	2	-	-	-	-	-	-
ONAGRACEAE		2	3	-	-	-	-	-	-
OXALIDACEAE		1	4	-	-	-	-	-	-
PAPAVERACEAE		1	1	1	-	-	-	-	-
PASSIFLORACEAE		1	4	2	1	-	-	-	2
PEDALIACEAE		7	8	2	1	-	-	-	-
PERIPLOCACEAE		3	6	-	-	-	-	-	-
PIPERACEAE		1	1	-	-	-	-	-	-
PITTOSPORACEAE		1	1	-	-	-	-	-	-
PLANTAGINACEAE		1	2	-	-	-	-	-	-
PLUMBAGINACEAE		1	1	-	-	-	-	-	-
POLYGALACEAE		1	9	-	1	1	-	1	-
POLYGONACEAE		4	10	4	-	-	-	-	-
PORTULACACEAE		3	6	-	-	-	-	-	-
PRIMULACEAE		1	1	-	-	-	-	-	-
PROTEACEAE		2	6	2	-	-	1	1	-
PTAEROXYLACEAE		1	1	-	-	-	-	-	-
RANUNCULACEAE		3	5	-	1	-	-	-	-
RHAMNACEAE		5	5	1	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
ROSACEAE		6	8	1	-	-	-	-	-
RUBIACEAE		22	41	12	4	-	1	2	-
RUTACEAE		5	5	-	-	-	-	-	-
SALVADORACEAE		1	1	-	-	-	-	-	-
SANTALACEAE		3	11	-	1	-	-	-	1
SAPINDACEAE		5	6	-	-	-	-	-	-
SAPOTACEAE		2	2	-	-	-	-	-	-
SCROPHULARIACEAE		25	45	3	2	1	1	2	-
SELAGINACEAE		3	8	-	-	-	-	-	-
SIMAROUBACEAE		1	2	-	-	-	-	-	-
SOLANACEAE		6	15	-	-	-	1	-	1
STERCULIACEAE		5	25	-	3	-	1	1	2
THYMELAEACEAE		3	9	-	-	-	1	1	-
TILIACEAE		3	19	-	2	-	-	-	1
TURNERACEAE		2	2	-	-	-	-	-	-
ULMACEAE		2	2	-	-	-	-	-	-
URTICACEAE		4	4	1	-	-	-	-	-
VERBENACEAE		9	25	1	8	-	1	2	2
VIOLACEAE		1	1	-	-	-	-	-	-
VISCACEAE		1	4	1	-	-	-	-	-
VITACEAE		3	18	2	-	4	-	5	-
ZYGOPHYLLACEAE		1	2	1	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
DICOTYLEDONAE	104	521	1384	153	152	14	17	45	52
ADIANTACEAE		5	13	1	4	-	-	-	-
ASPLENIACEAE		2	4	-	1	-	-	-	-
EQUISETACEAE		1	1	-	-	-	-	-	-
ISOETACEAE		1	1	-	-	-	-	-	-
LYCOPODIACEAE		1	1	-	-	-	-	-	-
OPHIOGLOSSACEAE		1	2	-	-	-	-	-	-
POLYPODIACEAE		1	1	1	-	-	-	-	-
SCHIZAEACEAE		2	3	-	1	-	-	-	-
SELLAGINELLACEAE		1	2	-	-	-	-	-	-
THELYPTERIDACEAE		1	2	-	-	-	-	-	-
VITTARIACEAE		1	1	-	-	-	-	-	-
PTERIDOPHYTA	11	17	31	2	6	-	-	-	-
AMBLYSTEGIACEAE		1	1	-	-	-	-	-	-
ARCHIDIACEAE		1	1	-	-	-	-	-	-
AYTONIACEAE		1	2	-	-	-	-	-	-
BARTRAMIACEAE		2	2	-	-	-	-	-	-
BRYACEAE		4	10	-	-	-	-	-	-
CALYMPERACEAE		2	3	-	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
DICRANACEAE		3	9	-	-	-	-	-	-
ENTODONTACEAE		3	3	-	-	-	-	-	-
ERPODIACEAE		2	2	-	-	-	-	-	-
EXORMOTHECACEAE		1	1	-	-	-	-	-	-
FABRONIACEAE		1	2	-	-	-	-	-	-
FISSIDENTACEAE		1	6	-	-	-	-	-	-
FUMARIACEAE		1	1	-	-	-	-	-	-
GRIMMIACEAE		1	1	-	-	-	-	-	-
HEDWIGIACEAE		2	2	-	-	-	-	-	-
HOOKERIAEAE		1	1	-	-	-	-	-	-
HYPNACEAE		1	1	-	-	-	-	-	-
LEPTODONTACEAE		2	2	-	-	-	-	-	-
LESKEACEAE		2	6	-	-	-	-	-	-
LEUCODONTACEAE		2	2	-	-	-	-	-	-
METEORIAEAE		4	4	-	-	-	-	-	-
ORTHOTRICHACEAE		2	2	-	-	-	-	-	-
PALLAVICINIACEAE		1	1	-	-	-	-	-	-
POLYTRICHACEAE		3	3	-	-	-	-	-	-
PORELLACEAE		1	1	-	-	-	-	-	-
POTTIACEAE		10	17	-	-	-	-	-	-
PRIONODONTACEAE		1	1	-	-	-	-	-	-
PTEROBRYACEAE		1	2	-	-	-	-	-	-

Table 39 continued.

Family	Fam.	Gen.	Spp.	Subsp.	Var.	sp. nov.	Forms	End.	N-End.
PTYCHOMITRIACEAE		1	4	-	-	-	-	-	-
RICCIACEAE		1	3	-	-	-	-	-	-
SEMATOPHYLLACEAE		1	1	-	-	-	-	-	-
SPHAGNACEAE		1	1	-	-	-	-	-	-
THAMNOBRYACEAE		1	1	-	-	-	-	-	-
TRACHYPODACEAE		1	1	-	-	-	-	-	-
BRYOPHYTA	34	63	100	-	-	-	-	-	-
<i>MONOCOTYLEDONAE</i>	<i>23</i>	<i>156</i>	<i>442</i>	<i>39</i>	<i>39</i>	<i>7</i>	<i>3</i>	<i>13</i>	<i>15</i>
<i>DICOTYLEDONAE</i>	<i>104</i>	<i>521</i>	<i>1384</i>	<i>153</i>	<i>152</i>	<i>14</i>	<i>17</i>	<i>45</i>	<i>52</i>
ANGIOSPERMAE	127	677	1826	192	191	21	20	58	67
PTERIDOPHYTA	11	17	31	2	6	-	-	-	-
BRYOPHYTA	34	63	100	-	-	-	-	-	-
TOTAL	172	757	1957	194	197	21	20	58	67

* Statistics incorporated with those for the family.

Table 40 Recommended IUCN Red Data List status of the Sekhukhuneland Centre of Endemism flora.

¹According to new IUCN categories (Hilton-Taylor 2000)

²According to Red Data List (RDL) of southern African plants (Hilton-Taylor 1996)

Species	Family	Global status ¹	National status ¹	RDL ² (1996)	Justification for allocation of status
<i>Adenia wilmsii</i> Harms	PASSIFLORACEAE	VU A1cd+D2	VU A1cd+D2	K	Restricted distribution
<i>Aloe burgersfortensis</i> Reynolds	ALOACEAE	VU A2c	VU A2c		Mining; residential development
<i>Aloe reitzii</i> Reynolds var. <i>reitzii</i>	ALOACEAE	VU A2ac+D2	VU A2ac+D2	1	Norite mining; afforestation
<i>Aneilema longirrhizum</i> Faden	COMMELINACEAE	EN B1+2bce	EN B1+2bce		Overgrazing; erosion
<i>Asparagus clareae</i> (Oberm.) Fellingham & N.L. Mey.	ASPARAGACEAE	VU D2	VU D2	K	Restricted distribution
<i>Asparagus sekukuniensis</i> (Oberm.) Fellingham & N.L. Mey.	ASPARAGACEAE	VU D2	VU D2	K	Restricted distribution
<i>Boscia albitrunca</i> (Burch.) Gilg & Gilg-Ben. "var. <i>macrophylla</i> Toelken"	CAPPARACEAE	VU D2	VU D2		Restricted distribution
<i>Catha transvaalensis</i> Codd	CELASTRACEAE	VU B1+2e	VU B1+2e		Firewood; mining in general
<i>Euclea</i> sp. nov. (Siebert 934)	EBENACEAE	VU A2c+D2	VU A2c+D2		Chromium mining
<i>Euphorbia barnardii</i> C. White, R.H.Dyer & B. Sloane	EUPHORBIACEAE	VU A1ac, B1, B2be, C1, D2	VU A1ac, B1, B2be, C1, D2	E	Diseases; over-grazing (Knowles & Witkowski 2000)
<i>Euphorbia sekukhuniensis</i> R.A. Dyer	EUPHORBIACEAE	VU D2	VU D2	R	Restricted distribution
<i>Gymnosporia</i> sp. nov. A (Van Wyk 13351)	CELASTRACEAE	VU D2	VU D2		Destruction of forests
<i>Huernia stapelioides</i> Schltr.	ASCLEPIADACEAE	VU D2	VU D2		Soil degradation; restricted distribution
<i>Melhania randii</i> Baker f.	STERCULIACEAE	-	VU B1+2bc	K	Norite mining
<i>Nemesia zimbabwensis</i> Rendle	SCHROPHULARIACEAE	VU B1+2e	CR B1+2c		Chopping down of forests

Table 40 continued.

Species	Family	Global status ¹	National status ¹	RDL ²	Justification for allocation of status (1996)
<i>Nuxia gracilis</i> Engl.	LOGANIACEAE	VU B1+2bc	VU B1+2bc	K	Mine dumps
<i>Pegolettia lanceolata</i> Harv.	ASTERACEAE	VU D2	VU D2		Afforestation
<i>Plectranthus venteri</i> Van Jaarsv. & Hankey	LAMIACEAE	VU D2	VU D2		Restricted distribution
<i>Plinthus rehmannii</i> G. Schellenb.	AIZOACEAE	EN B1+2bc	EN B1+2bc	V	Overgrazing; residential development
<i>Raphionacme chimanimaniana</i> Venter & R.L. Verh.	PERIPLOCACEAE	VU D2	VU D2		Trampling and overgrazing
<i>Rhus batophylla</i> Codd	ANACARDIACEAE	VU D2	VU D2	R	Restricted distribution
<i>Stylochaeton</i> sp. nov. (Siebert 1332)	ARACEAE	CR B1+2abcd	CR B1+2abcd		Overgrazing; residential development
<i>Tulbaghia coddii</i> Vosa & R.B. Burb.	LILIACEAE	VU D2	VU D2	K	Overgrazing; restricted distribution
<i>Tulbaghia</i> sp. nov. (Siebert 1304)	LILIACEAE	CR B1+2abc	CR B1+2abc		Overgrazing; housing development
<i>Zantedeschia jucunda</i> Letty	ARACEAE	VU A2d+D2	VU A2d+D2	I	Restricted distribution; residential development
<i>Zantedeschia pentlandii</i> (Watson) Wittm.	ARACEAE	EN B1+2bce	EN B1+2bce	R	Illegal collection; norite mining

Table 41 List of species in the Sekhukhuneland Centre assessed as not threatened, as well as those in need of assessment.

NE = Not evaluated

¹According to new IUCN categories (Hilton-Taylor 2000)

Species	Family	Global status ¹	National status ¹	Red Data List status (Hilton-Taylor 1996)
<i>Argyrolobium wilmsii</i> Harms	FABACEAE	LR (lc)	LR (lc)	
<i>Asparagus intricatus</i> (Oberm.) Fellingham & N.L. Mey.	ASPARAGACEAE	LR (lc)	LR (lc)	
<i>Boscia foetida</i> Schinz subsp. <i>minima</i> Toelken	CAPPARACEAE	NE	NE	R (northern provinces)
<i>Callilepis leptophylla</i> Harv.	ASTERACEAE	LR (lc)	LR (lc)	R (KwaZulu-Natal)
<i>Chlorophytum cyperaceum</i> Kies ex Oberm.	LILIACEAE	LR (nt)	LR (nt)	
<i>Combretum petrophilum</i> Retief	COMBRETACEAE	NE	NE	R (northern provinces)
<i>Dicliptera fruticosa</i> K. Balkwill	ACANTHACEAE	LR (nt)	LR (nt)	
<i>Disa rhodantha</i> Schltr.	ORCHIDACEAE	LR (lc)	LR (lc)	K (northern provinces)
<i>Dombeya autumnalis</i> I. Verd.	STERCULIACEAE	LR (lc)	LR (lc)	
<i>Dyschoriste erecta</i> C.B. Clarke	ACANTHACEAE	LR (lc)	LR (lc)	
<i>Dyschoriste perrottetii</i> (Nees) Kuntze	ACANTHACEAE	LR (lc)	LR (lc)	
<i>Dyschoriste rogersii</i> S. Moore	ACANTHACEAE	NE	NE	
<i>Elephantorrhiza praetermissa</i> J.H. Ross	FABACEAE	LR (lc)	LR (lc)	K (northern provinces)
<i>Eucomis autumnalis</i> (Mill.) Chitt. subsp. <i>clavata</i> Baker (Reyneke)	LILIACEAE	LR (nt)	LR (nt)	R (Free State); V (KwaZulu-Natal)
<i>Eucomis montana</i> Compton	LILIACEAE	LR (nt)	LR (nt)	R (northern provinces)
<i>Eulophia leachii</i> Greatrex ex A.V. Hall	ORCHIDACEAE	NE	NE	
<i>Euphorbia enormis</i> N.E. Br.	EUPHORBIACEAE	LR (nt)	LR (nt)	
<i>Euphorbia lydenburgensis</i> Schweick. & Letty	EUPHORBIACEAE	LR (nt)	LR (nt)	

Table 41 continued.

Species	Family	Global status ¹	National status ¹	Red Data List status (Hilton-Taylor 1996)
<i>Gossypium herbaceum</i> L. subsp. <i>africanum</i> (Watt) Vollesen	MALVACEAE	LR (lc)	LR (lc)	K (Swaziland)
<i>Hibiscus barnardii</i> Exell	MALVACEAE	LR (nt)	LR (nt)	R (northern provinces)
<i>Huernia insigniflora</i> C.A. Maas	ASCLEPIADACEAE	LR (lc)	LR (lc)	
<i>Ipomoea bathycolpos</i> Hallier f. var. <i>sinuatodentata</i> Hallier f.	CONVOLVULACEAE	LR (nt)	LR (nt)	
<i>Jamesbrittenia macrantha</i> (Codd) Hilliard	SCHROPHULARIACEAE	LR (nt)	LR (nt)	K (northern provinces)
<i>Jamesbrittenia silenoides</i> (Hilliard) Hilliard	SCHROPHULARIACEAE	LR (lc)	LR (lc)	V (KwaZulu-Natal)
<i>Jatropha latifolia</i> Pax var. <i>angustata</i> Prain	EUPHORBIACEAE	LR (nt)	LR (nt)	
<i>Jatropha latifolia</i> Pax var. <i>latifolia</i>	EUPHORBIACEAE	LR (lc)	LR (lc)	
<i>Ledebouria dolomiticola</i> S. Venter	LILIACEAE	LR (nt)	LR (nt)	
<i>Mosdenia leptostachys</i> (Ficalho & Hiern) Clayton	POACEAE	LR (nt)	LR (nt)	K (northern provinces)
<i>Orthosiphon fruticosus</i> Codd	LAMIACEAE	LR (lc)	LR (lc)	
<i>Orthosiphon tubiformis</i> R.D. Good	LAMIACEAE	LR (lc)	LR (lc)	
<i>Ozoroa albicans</i> R. & A. Fern.	ANACARDIACEAE	LR (nt)	LR (nt)	K (northern provinces)
<i>Pachypodium saundersii</i> N.E. Br.	APOCYNACEAE	LR (lc)	LR (lc)	K (Swaziland)
<i>Pavetta zeyheri</i> Sond.	RUBIACEAE	LR (lc)	LR (lc)	K (Swaziland)
<i>Pegolettia senegalensis</i> Cass.	ASTERACEAE	LR (lc)	LR (lc)	R (KwaZulu-Natal)
<i>Petalidium oblongifolium</i> C.B. Clarke	ACANTHACEAE	LR (lc)	LR (lc)	
<i>Rhoicissus sekhukhuniensis</i> Retief, Siebert & Van Wyk	VITACEAE	LR (nt)	LR (nt)	
<i>Rhus keetii</i> Schönland	ANACARDIACEAE	NE	NE	
<i>Rhus rogersii</i> Schönland	ANACARDIACEAE	LR (lc)	LR (lc)	I (Swaziland)
<i>Rhus sekhukhuniensis</i> Moffett	ANACARDIACEAE	LR (nt)	LR (nt)	R (northern provinces)

Table 41 continued.

Species	Family	Global status¹	National status¹	Red Data List status (Hilton-Taylor 1996)
<i>Rhus wilmsii</i> Diels	ANACARDIACEAE	LR (nt)	LR (nt)	K (northern provinces)
<i>Rhynchosia nitens</i> Benth.	FABACEAE	LR (nt)	LR (nt)	K (northern provinces)
<i>Scilla natalensis</i> Planch.	LILIACEAE	LR (nt)	LR (nt)	V (Free State); V (KwaZulu-Natal)
<i>Stapelia gigantea</i> N.E. Br.	ASCLEPIADACEAE	LR (nt)	LR (nt)	R (western provinces)
<i>Thesium gracilentum</i> N.E. Br.	SANTALACEAE	DD	DD	K (northern provinces)
<i>Thesium multiramulosum</i> Pilg.	SANTALACEAE	DD	DD	
<i>Tristachya biseriata</i> Stapf	POACEAE	LR (lc)	LR (lc)	K (northern provinces)

Table 42 Summary of the conservation value of the Sekhukhuneland Centre plant communities that are a priority for conservation. Figures in bold are of value to determine conservation priorities.

	O	O	O	O	G	O	O	O	O	O	C	C	C
	4	7	4.2	5	3	4.3	7.1	6	2	7.2	1	2	3
SCPE endemics	18	15	15	15	8	14	13	12	14	13	9	9	9
SCPE near-endemics	11	11	10	9	9	8	10	9	7	8	11	11	10
Red Data List taxa	6	4	5	2	8	4	3	4	2	3	3	1	2
Restricted taxa	4	3	1	1	6	1	0	3	1	1	6	2	3
Total	30	26	25	24	23	23	23	21	21	21	20	20	20

	O	O	O	O	C	G	O	O	G	G	G	O	O
	3	8	7.3	5.2	4	3.1	2.3	3.2	5	2	3.3	3.1	4.4
SCPE endemics	13	11	11	11	10	6	11	11	8	6	6	10	10
SCPE near-endemics	6	8	8	8	8	7	7	6	8	6	6	6	6
Red Data List taxa	2	1	3	1	3	7	1	2	3	7	6	2	2
Restricted taxa	0	0	0	1	5	1	0	0	7	5	0	0	0
Total	19	19	19	19	18	18	18	17	16	16	16	16	16

CHAPTER 12

GENERAL DISCUSSION

12.1 Introduction

The principle hypotheses of this thesis state that the SCPE is characterised by plant communities, each being specific to a particular set of environmental variables, including a rich biodiversity with endemic and threatened taxa, and a specific relationship between certain plants and heavy metal soils. The results obtained support the hypotheses. The SCPE proved to have a diversity of plant communities which are specifically related to certain environmental variables (Chapters 4 to 9). The study did not aim to determine the endemic and threatened taxa, but merely to establish how these species were linked to specific plant communities. Endemic taxa have already been determined as part of a study to classify the area as a Centre of Plant Endemism (Siebert 1998). However, the present study revisited the topic and concentrated on rare and threatened taxa in the light of conservation priorities (Chapter 10). In addition, a first checklist has been provided for the study area to support its recognition as a Centre of Plant Diversity. Although Siebert (1998) indicated that a correlation exists between ultramafic soils and plant endemism for the SCPE, the question still remained as to what influence different soils of the SCPE have on the vegetation (Chapter 11).

This study adopted a broad approach in the floristic classification of vegetation to address the need for sound information on the floristic patterns and diversity of the threatened plants and communities of the SCPE. It aimed to provide useful botanical information that was lacking for the SCPE until recently. Basic techniques and statistical procedures were used to describe the vegetation of the SCPE. Apart from the identification of plant communities, analyses of plant-soil associations of indigenous plants were also explored. Thoughts on the phytogeography of the SCPE were presented in an attempt to explain some of the patterns of diversity. Various ideas born from speculations on

conservation in the SCPE are put forward. Research opportunities were addressed to focus future activities of serpentine related research, not only in the SCPE, but also in similar savanna and/or ultramafic areas. Hence, this chapter not only comprises a discussion on the results of the study, but also on observations made during different stages of research which may be relevant to further botanical work in the ultramafic areas of the SCPE.

12.2 Plant communities

12.2.1 Syntaxonomy of major vegetation types

This study is the first attempt to classify vegetation types for the SCPE based on relevé data. It was intended to present a floristic classification of the vegetation of the SCPE and, where possible, correlate it with environmental factors. The plant diversity of the SCPE is enhanced by the complex topography and geology of the region, a sharp climatic gradient from northwest to southeast and specifically adapted plant endemics (Siebert 1998). A multitude of environmental factors give rise to complex ecosystems that are often characterised by diverse vegetation (plant communities) (Pignatti 1994). These diverse plant communities and heterogeneous environmental factors in turn constitute habitat for various plant species, which consequently lead to a high floristic diversity in the SCPE.

The study of vegetation often engenders the understanding of ecological processes and, therefore, for various practical, management and academic reasons, deserves to be described. Careful analyses of plant communities within the SCPE therefore constitute a valid scientific basis for assessing the floristic diversity.

The TWINSPLAN classification and its subsequent refinement by Braun-Blanquet procedures resulted in the delineation of six major vegetation types and 82 syntaxa. This is a very high number of syntaxa when compared with other savanna regions (Lubbe 1997; Winterbach 1998; Hin 2000). When considering that only 50% (1 010 plant species/infraspecific taxa) of the total flora was recorded for these syntaxa, the richness of the region's plant communities is further emphasised, probably because many other combinations of taxa have not yet been recorded. This could also imply that about 50% of the plant taxa are so scattered or so rare that they were not recorded in the representative

ecosystems identified. The 82 syntaxa belong to the major vegetation types in the following manner:

- Grassland and Wetland Vegetation – 17 (12 grassland; 5 wetland) plant communities
- Rock Outcrop Vegetation – 17 plant communities
- Open Mountain Bushveld – 20 plant communities
- Closed Mountain Bushveld – 20 plant communities
- Arid Northern Bushveld – 8 plant communities

Formal names of these major vegetation types, which represent higher syntaxa (probably at the class or order level), cannot be validly described according to the Code for Phytosociological Nomenclature (Barkman *et al.* 1986), because formal descriptions of the associations are not yet published. In addition, Pignatti *et al.* (1995) indicated that the definition of classes is not useful to give an account of vegetation under complex conditions. Taking into account the complexity of the SCPE, description were mostly restricted to the alliance and order level.

The SCPE predominantly falls in the Savanna Biome. Apart from the typical savanna (bushveld) plant species, such as *Dichrostachys cinerea*, *Enneapogon scoparius* and *Evolvulus alsinoides*, typical grassland elements such as *Acalypha punctata*, *Clerodendrum triphyllum* and *Thesium gracilentum*, and typical forest elements such as *Maytenus undata*, *Allophylus africanus* and *Apodytes dimidiata*, expresses the floristic identity of the SCPE. As discussed in the results, the Grassland and Wetland Vegetation show a relationship with the plant communities described by Bloem (1988), Deall *et al.* (1989), Du Preez & Bredenkamp (1991), Matthews *et al.* 1991 Smit *et al.* (1997) and Burgoyne *et al.* (2000). The Rock Outcrop Vegetation, Open and Closed Mountain Bushveld and Arid Northern Bushveld are related to communities identified by Werger *et al.* (1978), Van der Meulen (1979), Deall *et al.* (1989), Bredenkamp & Van Vuuren (1977), Matthews *et al.* (1992b), Bredenkamp & Deutschlander (1995), Visser *et al.* (1996) and Breebaart & Deutschlander (1997). The reasons for these relationships are discussed under the section on phytogeography (12.4).

Furthermore, these plant communities, in some instances, show species composition similarities with other regions in South Africa. A floristic link exists with the Northern Cape and Northwest Province (arid part of Savanna Biome), with species shared including *Gnidia polycephala*, *Jamesbrittenia atropurpurea*, *Nuxia gracilis*, *Polygala krumanina*, *Pterothrix spinescens*, *Rhigozum obovatum* and *Stipagrostis hirtughuma* subsp. *patula*. Another floristic link is with the Lowveld. These species most probably reached Sekhukhuneland via the Olifants River valley and include taxa such as *Balanites maughamii*, *Diospyros mespiliformis*, *Lonchocarpus capassa* and *Ptaeroxylon obliquum*. In addition, many other floristic links exist with other areas in South Africa, for instance, *Schotia latifolia* and *Protosparagus intricatus* with the Eastern Cape, and *Sesamothamnus lugardii* and *Commiphora tenuipetiolata* with the areas north of the Soutpansberg. It is, therefore, clear that although the SCPE falls predominantly in the Savanna Biome, it is extremely diverse and carries elements from various other regions in South Africa.

A heterogeneous environment gave rise to diverse vegetation patterns in the SCPE. Hence, the bushveld of the SCPE is floristically distinctive and deserves recognition as a separate major vegetation type, provisionally referred to as **Sekhukhuneland Mountain Bushveld**. There are also other Mountain Bushveld types in the northern Provinces of South Africa, e.g. those of the Lebombo Mountains, Soutpansberg, Waterberg and Ohrigstad area. However, the following aspects concerning the classification of the zonal vegetation in the SCPE separates it from all the other Mountain Bushveld types:

- *Acacia tortilis*–*Dichrostachys cinerea* Arid Northern Bushveld should be seen as part of the proposed class of *Panico maximi*–*Acacietea tortilis* (Winterbach *et al.* 2000) — it also has a link with the lowveld of South Africa in the form of tree species such as *Ptaeroxylon obliquum*, *Lonchocarpus capassa*, *Diospyros mespiliformis* and *Combretum imberbe*.
- *Themeda triandra*–*Senecio microglossus* Cool Moist Grassland is representative of the *Tristachya leucothrix*–*Trachypogon spicatus* Class proposed by Du Preez & Bredenkamp (1991)—however, in the case of the SCPE it might be considered as an ecotone between highveld grassland and mountain bushveld.

- Currently the *Kirkia wilmsii*–*Terminalia prunioides*, *Combretum hereroense*–*Grewia vernicosa* and *Hippobromus pauciflorus*–*Rhoicissus tridentata* vegetation types are considered as part of the proposed class of *Englerophytum magalimontanum*–*Acacia caffra* Mountain Bushveld (Winterbach *et al.* 2000). However, this class does not consider the entire range of mountain bushveld types on clay and sandy soils of South Africa. A more inclusive *Acacia caffra* Mountain Bushveld Class is proposed, with an *Englerophytum magalimontanum*–*Acacia caffra* Order on nutrient-poor sandy soils and a *Kirkia wilmsii*–*Acacia caffra* Order on nutrient-rich clay soils. It should be kept in mind that ecological characterisation of classes depends more on soil characters than climate, and therefore these vegetation types can be seen as separate classes. However, a vegetation class should have a wide distribution range (Pignatti *et al.* 1995) and a local class restricted to the SCPE would not be meaningful.
- The proposed *Kirkia wilmsii*–*Acacia caffra* Alliance (Figure 33) is representative of Sekhukhuneland. Diagnostic species for this alliance would be *Aloe burgersfortensis*, *Asparagus sekhukhuniensis*, *Catha transvaalensis*, *Cyphostemma* sp. nov. (Van Wyk 13389), *Elephantorrhiza praetermissa*, *Euphorbia sekukuniensis*, *Hibiscus barnardii*, *Jamesbrittenia macrantha*, *Plectranthus venterii*, *Rhoicissus sekhukhuniensis*, *Rhus batophylla*, *Rhus sekhukhuniensis*, *Stylochaeton* sp. nov. (Siebert 1332), *Vitex obovata* subsp. *wilmsii* and *Zantedeschia pentlandii* (species groups B, D, E, G, H, I and J; Table 1). This conforms to the proposal of Pignatti *et al.* (1995) to use character species with certain uniformity in their geographical distribution.
- Many types of natural vegetation are far less stable than it appears to be, for small transient environmental changes can cause large and long-lasting vegetation change (Trollope 1998; Sprugel 1991). Open Mountain Bushveld which is an unstable form of the Closed Mountain Bushveld, is a result of yet unidentifiable natural disturbance regimes (possibly soil related). In many instances this thesis addresses the phenomenon.

Some of the floristic relationships of the SCPE with other regions are strong and others are weak, which emphasises that, although it can be related to some extent, the SCPE is a too diverse system in its own right to be incorporated in the Mixed Bushveld and should

rather be seen as Mountain Bushveld. Additional support for the proposed recognition of the SCPE as a separate vegetation type, namely Mountain Bushveld, include the following:

- One of the characteristic trees in this type of bushveld is *Kirkia wilmsii*, a species that is relatively rare in other parts of the Mixed Bushveld;
- Almost pure grassland covers some of the mountain slopes in the region;
- Vegetation between the north- and south-facing aspects of the mountains are often strikingly different and floristically quite unlike other parts of the Mixed Bushveld;
- Intriguing vegetation anomalies associated with heavily eroded soils are present throughout the region;
- Species endemic to the region, for instance *Catha transvaalensis* and *Euphorbia sekukuniensis*, are abundant and are diagnostic species for certain major groups;
- Geology, and subsequently soil, is an important natural factor in the region, affecting both vegetation structure and composition.

This description and classification of the syntaxa of SCPE is a contribution towards the understanding of the vegetation and flora in the SCPE region as a whole. The identified vegetation units should be considered as ecologically interpretable communities for the area concerned at a given point in time. It has been claimed that no equilibrium exists in African savannas (Sprugel 1991), because individual disturbances are too large or infrequent and climate changes interrupt any movement toward equilibrium. However, not all workers are in agreement with this view. It is nevertheless important to note that the communities identified in this thesis were the “natural” plant communities for 1998 and 1999 seasons and the species composition may well change in future. The influence of climate on savanna plant communities has been described in detail on several occasions (Van Rooyen 1978; Bredenkamp 1982; Siebert 1998) and will therefore not be repeated here.

12.2.2 Ordinations

Plant communities of the SCPE can be related to certain environmental factors, which are illustrated along gradients in the various DECORANA scatter diagrams. This phenomenon is supported by the theory that local diversity and community patterns are strongly

influenced on temporal and spatial scales by regional processes such as immigration (Loreau & Mouquet 1999) and changes in rainfall, soil nutrients, fire regime and herbivory (Skarpe 1991), with geology and topographic diversity explaining much of the remaining variance (Holland 1978; Schulze & McGee 1978).

This indirect gradient analysis is an exploratory approach which aims to produce hypotheses about possible environmental factors causing the observed gradients in the data. Results of the ordinations not only confirm the classification, but also reflect floristic and associated habitat gradients. Floristic variation is explained by climate, hence the occurrence of grasslands in the moist, cool southern region, mountain bushveld in the moderate central region and thornveld in the dry, warm northern part of the SCPE. Rainfall patterns have a direct consequence as continuous water source in the case of mountain grasslands, permanent water bodies/sources in the case of wetlands, and drought stress in the case of bushveld. It is known that the amount of and availability of soil moisture is not just a simple function of precipitation. Soil moisture availability is affected by factors such as surface drainage, evapotranspiration due to high temperatures and moisture retention. However, a suspected correlation between plant distribution patterns and environmental factors, such as soil moisture, is no proof of a cause-effect relationship and should ideally be tested by experimentation (Heikkinen *et al.* 1998).

However, on a larger scale the ordinations strongly support a continuum instead of several distinct vegetation units for the SCPE. It may also be interpreted that the vegetation units occur in certain regions of the gradient, and that the ecotones between units may be narrow or wide, forming a complex mosaic of continuity and discontinuity (Whittaker 1977). This is due to the gradual change of soil moisture availability along the slopes, aspect, soil types and rock cover of the landscape. Dynamics of soil moisture in the SCPE landscape clearly control the structure of the community at the first physiognomic level. This is a common phenomenon in savanna areas (Skarpe 1992; Solbrig 1993) and on southern African serpentinites (Proctor & Cole 1992). It is in an indirect effect as a source of soil moisture that rainfall has its most profound influence on the major vegetation gradients of the SCPE (e.g. Figure 8, 10, 12, 14 and 16).

For instance, as water stress is reduced, conditions become more favourable, and productivity would normally rise (Specht & Specht 1999). This effect is commonly observed between the north and south facing slopes of hills in the central area of Sekhukhuneland. As water stress, in terms of the relative amounts of evaporative demand increases on the north slopes, drought hardy species become prominent. The floristic composition of this Mountain Bushveld has a definite relationship with the Arid Northern Bushveld. However, on the cool, moist south-facing slopes the Mountain Bushveld shows a strong floristic affinity with the Afromontane elements of the Rock Outcrop Vegetation.

Surface drainage, evapotranspiration, moisture retention, and hence soil moisture availability, is determined by the soil type, which in turn was determined by the topographical position of the substrate during pedogenesis. The gradients of the ordination scatter diagrams are therefore an indirect consequence of topography and climate. The topography and climate gave rise to a diversity of soil types, of which most have a clay base due to the mineral properties of the mother rock. It can be concluded that the clay content and moisture index of the soils are the most important components of the ecosystem affecting the vegetation.

The texture and the type of clay minerals in the soils of the SCPE determine the percentage moisture of the soils and therefore it can be said that the:

- southern region where rainfall is high and evenly distributed, soils have sufficient available moisture for growth and therefore variability in vegetation composition on different soils are small;
- drier central and northern parts have differences in vegetation as changes in soil texture become marked, and the moisture-demanding species move from the clay soils to the more loamy and sandy soils;
- arid, most northern part, has small differences in vegetation, as different textured soils are all water deficient and become inhabited by the same drought-resistant species.

Catenal differentiation also plays an important role in that hill scarps, slopes and valleys all have different soil types and mineral concentrations (Chapter 5). Preference of plant communities for specific habitats in the Klaserie Nature Reserve (Witkowski & O'Connor 1996) compares well with the situation derived from the ordinations for the SCPE. The similarity in tree species composition and resulting topo-edaphic preferences between the two studies supports the results in this thesis, to name but a few:

- Vegetation types characterised by *Acacia nigrescens* in both studies prefer deep soils of relatively flat areas;
- Vegetation types characterised by *Spirostachys africana* in both studies prefer seasonal watercourses with clay soils;
- Vegetation types characterised by *Combretum imberbe* in both studies prefer lowlying areas with high silt content;
- Vegetation types characterised by *Pappea capensis* in both studies prefer rocky hillsides with gravel soils.

Although the various ordinations allowed a meaningful description of floristic variation locally, it does not fully identify the responsible environmental gradients. This can be explained through a holistic approach, because the region has an extremely heterogeneous environment resulting in intermingled major vegetation types with ecotones. For example, if the geology is considered, grasslands tend to be restricted to norites, mountain bushveld to pyroxenites, and mixed bushveld to alluvium.

As stated before, the study area lies on soils and exposed rock derived from related ultramafic substrates (Wild 1974; Roberts & Proctor 1992). It has been shown that the vegetation of rock outcrops is specifically adapted to their chemical environments (Morrey *et al.* 1989; Bredenkamp & Deutschlander 1995; Tyler 1996). It is therefore speculated that in addition to soil moisture availability, the chemistry of the study area's rocks, and subsequently soils, as well as the soil structure and soil depth, are responsible for the unique plant communities that occur in this region (this is discussed in sections 12.3.2 and 12.3.3).

12.2.3 Vegetation processes

Many studies have shown that the vegetation of serpentinite contrasts markedly with adjoining non-serpentinite vegetation in its structure (e.g. Wild 1965; Davie & Benson 1995; Brooks 1998). This is because the species have adapted to the chemical composition of the soil and the harsh, shallow-soiled physical environment of serpentinite outcrops (Baker 1981; Reeves *et al.* 1983; Morrey *et al.* 1989). The areas of the SCPE that are most influenced by soil chemistry are recognisable as areas with stunted and/or depauperated vegetation. It is clear that soils from serpentineferous areas are a distinct and important factor in plant ecology.

The vegetation classification emphasized the dominance of grasses in the herbaceous layer of plant communities on ultramafics, a phenomenon also characteristic of the vegetation on the ultramafics of Zimbabwe (Wild 1974; Guy 1975; Proctor & Cole 1992). Grass-tree coexistence in the SCPE, like other southern African savannas, is driven by the limited opportunities for tree saplings to escape both drought and the flame zone into the adult stage (Higgins *et al.* 2000), and hence is influenced by a complex network of local and large-scaled factors, notably water availability, herbivory, fire, soil texture, nutrients, phenological changes and anthropogenic interference (Cole 1986; Skarpe 1992; Breshears *et al.* 1998; Briske & Henderson 1998; Jeltsch *et al.* 1998; Lock 1998; Bjornstad *et al.* 1999; Higgins *et al.* 1999; Fischer 2000).

The *Kirkia wilmsii*-dominated vegetation of the ultramafic mountain slopes is dominated by broad-leaved woodlands and as a result of its structure should not be seen as Mixed Bushveld, but rather a type of Mountain Bushveld. Woodlands are common on ultramafic soils (Jaffrè 1980), and ultramafics should not always be seen as open grassland areas (Wild 1965). Guy (1975) and Chiarucci (1994) has reported woody coenoses that grow almost exclusively on sites with special pedo-morphological characters and do not show the extremely stunted woody species and grassland dominated communities typical of continents where the flora evolved before the ultramafic rock was exposed.

In addition, the classification of the vegetation indicates that long-term intensive grazing and wood harvesting has modified the vegetation structure of this dry bushveld in certain

areas. Vegetation structure of savanna ecosystems can strongly be influenced by land-use. Altered species composition, decreased biomass and decreased species richness have been recorded in the woody communities of southern African communal grazing lands (Higgins *et al.* 1999). Briske & Hendrickson (1998) explain changes in vegetation structure, as a result of over-utilization, as an ecological consequence to minimise the effect of selective grazing/harvesting. This change in vegetation structure will reduce the probability of localised population extinction caused by long-term selective grazing/harvesting. Thus we can speculate that the dry bushveld areas of the SCPE are event-driven systems, and should the disturbance be removed, it will return to a type of savanna that will be determined by the environmental factors at that given time (Du Plessis 2001).

It has been shown that a good relationship exists between the floristic and structural-physiognomic classification of vegetation (Werger & Sprangers 1982). This implies that species composition is of the same level of importance as the structural-physiognomic feature. In turn this indicates that an area such as Sekhukhuneland, where the structural-physiognomic feature changes frequently, has a rich alpha diversity. This was supported by the findings of the phytosociological study. Areas with a heterogeneous environment has a varying structural-physiognomic feature and hence a rich plant diversity.

Interestingly, species diversity of vegetation anomalies is high when compared with bushveld vegetation types in the region (Tables 5, 10, 16, 21 and 26). The reason being that the vegetation anomaly has many open niches where the seed from plants in surrounding areas can germinate. Unlike favourable habitats, there are usually not many species dominating in a vegetation anomaly. Although the species richness of anomalies is lower than that of surrounding areas, the species diversity is high in comparison.

Foliar Projective Cover (FPC) determined for the vegetation structure on anomalies is quite different from the surrounding vegetation (Specht *et al.* in press). Where open bushveld usually has a FPC of Σ (20% overstorey and 30% understorey), an anomaly tends to have a FPC of Σ (5% overstorey and 45% understorey). The overstorey is comprised of scattered, sparse shrubs and the understorey by a few perennial and annual forbs and grasses. As the average height of a plant community increases, so does the FPC (Specht &

Specht 1999). Vegetation anomalies have a much lower average height than surrounding vegetation due to the stunting effect of the soil. A lower FPC implies lower soil moisture, because more bare areas are exposed to the sun. This in turn implies that a harsher environment is induced, which worsens the hostile effect of the soils towards the colonisation of the area by plant species from surrounding moister areas. This also explains why Karoo elements (*Pterothrix spinescens*, *Gnidia polycephala*, *Jamesbrittenia atropurpurea*, etc.) found these soils so attractive, because the soil moisture is probably the same as that which is experienced in the arid parts of the Northern Cape. Typical bushveld species prefer the moister slopes of hills and mountains. The absence of microphyllous thornveld on the anomalies, which are usually typical on clay soils in the valleys of the SCPE, can possibly be ascribed to the low nutrient levels and high Mg-levels found in the soils of anomalies.

Wild (1974a) reported that there is strong field evidence that where nickel values are low and the Mg:Ca ratio is high, pronounced vegetation anomalies are produced in the absence of a nickel effect. It is speculated that the scattered treeless hills among a majority of tree-covered hills in Sekhukhuneland can possibly be ascribed to extremely high Mg:Ca ratios rather than toxic effects of metals. A rock analysis of the treeless Mashishi Hill showed similar concentrations of Mg and relatively high Mg:Ca ratios comparable with that of serpentinite (Appendix 1).

12.2.4 Disturbance

Frequent droughts, extensive plant harvesting and unsustainable former land-use have left its scars in the SCPE. An analysis of the size structure in southern African communal lands suggested that grazing lands have a reduced capacity for regeneration that consequently predicts future species losses (Higgins *et al.* 1999). Large areas of the study area have already reached this stage.

The Afromontane Forests (<1 000mm/annum) in the SCPE are not as diverse as in the past due to over harvesting. It is doubtful whether 'disclimax' in forests created through past land use activities will ever develop into stands similar to the previous state, given the present state of fragmentation and continued disturbance taking place within these

ecosystems (Roth 1999). Not only the forests, but also the mountain bushveld vegetation types are experiencing the same problem.

The ongoing unsustainable destruction of the woody canopy of the Bushveld plant communities is detrimental to its future recovery, as it has been shown that the woody canopy of communities in the SCPE region has a nurse plant effect on younger seedlings of trees and especially succulents (Thrash 1998). Due to continuous non-sustainable harvesting of indigenous trees in this region no more protection is given to seedlings during fire. Hence, the main factor for vegetation distribution and depletion during the past 50 years has possibly been anthropogenic. Small-scale disturbances act to increase the range of environmental conditions under which trees and grasses coexist as savanna (Jeltsch *et al.* 1998). However, large-scale disturbance, such as over-harvesting of trees, result in annual grasslands or bush encroachment by certain shrubs. According to Roth (1999), thorn scrub, which is structurally similar to the *Acacia tortilis* dominated shrublands of the northern part of the SCPE, is a form of secondary climax created through past land-use activities in areas once bearing more diverse dry woodlands. In semi-arid regions where event driven systems prevail, sustained disturbance will alter species composition to such an extent that the original, viable composition may never be regained (Westoby *et al.* 1989).

Alien species primarily invade areas of high indigenous species richness (Lonsdale 1999; Stohlgren *et al.* 1999), such as the grasslands of southern Africa. *Acacia dealbata*, an alien tree from Australia, has invaded large areas of the Roosenekal Subcentre and especially the adjacent Steenkampsberg. Removal of these trees is totally dependent on the owner of the land, with no large-scale projects being implemented. It is an ironic situation, with people 50 km to the north extensively chopping down indigenous bushveld trees for firewood. Future legislation might counter this indirect disturbance regime.

Species richness for small areas are positively related to the isolation of a plant community (Bruun 2000), which means that should rocky outcrops be disturbed, the species richness will be influenced negatively due to the long distances between similar plant communities. Therefore certain vegetation units, for example Rock Outcrop Vegetation and the associated habitats, will need special attention and should be considered for

conservation purposes. Certain SCPE plant endemics of the rock outcrops are restricted to specific communities and these areas therefore require immediate attention in the light of the rapid developing mining industry of the region.

Certain SCPE plant endemics of the Open Mountain Bushveld are restricted to specific plant communities with a restricted distribution on heavy metal soils. Conservation of many localities of the same plant community is the most effective approach for the protection and survival of endemics of fractal landscapes such as ultramafic substrates (Witkowski & Liston 1997; With & King 1998; Harrison 1999). In the light of the intensive mining of areas rich in heavy metals, certain vegetation units or areas need immediate attention and should be considered for conservation purposes, as it may provide detailed historical knowledge for the application of ecosystem management (Swetnam *et al.* 1999).

No formal measures are in place for the protection of sponges in the major water catchments of the SCPE. Seepage areas are under threat on the Leolo Mountains. Increasing overgrazing and farming activities on the Leolo Mountains might cause future destruction of this important endemic area.

Highly degraded ecosystems, especially those in semi-arid regions, do not recover once the stress loads are lessened (Rapport & Whitford 1999), for these systems are event-driven (Ellis & Swift 1988). If the disturbance was drought, the species composition alternates between this event and the one during wetter periods. However, if this species composition is changed as a result of persistent human disturbance, the vegetation might be unable to recover to its so-called stable state. This is quite obvious in Sekhukhuneland, with old fields, heavily grazed areas, open cast mines and mine dumps covered by an annual grass layer and alien species infestations in the Closed Mountain Bushveld and Arid Northern Bushveld.

Locally dominant species are usually the most abundant during early successional phases and locally subordinate species are usually restricted to very harsh conditions (Olf & Bakker 1998). This phenomenon is a possible explanation for the Closed Mountain Bushveld-Open Mountain Bushveld gradient in the SCPE. In the Closed Mountain Bushveld, that has a low disturbance and late successional phase, the most common species

are regionally dominant and include *Acacia nigrescens*, *Commiphora mollis*, *Acacia senegal* var. *leiorachis*, *Combretum apiculatum*, *Kirkia wilmsii*, *Terminalia prunioides*, *Clerodendrum ternatum*, *Barleria saxatilis*, *Psiadia punctulata*, *Sansevieria hyacinthoides*, *Aristida canescens*, *Enneapogon scoparius*, *Heteropogon contortus* and *Panicum deustum*. Open Mountain Bushveld can be divided into three different successional phases. The first is the vegetation of mountain slopes that is induced by a dry environment (form of natural disturbance) and include species such as *Combretum apiculatum*, *C. molle*, *Dombeya rotundifolia*, *Kirkia wilmsii*, *Ozoroa spahaerocarpa*, *Acacia ataxacantha*, *Enneapogon scoparius*, *Eragrostis chloromelas*, *Panicum maximum*, *Justicia protracta*, *Thesium burkei*, *Tephrosia purpurea*, *Pellaea calomelanos* and *Aloe castanea*. Locally dominant species are starting to colonise these dry habitats. The second successional phase is the Open Mountain Bushveld of the valleys, which is kept in this state by continuous sheet erosion during the rainy season. Both local dominant species like *Bolusanthus speciosus*, *Combretum hereroense*, *Aloe burgersfortensis*, *Rhynchosia komatiensis*, *Andropogon chinensis*, *Aristida adscensionis*, *Eliomurus muticus*, *Loudetia simplex*, *Diheteropogon amplexans* and *Heteropogon contortus* and subordinate species like *Dicoma gerrardii*, *Tinnea rhodesiana*, and *Rhus keetii* are part of this system. Eroded donga systems are the third successional phase and are characterised by mainly subordinate species that prefer the harsh environment to escape competition. These species are *Gnidia polycephala*, *Pechuel-Loeschea leubnitzia*, *Nuxia gracilis*, *Rhus sekhukhuniensis*, *Stipagrostis hirtigluma* var. *patula*, *Euclea* sp. (Siebert 934), *Dicoma gerrardii*, *Jamesbrittenia* sp. (Van Wyk 13026), *Ledebouria marginata* and *Polygala* sp. (Siebert 449).

Throughout the SCPE the remaining natural populations of plants and animals are under intense pressure from exploitative land uses that can cause the local extinction of certain plant species due to the smaller range size and moderate to low local abundance. This is in accordance with the hypotheses on the relationship between distribution and abundance (Johnson 1998). There are certain areas with specific syntaxa (plant communities) that need special attention and were identified for consideration as a priority for conservation purposes. Some plant endemics of the southern region of the SCPE are restricted to specific syntaxa and these habitats therefore require urgent attention for conservation as a result of

the rapid expanding mining industry, a common threat to southern Africa's rich phytodiversity (Dold & Johnson 1997).

12.3 Plant-soil associations

12.3.1 Maize experiment

It was observed that maize grown in the chromitite outcrop soil mixture became severely stunted (low Average Biomass Production) as a result of two factors. The first factor is directly related to interspecific competition for nutrients, with containers with eight seedlings showing retarded growth. However, the same was witnessed for the control. The second factor relates to soil toxicity. Cr and Ni are responsible for a reduction in biomass production. It is claimed that Cr and Ni limits the growth of maize indirectly by inducing phosphate deficiency (Robinson *et al.* 1935; Soane & Saunder 1959).

The study of the maize on typical ultramafic soils shows that areas in the SCPE have Cr and Ni available for uptake by plants, as low concentrations of both were accumulated by maize and symptoms characteristic of Ni and Cr toxicity were visible in maize leaves. Although Cr toxicity was not as intense as expected, the results predicted potential Cr toxicity in the SCPE, because many soils of the region contain high levels of total Cr in the subsoil.

As no leaf splitting was noted in the experiment, there was apparently no Ca-deficiency, which supports a theory that the ultramafic soils of Sekhukhuneland are Ca-rich and different from those of the Great Dyke in Zimbabwe; maize grown in serpentineferous soils of the Great Dyke displayed leaf edge splitting due to Ca deficiency (Cooper 1986). Maize seedlings had higher concentrations of Ca in their leaves than the levels of the ultramafic soil samples used for the experiment. This phenomenon possibly buffers the heavy metal toxicity to a certain degree, as high Ca concentrations in plant tissue is known to protect plants against heavy metal toxicity (Proctor & Cole 1992).

After the first two weeks, the root development of the maize seedlings grown in the toxic soils was stunted and the accumulation of the heavy metals was at its highest levels in the

roots (Figure 27). It is speculated that a kind of exclusion mechanism was initiated in the third week, with the root length catching up to that of the control and the heavy metal concentrations dropping slightly. Another reason for lower heavy metal concentrations in the root tissue during the third week could possibly be the depletion of heavy metals in the roots' soil environment as a result of intense uptake during the first two weeks and translocation to the leaves during weeks 3 and 4.

The maize experiment was motivated by the work of Cooper (1986) on the Great Dyke and speculations by Siebert (1998) that Cr levels in the soils of ultramafic rocks are available for plant uptake. However, once again no conclusive results were obtained with regards to Cr accumulation by plants. The results obtained are best supported by a study conducted on seven common vegetable crops by Zayed *et al.* (1999). They found the following with regards to Cr accumulation:

- Cr (VI) is converted in the root to insoluble Cr (III);
- Translocation of both Cr forms from roots to shoots is extremely limited;
- Accumulation of Cr by roots was 100-fold higher than in shoots.

Chromium is known to interact with Fe nutrition in plants (Bonet *et al.* 1991) by increasing its availability. This explains the extremely high concentrations of over 1 000 mg/kg of Fe in the roots and leaves of *Diheteropogon amplexans* in the natural environment and is supported by high levels in the other two indigenous grasses. These indigenous species, like *Zea mays*, belong to the same family as the Poaceae, and although maize is a possible indicator that high Cr levels are available for plant uptake, none of these indigenous grasses accumulated significant levels. It is a more likely scenario that Cr-induced Fe accumulation is the limit of the Cr effect in natural systems.

12.3.2 Catena soils

The physical and chemical properties of soils (edaphic factors) can elicit sharp discontinuities in the distribution of plants, and soils of highly contrasting lithological origin exert marked selective effects on floras (Kruckeberg 1969; Van Wyk & Smith 2001).

Across the ultramafic catena studied, soils vary considerably and harbour different plant communities with quite different species composition. This is because plants are adapted to different chemical concentrations and soil structures. There are various possible causes of the chemical concentrations and structure of the soils. The most important are the pH, Mg:Ca ratio and nutrient levels. Heavy metal concentrations are also important and are discussed in section 12.3.3.

The formation of organic floor humus after establishment of vegetation on ultramafic soils is certainly a reason for top-soil acidification and subsequent Mg leaching (Roberts & Rodenkirchen 1995). In similar studies conducted on the soil profiles of Australian serpentinites, it was found that pH becomes more alkaline (rises) with increasing depth (Forster & Baker 1995). It was also shown that as the soil depth increases, Ca concentration decreases and Mg increases, giving rise to a higher Mg:Ca ratio. The binding strength of Mg at humic exchange places is lower than that of Ca. As in Australian ultramafic soils, Mg moves (leaches) down the soil profile in alluvium soils of Sekhukhuneland. A similar sequence of events was most probably responsible for the leaching and subsequent donga formation (erosion) in the lowlands of Sekhukhuneland. This is supported by the concretions which are exposed by erosion. These concretions consist of 27% silicon, 17% magnesium, 13% calcium and 13% aluminium (Figure 24). Magnesium leaching weakens the structure of the top-soil and extensive soil erosion takes place – a natural phenomenon which is enhanced by prolonged overgrazing and trampling.

Chemical and physical analyses of soils derived from ultramafic rocks of the SCPE region have demonstrated similarities with some soils of the Barberton Greenstone Belt (Morrey *et al.* 1991). However, differences in chemical and physical characteristics between soils of both regions were evident (Table 37), and are likely to have resulted from differences in geochemistry, elevation and climate.

Soils of certain mountain slopes of the SCPE have Ca concentrations which are similar to those that can be expected for calcretes (Specht *et al.* in press) and gypsum (Wild 1974c). Although the Ca-rich mountain slopes of the SCPE are not calcrete or gypsum soils, they

harbour a rich plant diversity with many SCPE endemics, SCPE near-endemics and Red Data List taxa. In addition the flora is ecologically distinctive and the dwarfing of woody species very characteristic (certain plant communities of the Open Mountain Bushveld). It is speculated that these soils have a similar chemical composition to the dolomites of the Wolkberg Centre of Plant Endemism (Van Wyk & Smith 2001).

Vegetation anomalies on serpentinites have been shown to be a result of soil infertility (Brooks 1987). Fertility levels of P, K and S are higher in Sekhukhuneland soils (Appendix 3) than on serpentinites (Morrey *et al.* 1989; Balkwill *et al.* 1995; Forster & Baker 1995). However, the anomalies in Sekhukhuneland have low nutrient levels, and although the average nutrient level for the whole SCPE is higher than that of serpentineferous areas, the anomalies have similar levels and subsequent stunted vegetation. The heterogeneous geology of the SCPE gave rise to diverse soil patterns, and subsequently areas with high nutrient levels, especially the lower mountain slopes.

The pH levels for the ultramafic soils of the SCPE are more alkaline than the levels known for serpentinite. Under high rainfall conditions soils tend to be acidic, but where leaching is not severe under lower rainfall regimes, such as is the case in the SCPE, soils are often decidedly alkaline (Rattray 1963). Similar to the results obtained by Wild (1974a) for the Great Dyke, in Sekhukhuneland two types of ultramafic rocks are present, namely those with high Mg:Ca ratios and those with high Ca levels (Appendix 2). Hence, this higher soil fertility, higher Ca-levels and more alkaline pH levels in certain areas of the SCPE are not typical for serpentineferous areas and indicate that the habitats in Sekhukhuneland are even more diverse than serpentinite areas, as both serpentine and non-serpentine (dolomite-related) characteristics are intermingled.

12.3.3 Metal accumulation

Thresholds of hyperaccumulation of heavy metals have not yet been officially formulated, but it can be explained that 1 µg/g of gold in plant material might well represent hyperaccumulation since this level is probably a few hundred times the normal concentration of this element in soil (Brooks 1998). However, hyperaccumulation of heavy metals has been arbitrary defined as the accumulation of a heavy metal to concentrations of more than

1 000 $\mu\text{g/g}$ on a dry matter basis in above ground plant tissues (Brooks *et al.* 1977). If geochemical associations in the soil are reflected in the plant material, then the accumulation is indicative of passive uptake by the plant without specific accumulation or exclusion (Brooks & Yang 1984).

The main interest in heavy metals of the SCPE arose from the high levels of Cr in its soils. Despite high total Cr concentrations in ultramafic rocks, and subsequently soils, of the SCPE, its toxicity in plants is rare in the field, because its plant availability is generally low (Kimbrough *et al.* 1999). Soil Cr concentrations are largely determined by parent material, but total soil Cr content is of little relevance to plant uptake because most is present as insoluble Cr (III) at normal pH (Wild 1974b; Bartlett & James 1988; Sumner & Naidu 1995), which is mostly the case in Sekhukhuneland.

Chromium can exist in soil solution in a number of oxidation states, the dominant state being determined by both the E_h and pH of the soil environment (Rai *et al.* 1989). Under normal soil pH and E_h conditions, Cr (VI) species are anionic and are generally mobile in most neutral to alkaline soils. In acidic soils Cr (VI) is removed from the solution by adsorption on to positively charged sorption sites (Zachara *et al.* 1989). Cr (VI) is also rapidly reduced to Cr (III) by Fe (II) minerals and organic compounds under acidic conditions (Hughes & Noble 1991). It is speculated that this may be the case in the SCPE, which would explain the low levels of available Cr.

Chromium (VI) is the source of plant available chromium (Nriagu & Nieboer 1988). The argument in the previous paragraph supports the lower Cr accumulation on mountain slopes, because Cr (VI) is rapidly converted to the insoluble Cr (III) compounds by organic matter (acidic). However, the lower the pH, the greater the solubility in the soil and the higher the accumulation of heavy metals such as Ni by plants (Sumner & Naidu 1995; Steyn *et al.* 1996). Nickel moves from the insoluble pool into the soluble pool in the soil when it is taken up by plants (Balkwill & Burlin 1995). Nickel is able to use the calcium transport proteins to facilitate its uptake into the plant (Antonovics *et al.* 1971). Calcium is limiting in serpentineferous soils, thus it could be expected that more Ca-ports are open to enhance the

Ca-uptake and subsequently Ni-uptake. This was not the case in the Sekhukhuneland study area and Ni was not markedly accumulated.

As is the case with ultramafic soils in Australia (Forster & Baker 1995), heavy metals do not appear to mobilise down the soil profile, but is transported via the different soil groups onto the alluvial plains. Where surface soils are exposed in the eroded areas, such as certain parts of the Steelpoort River valley, Cr (VI) mobility in subsurface soil horizons are less likely to be retarded due to the absence of organic matter. Hence, the higher uptake of Cr by plants growing in the dongas of the valleys. However, the pH is also lower in these areas and subsequently inhibits Cr accumulation to the relatively low levels recorded for this study as a result of the reduction of Cr (VI) to the insoluble Cr (III). High levels of Fe (II) minerals might also have a binding effect.

Concentrations of elements in plant material of species growing naturally on ultramafic soil in Sekhukhuneland show that species are unable to totally isolate themselves from the unusual chemical composition of the soils. Many studies have been done on the physiological methods whereby plants exhibit tolerance or react to heavy metals (Gabbrielli *et al.* 1995; Mesjasz-Przybylovics *et al.* 1995; Mattioni *et al.* 1997; Pletsch & Charlwood 1997; Takuwa *et al.* 1997; Chardonnens *et al.* 1998; Zheng *et al.* 1998; Dannel *et al.* 1999; Pandey *et al.* 1999; Przymusinski & Gwozdz 1999; Schickler & Caspi 1999; Wollgiehn & Neumann 1999; Yamaguchi *et al.* 1999). In a scatter diagram of the nutrient level versus the heavy metal concentration of all plant material collected along the catena, it is shown that metal uptake increases as nutrient uptake decreases (probably due to low soil fertility). The reason for this remains unclear as element levels alone are inadequate for understanding ultramafic tolerance and need to be interpreted in the context of the nutrient requirements and tolerance of each species. As this and other studies have shown, ultramafic tolerance can be achieved by species differing markedly in the heavy metal levels of their tissues.

Normal linear relationships between soil concentration and plant uptake of nutrients and Mg was recorded for the catena. However, the same trend was not evident for the heavy metal concentrations and a noteworthy phenomenon was recorded for the study area. As the metal concentrations in the soil increases, the levels in the plants decrease. This was

investigated further and it was found that the plants take up heavy metals from the soil up to a certain threshold level, where after an exclusion mechanism switches on to prevent excessive uptake and subsequent toxicity. Hence, the plants of the study area can be seen as excluders of heavy metals when a specific soil concentration level is reached. The critical levels are different for different elements.

It is known that certain plants accumulate up to four times higher calcium concentrations in their tissues to counter the toxic effects of heavy metals (Robertson 1985; Brooks 1987). Uptake of calcium is not related directly or otherwise to magnesium, but rather that magnesium affects uptake of other nutrients (Brooks & Yang 1984). The Mg:Ca ratio is in almost all cases higher than 1 in serpentineferous soils (Johnston & Proctor 1981), but the contrary is true in plants, where Ca concentrations tend to be higher than Mg concentrations (Konstantinou & Babalonas 1996). It has also been shown that plants can be calciotropic, especially succulents, which means they are able to accumulate and store calcium in their tissue saps (Meyer & Popp 1997). A more likely scenario for the higher Ca concentrations in plant species from the SCPE, therefore, possibly relates to the biological Ca-cycle. Foliar concentrations of Ca invariably exceed those of Mg. Subsequently the plant species analysed in the present study (these are found on both ultramafic and non-ultramafic soils), have higher Ca than Mg foliar concentrations, but have lower foliar concentrations of Ca than those higher plants restricted predominantly to ultramafic soils (Brooks & Yang 1984; Morrey *et al.* 1989) (similar trends were found by Lee *et al.* (1995)). This could be ascribed to the lower toxicity of SCPE soils.

In addition, the presence of savanna on the dolomites of the adjacent northeastern Drakensberg Escarpment (Wolkberg Centre of Plant Endemism) also reinforces the floristic relationship which exists with the SCPE. The arid dolomitic areas of the Wolkberg Centre share many near-endemics with the SCPE. The floristic similarities may be explained in part by the high concentrations of Mg and Ca in both the dolomite-derived soils of the Wolkberg Centre and norite/pyroxenite-derived soils of certain mountain slopes in the SCPE.

12.4 Phytogeography

12.4.1 Local speciation

The extreme diversity of landscapes in the study area is reflected in the diversity of its botanic composition. Diversity increases with altitude and is highest on the grassy slopes of the mountainous areas in the south. In the bushveld areas, rocky outcrops and footslopes of hills have lower diversity, but midslopes of hills and valleys have higher diversity of almost the same magnitude as the grasslands. The diversity of the study area must not be underestimated, as floristic elements from the adjacent Northeastern Mountain Grassland, Mixed Bushveld and Afromontane Forests are well represented. In addition the study area has an endemic flora of its own, and floristic relationships with the Eastern Cape forests, Northern Cape Kalahari thornveld, Northern Province semi-arid Mopaneveld north of the Soutpansberg and the Mpumalanga Lowveld.

In the SCPE soils of ultramafic origin have obviously stimulated the development of syntaxa adapted to the specific soil conditions and have created refugia for taxa from other areas, with high concentrations of certain elements, notably heavy metals. Such a plant community (syntaxon)-soil association on ultramafic substrates has previously been identified for southern Africa, on the Great Dyke of Zimbabwe (Werger *et al.* 1978) and the Barberton Greenstone Belt in South Africa (Morrey *et al.* 1989). Due to the ultramafic nature of the serpentinitized harzburgite, pyroxenite, anorthosite and norite of the SCPE, many taxa of the study area are uncommon or absent in other savanna areas of southern Africa (Siebert 1998). Variation in the plant community can therefore be seen as synchronic or ecological (factors acting in the present) as was indicated with the scatter diagrams of the ordinations (section 12.2.2) (Pignatti 1994).

However, variation in plant communities can also be ascribed to historical or diachronic factors (Pignatti 1994). Many plant communities in the SCPE are rich in endemic species. Plant endemics and distribution patterns are a direct consequence of the earth's historical phytogeography (Stott 1981; Major 1988). For instance, many plants in the northern hemisphere exhibit endemism and distributions which correlate with past glacial advances (Stuessy 1990). Endemism on the ultramafic soils of Sekhukhuneland is extremely low when

compared with other ultramafic areas of the world, for instance Cuba (Reeves *et al.* 1999) and New Caledonia (Jaffre 1992). Time on the million year scale (possibly since the Miocene), without glaciation, is necessary for speciation processes to take place on ultramafics, as the surface cover of these soils are well out of proportion to the land area covered by other soils of the same floristic region (Reeves *et al.* 1999). Croizat (1968) indicated that the dispersal of an endemic taxon is never less complex than the historical geology of its substrate. However, Balkwill *et al.* (1995) has shown that a stronger similarity exist between true serpentinite floras of Mpumalanga and those grassland areas of other parts of Mpumalanga, than with other serpentinite areas of southern Africa such as the Great Dyke of Zimbabwe. Admittedly these two serpentinite areas are quite far apart.

There is some evidence that endemic taxa of the eastern Rustenburg Layered Suite have evolved as a result of a neoendemic process due to the presence of nearby possible precursors which might have led to recent speciation to become operative (Siebert 1998). It is speculated that the endemic forms of common widespread species are “soil-adapted” neo-endemics which speciated recently, perhaps after the Pleistocene (Brooks 1983; Reeves *et al.* 1983), and has not yet had the time to migrate out of the Steelpoort River valley. It is suggested that these ecotypes developed from common species as a result of the genetic propensity of the latter to colonise ultramafic soils such as serpentinite (Wild 1974a). The presence of physiological races of widespread species on soils rich in heavy metals implies tolerance of metal toxicity.

Sekhukhuneland endemics prefer the Ca-rich soils. Very few endemics were recorded on the Mg-rich chromium outcrops and eroded areas (dongas). Morphologically slightly deviating forms of abundant common species were, however, common to Mg-rich soils—possibly indicating early adaptation and the beginning of speciation. Tolerance of heavy metals by plants of the Sekhukhuneland region is a direct selective consequence of the presence of heavy metals and has a high heritability. According to Kruckeberg & Rabinowitz (1985), populations in non-toxic environments may contain tolerant genotypes preadaptively, so natural variation in the capacity to withstand the metals is present in natural populations. In other words, it is the genetically inherited exclusion mechanisms within indigenous plants (Morrey *et al.* 1989), which counter heavy metal toxicity.

Generally ecologically driven speciation is the result of habitat specific preferences. This has been investigated and confirmed for an endemic species and its widespread congener (Chung & Kang 1996), as well as for two endemics of the same region (Menges *et al.* 1999). In the case of the endemics of the SCPE, open niches of vegetation anomalies drove speciation on an anomalous Ca-rich substrate or Mg-rich substrates. Similar trends have been perceived between especially limestone (Ca-rich) and sandstone, once again for an endemic and its widespread congener (Walck *et al.* 1999), as well as two endemics of the same region (Mustart *et al.* 1994). Like limestone, the soils of mountain slopes of pyroxenite and norite hills are Ca-rich, being almost double that recorded for the growth medium of surrounding soils. Furthermore, the Ca-rich soils have relatively high concentrations of Al, Fe and Ni (typical elements of serpentinite).

The plant taxa from heavy metal soils analysed in this study are recurring members of the flora, and also occur on other phytogeographical distinct associations on uncontaminated soils elsewhere in the Northern Province and Mpumalanga. The ecological amplitude of a species can be wide enough for it to live not only in its usual habitat, but also in less favourable surroundings, where under different conditions a base is provided for further ecological adaptation (Ratray 1963). Physiological races of a species can explain this adaptation. However, it is not yet clear if physiological races of widespread taxa exist for the SCPE.

Species that are totally confined to metalliferous soils are often accumulators and those, which have evolved tolerant and non-tolerant races on and off contaminated soils, frequently behave as excluders (Baker 1981). It can therefore be accepted that no hyperaccumulators of Cr and Ni were recorded for the SCPE, for the majority of species occurring on metalliferous outcrops are probably physiological races belonging to the group defined as excluders. It can, however, also be speculated that species from surrounding non-ultramafic soils are probably accumulators when in rare occasions they do grow on the ultramafic soils. Common plant species on the ultramafic soils of the SCPE are therefore classified as heavy metal tolerant, have developed exclusion mechanisms and therefore perform much better than other local species. These excluders are dominant in the plant

community, although they can grow better elsewhere where they are usually not the dominant species. Most of these plant species appear to have a broad tolerance of shallow, poorly drained, rocky soils.

To give one single explanation for the high degree of endemism in Sekhukhuneland would be impossible, because endemism is the product of a number of interactive environmental and biotic factors. Soils rich in heavy metals have already been discussed. Certain soils in Sekhukhuneland are also rich in nutrients, such as Mg and Ca, and occur in drier areas where nutrients are not significantly leached out. Sharp changes in climate as a result of the region's topography also contribute to endemism. Annual precipitation is for instance an important vegetation determinant in the Mixed Bushveld and can be used to determine the distribution of plant communities (Palmer & Van Staden 1992). In the SCPE the regions that fall within the rain shadow of the Drakensberg Escarpment is a prime example of this. The diverse habitats that result from the varying patterns of high and low rainfall and/or temperature over short distances create ample opportunities for plants to adapt to specific habitats and to give rise to unique floristic pockets restricted to specific geographical regions. One way of analysing this unique flora as a consequence of a heterogeneous environment is to look at the environmental factors that gave rise to the specific plant communities (Chapters 4 to 9).

12.4.2 Local floristic classification

Floristic plant geography is applied to classify the land areas of the earth into floristic areas. Unfortunately, floristic geographers usually adopt such classifications for reasons of convenience, not because analyses of plant distributions have revealed geographic patterns that are inherently hierarchical and hence best described by a hierarchical system.

According to McLaughlin (1992), some of the earliest classifications of land areas into floristic regions were conducted at the beginning of the 1800s. A thorough treatment of the floristic kingdoms and regions of the world is provided by Takhtajan (1986). He refers to floristic areas of any rank as phytochoria and classifies these hierarchically as district, province, region and kingdom. These classifications are hierarchical—smaller areas are nested within successively larger areas. The primary purpose of a floristic classification is

storage and retrieval of information. It is used to determine to what degree the choria defined at lower levels are nested within those defined at higher levels.

A hierarchical classification is also evident for the northeastern Escarpment. However, it is unclear how the SCPE fits into it. The occurrence of Wolkberg Centre elements in the Sekhukhuneland Centre and *visa versa* accentuates the close floristic affinity that exists between these two Centres of Plant Endemism. This implies that although it seems appropriate to classify the Sekhukhuneland Centre as a subcentre of the Wolkberg Centre, it has a strong Zambezan affinity and cannot be classed at the same hierarchical level as the Blyde and Serala Subcentres of the Wolkberg Centre (Matthews *et al.* 1993), because these subcentres are mainly Afromontane. The SCPE lies mainly in the Zambezan Region, with Afromontane Elements. When the families of endemic plant taxa are compared with the ranking of families which predominate in the Afromontane, Grassland and Savanna Biomes (Gibbs Russell 1987), it shows a better association with savanna (Siebert 1998).

Only after all the Centres of Endemism in the northeastern Drakensberg Escarpment have been adequately resolved and their floras described, will it become clear where the SCPE should be classed in a hierarchical classification of floristic regions. The ideal scenario is a main Centre of Endemism for the northeastern Drakensberg Escarpment with several subcentres, similar to the idea proposed by Croizat (1965), concerning the Barberton Node of Diversity. Such a main centre in the northeastern Drakensberg Escarpment may well solve the problem concerning the status of near-endemics on the regional scale.

At present a viable alternative to the hierarchical classification of the Sekhukhuneland Centre under the Wolkberg Centre as a subcentre, is to consider the Sekhukhuneland Centre areas, which are rich in Wolkberg Elements, as transitional zones. Recognising the arid bushveld vegetation of the adjacent Transvaal Sequence, with its similar physiognomy, as floristically different to Sekhukhuneland, further strengthens this alternative. In addition, the demarcation of the SCPE as the land area underlain by the Rustenburg Layered Suite further emphasise its uniqueness, as floristic regions have shown to be associated with specific geological units. The above is suggested because the northeastern Drakensberg

Escarpment has a very rich and heterogeneous flora and no definite lines can be drawn for floristic regions based on existing floristic information.

It is speculated that much of the floristic diversity and vegetation distribution in the savanna of the SCPE can be attributed to the vegetation dynamics and historic evolution of the region, which is influenced by the surrounding flora and continual disturbance by flooding of the Olifants River. Immigration from introduced (human) and regional (Olifants River valley) sources had a considerable influence on the local patterns and species composition of this region. Loreau & Mouquet (1999) have demonstrated that local diversity, community patterns and ecosystem processes are strongly influenced by plant immigration. This is certainly the case for the bushveld of the SCPE with its link with the surrounding flora (Serala, Lowveld, Pietersburg Plateau), continual flooding disturbance (alien species, bush encroachment) and aridity (Karoo, western Rustenburg Layered Suite, area north of Soutpansberg). The history of the region therefore illustrates how the Sekhukhuneland Centre has played a role as a transitional zone for plant migration.

The above argument brings us to the question whether the higher syntaxonomic levels (class or alliance) of plant communities can be used to determine the lower hierarchical levels of Centres of Endemism. Binary (presence/absence) data sets have been used successfully in many biodiversity and phytogeographic studies and will for the foreseeable future remain the source of information for broad-scale analysis of plant diversity and distributions (Kadmon & Heller 1998; Siebert 1998; Van Jaarsveld *et al.* 1998; Van Rooy 2000).

It is for this reason that vegetation and floristic data cannot be brought together in a hierarchical system of classification. The flora is classified on the grounds of species presence/absence, usually at the quarter degree grid scale. However, vegetation classifications work at a different scale, usually plot size and are based on species abundance in plant communities (syntaxa). Since character species have their specific ecology, their presence implies that the members of a syntaxon must correspond to the same ecological space. Syntaxa are therefore not only small floristic units, but also have an ecological meaning. In contrast, centres of endemism are large floristic units, and character species do not necessarily correspond to the same ecological space.

The measure of abundance, namely the number of specimens of each taxon collected, which is used in phytosociological databases, is not considered as practical for biodiversity and phytogeographic studies (Oliver *et al.* 1983). It can be said that the main reason why floristic regions cannot be linked to phytosociological classes, is that the floristic region's definition is based on the occurrence of rare species with restricted distributions and that of the vegetation class on the abundance of common species. Also, vegetation classification does not, at least at lower hierarchical levels, consider the total geographical range of a species, but merely presence/absence in a plot.

Pignatti *et al.* (1995) proposed that associations belonging to a class should be grouped according to a common ecology and be recognised by character species with a similar geographical range. Therefore, the higher syntaxa (class or alliance) should show some relationship with phytogeography as it takes into account the distribution range of the most abundant taxa. However, it also takes into account the ecological species composition, which is usually very specific for endemic species.

In South Africa vegetation classification at the higher levels does not currently take into account the occurrence of local endemic species, but focuses more on widespread, prominent species. The current study takes into account the common ecology of associations with a similar geographical range to argue for the recognition of an Alliance (section 12.2.1). If this alliance is recognised by the broader scientific community, this thesis has brought together phytosociology and phytogeography, as the alliance and the Subcentre of Endemism are likely to have the same geographical range.

However, presently the SCPE will be treated as a Centre on its own. It has levels of endemism and diversity comparable with various other centres of floristic endemism in southern Africa. Its unique geology and associated plant diversity alone indicates its recognition as a Centre of Plant Endemism and a Centre of Plant Diversity when measured against the criteria given by Davis *et al.* (1994). Should the proposed alliance be accepted, we will have a measurable entity to accurately map the extent of the SCPE based on the distribution of specific associations. In addition it will be a good example to illustrate the

importance of phytosociology in the demarcation and lower classification of Centres of Endemism/Diversity.

12.5 Conservation essay

The rapid political, economic and social changes in South Africa have resulted in a critical review of issues such as land allocation, sustained utilisation of natural resources and conservation policies (Smith 1994; Wells 1996; Hackel 1999). In addition, conservation of rare plant populations has become an important dimension of, and central to, the preservation of biodiversity (Smith 1994; Naeem & Li 1997). The argument for conservation of plant populations is determined by a high plant diversity and plant endemism, a high degree of threatened plant taxa, as well as a unique climate and physiography of a floristic region (Prendergast *et al.* 1999; Myers *et al.* 2000).

The study area is a part of South Africa with hardly any formally protected areas; it is also a region where the emphasis is on mining, farming and rural development. The Sekhukhuneland floristic region also has a rich plant diversity and endemism, a high degree of threatened plant taxa, as well as a unique climate and physiography (Siebert 1998; Siebert *et al.* 2002b). This satisfies the *international requirements for the conservation of plant populations* (Prendergast *et al.* 1999; Myers *et al.* 2000) and means attention should be given to the development of conservation plans for the region. However, currently only one conservation area (Potlake Nature Reserve - proclaimed in 1975) enjoys official conservation status in the region. Three conservation areas were proposed for Lebowa (Botha 1983) of which Potlake Nature Reserve would have been located within the SCPE. It is clear that nature conservation in this unique floristic region has lagged behind and there is a need for this neglect to be addressed as soon as possible.

When the state of the environment in the SCPE is considered in the light of current developments in the region, the future looks rather bleak. Pressure from the mining industry and a growing human population are not likely to disappear, nor is it likely that government will spend much money on the development of conservation areas in this relatively small

Centre. Hence, an obligation to develop a conservation area in the SCPE should lie with financially strong parties, such as the mining industry.

In my judgement the future conservation of the SCPE is dependent on the *formation of a partnership for ecosystem conservation* (Franklin *et al.* 1995). This partnership should involve the mining industry and leading, capable agencies such as the provincial nature conservation departments and interested parties. A sound and successful conservation plan would, however, be totally dependent on the participation of a third party, the local people. The attitude of local people towards sustainability and extinction is a rather controversial topic, and should be addressed before an area is conserved (Mace & Hudson 1999).

Land-use change is seen as the most important factor in biodiversity change in the world over the next 100 years (Sala *et al.* 2000). Although the mining industry owns extensive land areas, their activities only impact negatively on the biodiversity of small areas of their property. It is especially obvious when compared with large-scale activities such as commercial afforestation. It therefore seems appropriate to target the land areas of mining companies for conservation actions.

For obvious reasons, no mining company will part with its land. It is suggested that the mining companies, in collaboration with nature conservation agencies and the local people, design a management plan for pristine areas of their land. Such a plan would consider the sustainable utilisation and conservation of these management units, because no-entry for parks and reserves are rejected by large numbers of local people who live off the land (Carruthers 1993; 1994).

The main conservation objective in the SCPE is therefore the sound management of the land. When management units are declared, the carrying capacity of each should be determined. These units should then be managed according to their ability and resilience, and monitored to prevent future loss of important species. Sustainable harvesting of wild and/or endangered plant species should be based on basic principles of economic behaviour and should be properly monitored. This will ensure species protection through control measures to avoid wasting of valuable resources and through financial incentive projects to

realise the monetary value of ecosystems (Hampicke 1994; Medellin 1999; Shogren *et al.* 1999; Gullison *et al.* 2000; Musters *et al.* 2000).

Among the initial expenses will be the training and employment of local people to control the harvesting of natural resources. Sacrifices to be made by the mining companies would be limited to the sustainable use of their land by the local people, a pledge to sell the land for the sole purpose of more comprehensive conservation actions, and to refrain from any development in the pristine conservation areas. This would make the protection of this unique floristic region a relatively inexpensive incentive. If approached in the correct manner, this could be the first step towards a biosphere initiative for the SCPE. Conservation outside nature reserves in hospitable environments in managed landscapes is essential in a species-rich area such as South Africa, because large numbers of plant species are not being protected formally (Wessels *et al.* 2000).

Red Data List information should be used to motivate for the management and conservation of the vegetation and habitats, especially the areas threatened by the mining industry and inappropriate forms of land-use, specifically overgrazing by domestic stock. Baseline data such as this will provide botanists with sites to conduct further studies on rare and threatened plant species (Bevill & Louda 1999; Golding 2001a), which will provide a rough guideline of important botanical regions to conserve formally. Detailed site-specific studies remain a prerequisite before suggestions concerning land-use (mining, farming, conservation, etc.) can be made and work should be based on local SCPE studies such as the work conducted by Knowles & Witkowski (2000). It is also important to remember that species diversity 'hotspots' are rarely congruent for all groups of organisms (Van Jaarsveld *et al.* 1998) and future research might show the importance of other groups of organisms, such as the herpetofauna or lepidoptera. Biodiversity increases ecosystem stability by promoting diversity among species in their responses to environmental fluctuations (Naeem & Li 1997; Grime 1998; Ives *et al.* 1999) and hence, is imperative for successful conservation initiatives.

Statistical analysis incorporating all the threatened and endemic groups can then be used to select fully representative reserve networks for the SCPE (Bedward *et al.* 1992; Pressey

et al. 1999). The establishment of nature reserves or protected areas is one solution to this problem of biodiversity loss; this is best achieved through a land-use stratification derived from a holistic overview. Such a strategic environmental assessment that includes an adequate database of natural features and other land uses (Bedward *et al.* 1992; Wessels *et al.* 2000) should be a priority for conservation agencies in the region. This provides a basis for proper and sound assessment of the region's vegetation, as it includes aspects such as species richness, rarity and habitat preference.

However, to abscond from yet another priority-setting exercise, it is important for nature conservation agencies to work in collaboration with other role players such as academics at institutions of tertiary education and the National Botanical Institute. Such an effort would establish teams that are capable to negotiate on the basis of factual evidence with the relevant mining companies. Partnerships are a means to increase the capacities of local communities, government agencies, outside experts and financially capable companies for environmental stewardship (Michaels *et al.* 1999).

If we manage to gain the scientific, financial and political means to protect the rare and threatened plant species of the SCPE by accomplishing the above conservation objective with the help of the South African mining industry and nature conservation agencies, we will comply with the means for effective biological conservation, namely to satisfy human needs in a sustainable manner while still protecting our unique floral heritage in southern Africa (McLarney 1999). To ensure the long-term support of the rural people in the SCPE, local schools should be actively involved and children educated about the importance to conserve the natural ecosystems in their region (Rivas & Owens 1999).

Even if we manage to gain the scientific, financial and political means to save the main subcentres in the SCPE, we would still face loss of species diversity due to the large human population (Cincotta *et al.* 2000; Harcourt *et al.* 2001). Unless we find ways to protect ecosystem (plant community) function and ensure the long-term stability and well-being of the poor rural people, priority-setting exercises would merely serve as historical documents showing us the patterns of diversity we have lost.

The SCPE is an important area for the protection of taxa with conservation value along the northeastern Drakensberg Escarpment, especially the plant communities of the *Tristachyo leucothricis*–*Cussonietum transvaalensis* (specifically the *melinetosum nerviglumis* and *argylobietosum wilmsii*) moist bushclump areas of grasslands, the *Loudetio simplicis*–*Eucleetum linearis* (specifically the *diheteropogonetosum amplectentis* and *heteropogonetosum contorti*) anomalous open mountain bushveld, the *Eragrosti lehmanniana*–*Hippobrometum pauciflori* bushclumps of dongas, the *Enneapogono scoparii*–*Acacietum leiorachis* dry woodland stands, the *Aristido rhiniochloo*–*Gnidietum polycephalae* disturbed donga vegetation and the *Brachiario serratae*–*Melhanietum randii* rocky hill grasslands.

Hence, SCPE plant taxa are restricted to specific plant communities with a restricted distribution. Conservation of many localities of the same plant community is the most effective approach for the protection and survival of endemics of fractal landscapes such as ultramafic substrates (Witkowski & Liston 1997; With & King 1998; Harrison 1999). In addition, the region boasts a rich natural and human history (Pollock *et al.* 1963), and representative ecologically viable portions of the region should be protected and conserved for future generations.

12.6 Future research

There is a growing interest worldwide in applying knowledge on vegetation ecology in nature conservation and natural resource management. The new interest is based on the increasing awareness that careful analyses of plant communities and their associated habitats constitute a valid scientific basis for evaluating the consequences of environmental change. Future vegetation studies can provide detailed information on the vegetation change on a regional scale. A holistic approach is needed to explain the ecological processes of the SCPE before sound information can be provided for environmental management.

The information provided in this thesis is based on data acquired on a regional scale and could provide meaningful baseline data to which vegetation dynamics can be referenced. A better understanding of the region's vegetation dynamics will allow local authorities to

develop comprehensive management plans for the conservation and sustainable use of the SCPE's natural resources. However, much still remains to be done. With this section it is hoped that a detailed assessment is given to focus future research on the vegetation of the study area:

Plant communities

- A complex mosaic, together with a gradient distribution pattern, makes the mapping of the plant communities in the SCPE extremely difficult. Mapping the communities is a study on its own and should be considered on a fine scale, possibly 1:50 000. Palmer & Van Staden (1992) has used annual rainfall and elevation to map plant communities of Mixed Bushveld in semi-arid regions. This method could prove useful for future work.
- Winterbach *et al.* (2000) did not consider the work of Van der Meulen (1979) in their classification of the South African central bushveld. This leads to confusion in the classification of the SCPE. Further work should attempt to combine into a single database the relevés of this study and those of Van der Meulen (1979) which were sampled on gabbro, norite, pyroxenite and allied rocks (such as anorthosite) of the western Rustenburg Layered Suite.
- A phytosociological synthesis of data acquired from the vegetation of the entire Rustenburg Layered Suite will improve our knowledge of the processes that gave rise to the SCPE flora and plant communities. Data from the serpentine-related ultramafic rocks of the Bushveld Complex can be included into this phytosociological data set for comparative studies; this will contribute towards a better understanding of the plant community ecology of the unique vegetation types on ultramafic rock.
- From a management point of view it is therefore proposed that further research be conducted in the ecosystems and management units of the SCPE. Van Rooyen (1978) and Bredenkamp (1982) indicated the need for research into the following aspects when management of plant communities becomes pivotal to a region:
 - carrying capacity of the different plant communities;
 - quality, availability and utilisation of grazing in different seasons;

- production of the different useful plant species;
 - water requirements of the different plant species;
 - influence of artificial water sources and infrastructure on the distribution of animals and the subsequent utilization of vegetation;
 - phenology of the different plant communities;
 - veld reclamation in over-utilised/disturbed areas.
- There is a need for detailed phytosociological studies on disturbed vegetation types of different ages to derive hypothetical succession pathways for future grazing management and rehabilitation in especially the overgrazed and intensely harvested areas as well as surrounding mining areas. Pristine species rich bushveld, together with man-made ecotones, should be studied further to understand the system dynamics of the plant communities using the following as a guideline:
- immediately after disturbance re-colonisation of the site depends on the seedbank that remained or arrived from an external source and the vegetative resprouting of survivors;
 - recruitment is rapid at first due to little competition;
 - recruitment decreases as competition increases and established plants start to dominate;
 - recruitment of new species becomes restricted and inhibited by the species present;
 - with no further disturbances the long-lived vegetation will dominate the site and regeneration will be mainly for selected dominant species.
- Fire has been identified as an important determinant of vegetation structure on ultramafics (McCoy *et al.* 1999), but in the SCPE the fuel load is extremely low due to overgrazing, over harvesting and frequent droughts. Future research should investigate the influence of fire, especially as it relates to the vegetation structure and dynamics of the still to be described plant communities of the SCPE.
- Seasonal fire obviously has an effect on the plant species composition of the study area. What is the 'normal' fire cycle of plant communities and is recruitment taking place? Further work should look at the occurrence of fire and determine how best control too frequent burning in the SCPE.

- The phytosociological study did not focus in detail on threatened areas, but provided a broad overview of the region. Areas containing threatened vegetation units require immediate research in the light of the rapid developing mining industry and fast growing human population in the region. Particular emphasis should be placed on documenting the plant communities on the rocky ridges east and west of the Potlake Nature Reserve and the adjacent lying Leolo Mountains, which possibly harbours still to be discovered plant communities.
- A detailed investigation into the vegetation and catchment ecosystems of the Leolo Mountains and Mapochs Gronde is required and should receive priority due to its importance as a water reservoir for a very arid environment in the Steelpoort River valley. These systems should be studied with regards to plant community dynamics and subsequent state of the environment analysis focussing on the plant diversity as an indicator.
- To gain a more comprehensive knowledge of the class, it appears necessary to integrate the actual aspect of the vegetation with its historical interpretation (Pignatti *et al.* 1995). Syntaxonomic work in the central Bushveld of South Africa will need more work in this regard before it can be classified as Winterbach *et al.* (2000) attempted. The SCPE is a very small part of a poorly studied, possibly larger, Mountain Bushveld system. Sekhukhuneland has already shown that the system has a complex and heterogeneous history and physical environment, which should be studied in more detail before classification at the class level can be attempted.

Plant-soil associations

- Description and classification of the different vegetation units of the SCPE contribute towards the understanding of the association between plant communities and geology in the SCPE and southern Africa as a whole. As Brooks (1998) rightly stated, it is clear that the ‘serpentine problem’ is far from solved and much work remains to be done before it can be established with certainty why certain plant communities can be found over ultramafic rocks.

- This thesis was the first study to focus on the accumulation of heavy metals by plants in Sekhukhuneland. The data is of a baseline level and future work should include the following, as the soils of the SCPE will start playing a major role in mine rehabilitation in the near future:
 - investigate the Ni pool and forms and mobility of Ni in ultramafic soils to measure its unavailability to accumulators in the SCPE;
 - investigate Cr toxicity to determine if it is seasonal and depended on rainfall cycles, as oxidation of Cr (III) from chromite in soil to soluble forms of Cr (VI) may occur as a result of weathering;
 - investigate whether Cr (III) and/or (VI) cause changes in soil pH that can inhibit nutrient uptake;
 - determine whether plant element levels of ultramafic tolerant species reflect, when growing on ultramafic soil, any of the distinctive chemical characteristics of ultramafic soils;
 - determine whether element accumulation patterns differ amongst different topographical positions on ultramafic outcrops of Sekhukhuneland;
 - establish what influence does different accumulators have on one another in a system;
 - determine what influence do accumulators have on excluders; do their accumulation favour excluders?
 - what is the ratio of accumulators and excluders in a plant community on ultramafic soils?
- Further research is needed on the plant-soil association phenomenon of the SCPE, especially as it relates to the formal description of the still to be described endemic taxa which may well include edaphic specialists.
- Plants proven to be resistant to heavy metal toxicity, can find a ready application in the rehabilitation of disturbed sites. The following work is needed:
 - it is known that certain plants accumulate high calcium concentrations in their tissues to counter the toxic effects of heavy metals. Certain succulent genera, which do occur in

the study area, are calciotrophic CAM plants. Future work should investigate the tolerance of succulents to toxic soils.

- higher Ca concentrations in certain soils of the SCPE could be very important in the biological Ca-cycle of plants growing on heavy metal soils. It is recommended that future work in Sekhukhuneland should test rare species on the ultramafics for possible accumulation of Ca and exclusion of heavy metals. It is suggested that research focus should be more on excluding mechanisms, as much less is known of this plant physiological ability.
- research elsewhere has shown that specifically heavy-metal soil adapted mycorrhizae have an economical potential and practical application as inoculants on certain plants for the revegetation of heavy-metal polluted areas (Gildon & Tinker 1983; Gadd 1993; Gonçalves *et al.* 1995; Hildebrandt *et al.* 1999). Work in this direction might prove useful for rehabilitation in Sekhukhuneland.
- Leopold *et al.* (1999) indicated that the induction of phytochelatins is a general answer of higher plants to heavy metal exposition, but only some of the heavy metal ions are able to form stable complexes with phytochelatins. With regard to rehabilitation of mining sites, it could prove profitable to determine whether phytochelatins are responsible for heavy metal tolerant phenotypes of certain plants.
- analysis of variance need to be applied to determine whether there was a difference in the results of the numbers of plants per pot. Competition plays an important role in the phytotoxicity of soil (Weidenhamer *et al.* 1989). Plants might survive easier on heavy metal soils if they grow close to other species.

Phytogeography

- As is the case with the Zimbabwean Great Dyke (Wild 1965), the flora of the SCPE provides considerable opportunities to study the evolution of edaphic specialist plants on ultramafic substrates. There is a great need for closer taxonomic scrutiny of taxa in the SCPE to ensure the appropriate labelling of ecotypes, endemic forms of common species and undescribed taxa.
- Attention must be given to the further analysis of the flora in Chapter 11. Appropriate figures and charts should be used to make comparisons between regions using quantitative

techniques. Comparisons between the subcentres are also necessary once more accurate numbers have been obtained on the endemic and near-endemic species. The Chapter can be taken much further.

- Species in any given region may not have completed natural migrations and may still be in the process of extending its range. However, it does hold that a species can only live in the area to which it is confined, such as is the case with serpentinite endemics. The following questions arise with regards to the phylogeography of the SCPE:

- how did the disjunct species get to their current location in the SCPE?
- how far, if at all, does the plant communities extend beyond their currently known boundary?
- how large is the Centre and what are the most accurate boundaries for the SCPE?
- what is the biological status of the threatened plant populations? (are the number of individuals increasing, decreasing or stable?)
- what life history stage(s) have the greatest effect on population growth?
- what are the biological causes of variation in those life history stages that have a major demographic impact?
- should long-term monitoring of the plant diversity distribution be implemented?
- what is the real and potential impact of exotic weeds on the indigenous vegetation of the SCPE?

- Future research should focus on ways to determine the genetic resources of the plant diversity of the SCPE (genetic resources are defined as plant material with a current or future value for food, agriculture and forestry (Allem 2000)). This can be achieved by including Sekhukhuneland species in projects related to biochemistry and molecular biology.

- The demarcation of plant diversity foci in the SCPE is based in part on field observations and plant diversity work done by Siebert (1998). This work needs to be refined and the areas defined using accepted statistical methods. Available techniques for the identification of diversity 'hotspots' include approaches such as under-represented or rare ecosystems and distributions of rare plants as focal areas (Pfab & Witkowski 1997; Loomis & Echohawk 1999), vulnerable or threatened taxa as focal species (Lambeck 1997; Hoffmann & Welk

1999) and statistical analysis to select fully representative reserve networks (Bedward *et al.* 1992; Pressey *et al.* 1999).

- The human influence cannot be ignored as a factor that influence vegetation distribution, for anthropogenical plant communities are common in former communal lands, for example the old-fields in the Transkei (Smits *et al.* 1999). Work in this direction might shed some light on the doubtful occurrence of many species in the SCPE.

Conservation

- The main question that prevails in the light of rapid future development, is how ecosystem functioning and species richness are related? And in addition to this, which plant species are an essential component of an ecosystem? This is baseline information required for conservation initiatives and monitoring, and of which no information exist for the threatened plant communities of the SCPE.

- Further studies are needed to derive hypothetical succession pathways for future management of the dwindling valuable plant resources of the SCPE. The manner in which natural resources are used will have a direct relation to its future productive capacity (Aucamp *et al.* 1992). The following questions arises:

- what are the socio-economic and biophysical factors/dynamics associated with the plant communities?
- to what extend and which plant species are being used by local communities?
- for what purposes do the local communities use the plant species and is the harvesting of the sustainable?
- what additional threats are being faced by the plant populations?
- how can the plant communities be protected whilst at the same time also benefiting the local communities?
- what impact will increase access to, and public awareness of, the threatened plant populations have on its long term survival?
- what are the present patterns of land use in the area, and what are their environmental, historical and socio-economic determinants?

- at what rate are the patterns of land use changing, and why?
 - what are the key ecological processes sustaining production in the plant communities and how are these being affected by current and envisaged land use in the area?
 - what are the consequences of current and planned/predicted land use changes in the area?
- It is clear that the plant resources of the SCPE need to be conserved. Future research on conservation should consider the following perspectives that shape societal choices in the conservation of species as illustrated by Knegetring *et al.* (2000):
- aesthetical perspectives, especially the appreciation of physical and behavioural characteristics of the individuals of certain species;
 - ecological perspectives, in particular knowledge of species populations;
 - ethical perspectives regarding species with respect to specific human-species relationships such uses.
- The following questions can be addressed in future projects related to sustainable harvesting of useful plants and rehabilitation of mine dumps in the SCPE:
- what are the plant biodiversity patterns in the woodlands of the region, and what factors control these patterns?
 - what is the relation between stand structure, stand development stage and biodiversity in different woodland types, and how could this be used in mapping biodiversity patterns across the Centre?
 - what are the trends and patterns in recruitment, growth and mortality of species and stands in different woodland types and in different stand development stages?
 - what are the growth rates through the life cycle of important species across their areas of occurrence in the Centre, and how are these growth rates affected by climate, competition and harvesting intensity?
 - what rapid growth assessment techniques would give the best estimate of the actual growth as measured on the monitoring plots, and could be used as a general tool in timber harvesting planning?

- The creation of well placed nature reserves for the sustainable harvesting of natural resources is a solution to the problem of habitat loss in the SCPE. Its effectiveness will depend on an adequate database of natural features and other land uses (Bedward *et al.* 1992). A strategic environmental assessment should be conducted to source all data available on the study area's natural resources.

- Use of species composition in addition to species richness as a parameter of ecosystem quality is applicable to compare ranges within savanna ecosystems (Van Andel 1998). The best approach for the monitoring of nature reserves used for the sustainable harvesting is to evaluate the occurrence of unique plant communities. An analysis of species composition will determine the level of disturbance by evaluating the changes in plant communities. This is logically a better approach for future work to not only focus on species richness, but also the region's diverse species composition (plant communities).

- The SCPE is in urgent need of research to determine the endangered plant taxa and plant communities:
 - a useful initiative for future work in Sekhukhuneland would be to interpret Red Data List information in herbaria (Golding 2001b) in the light of rapid development objectives in the SCPE. From this study it became clear that the threatened plant species are not well known and have remained absent in the most recent literature on threatened species (Golding 2001a).
 - this thesis linked threatened species to plant communities, plant communities to GIS points, and hence, GIS points to threatened species. The locality information can prove extremely useful in future studies on the rare and threatened plants of the SCPE.
 - the work of Bevill & Louda (1999) provides a useful overview of the variables necessary for comparative studies on rare and common related plant species. This kind of work supplies data that are useful in determining the boundaries for a conservation area. Research in this field will comply with the latest initiatives for southern Africa.
 - species diversity 'hotspots' are rarely congruent for different groups of organisms (Van Jaarsveld *et al.* 1998). Diversity 'hotspots' for the SCPE are currently only seen as

important **botanical** regions to preserve. Further research might show the importance of other groups of organisms, such as the herpetofauna or lepidoptera.

- The hierarchical Braun-Blanquet classification of this study will enable authorities to group floristic and ecological related plant communities into bigger units encompassing the whole biological spectrum, which can be used in the formulation of effective and practical management systems. This should receive immediate priority and could form the basis for a strategic environmental assessment.
- A detailed investigation into the endemism, vegetation and catchment ecosystems of the grasslands of the Leolo Mountains and the Mapochs Gronde is required and should receive priority due to its importance as a water reservoir for the industrial development zone in the very arid Steelpoort River valley. The dynamics of these systems should be studied with regards to human impact; determining what the human carrying capacity of these catchments are. The Leolo Mountains are also important for the relictual Afromontane elements it may harbour.
- Alien plant invasions in habitats and distinctive plant communities pose a significant challenge in centres of plant diversity (Chiarucci & De Dominicis 1995; Stohlgren 1999). Ultramafic vegetation is poorly protected in South Africa and therefore more areas in Sekhukhuneland deserve to be conserved. Management plans should be drawn up for heavily populated residential areas of the SCPE, to ensure that potential invasive alien taxa are not introduced to the unique ecosystems of this region.
- A detailed assessment of the phytodiversity, endemism and Red Data List taxa in the plant communities of the study area is needed to supply authorities with baseline data to apply in future conservation actions and ecosystem management. An adequate database of natural features and other land uses is essential for effective land-use management and implementation (Kent & Ballard 1988; Bedward *et al.* 1992; Rhoads & Thompson 1992; Wessels *et al.* 2000).

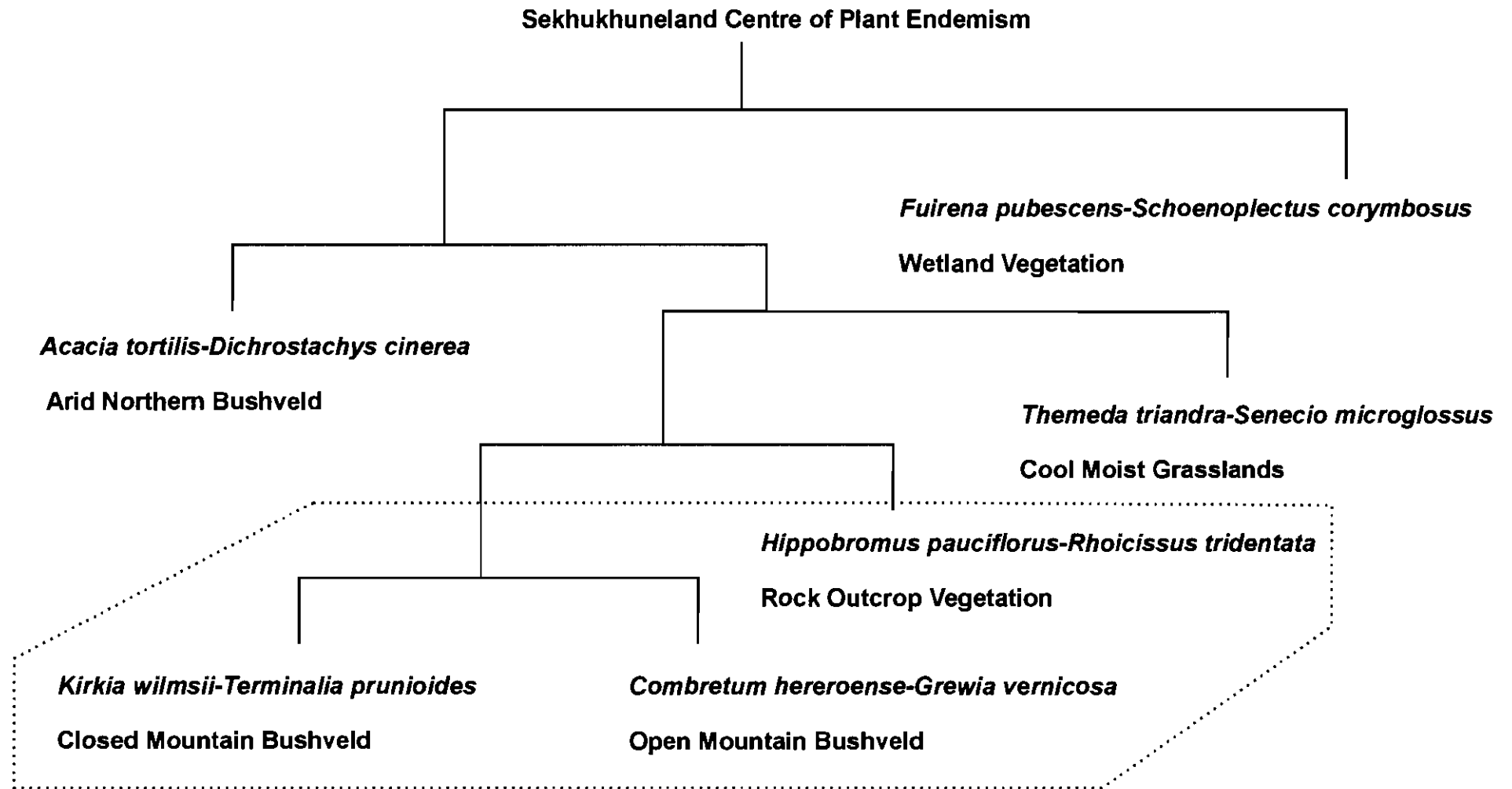


Figure 33 Dendrogram depicting the TWINSpan division of the six major vegetation types of the Sekhukhuneland Centre of Plant Endemism (Dotted lines demarcate the vegetation types that are part of the proposed *Kirkia wilmsii-Acacia caffra* Alliance on clay soils).

CONCLUSION

Phytosociology

- Structure and distribution patterns of the indigenous vegetation of the SCPE are a direct product of the environment.
- Six major vegetation types have been identified for the SCPE, namely Wetland Vegetation, Cool Moist Grassland, Rock Outcrop Vegetation, Open Mountain Bushveld, Closed Mountain Bushveld and Arid Northern Bushveld.
- Several ecological interpretable plant communities have been distinguished for each of the major vegetation types. Eighty-two syntaxa were identified, characterised, classified, described and ecologically interpreted for the study area.
- Fifty-two SCPE endemics, 52 SCPE near-endemics and 37 Red Data List taxa were recorded for the 82 syntaxa.
- Analysis of the Grassland and Wetland Vegetation resulted in the identification of 17 plant communities, ordered as eight associations, 11 sub-associations and four variants.
- Nineteen SCPE endemics, 18 SCPE near-endemics and 17 Red Data List taxa were recorded for the 17 syntaxa of the Grassland and Wetland Vegetation.
- Analysis of the Rock Outcrop vegetation resulted in the identification of 17 plant communities that were subsequently hierarchically classified as 17 associations.
- Twenty-three SCPE endemics, 24 SCPE near-endemics and 13 Red Data List taxa were recorded for the 17 syntaxa of the Rocky Outcrop Vegetation.
- Analysis of the Open Mountain Bushveld resulted in the identification of 20 plant communities, which are grouped as eight associations and 18 sub-associations.
- Thirty-one SCPE endemics, 20 SCPE near-endemics and 13 Red Data List taxa were recorded for the 20 syntaxa of the Open Mountain Bushveld.
- Analysis of the Closed Mountain Bushveld resulted in the identification of 20 plant communities, which are grouped as five associations and 20 sub-associations
- Twenty-eight SCPE endemics, 22 SCPE near-endemics and 10 Red Data List taxa were recorded for the 20 syntaxa of the Closed Mountain Bushveld.

- Analysis of the Arid Northern Bushveld resulted in the identification of eight plant communities, classified as four associations and five sub-associations.
- Four SCPE endemics, seven SCPE near-endemics and four Red Data List taxa were recorded for the eight syntaxa of the Arid Northern Bushveld.
- Heterogeneous environmental factors in the SCPE give rise to an intricate mosaic of plant communities, thus making it extremely difficult to produce a vegetation map.

Plant-soil associations

- Root development of maize seedlings grown in soil samples from a chromitite outcrop was stunted during the first two weeks and leaf growth during weeks three and four.
- Interveinal chlorosis and purpling of leaves indicated Ni and Cr toxicity.
- No calcium deficiency was recorded in the maize seedlings, which indicates that the soil of the SCPE is different from that of serpentinites.
- Two major groups of rock occur in the SCPE, namely rocks related to serpentinite with high Mg levels and rocks related to dolomite with high Ca levels.
- Chemical compositions of the rocks in the SCPE are highly variable.
- Soil analysis of a catena across the Critical Zone of the Rustenburg Layered Suite showed that topographic positions determine the serpentinite affinity.
- Rock outcrops and eroded areas are chemically most related to serpentinite and mountain slopes are most related to calcretes.
- Elements are associated with specific topographic positions, e.g. eroded areas are rich in Cu and Mn, chromitite outcrops are rich in Cr and Ni and mountain slopes are rich in Al and Pb.
- Soil metal concentrations decrease as nutrient levels increase; soil metal concentrations increase as Mg levels increase; nutrient levels in the soil decrease as the Mg levels increase.
- Sekhukhuneland has low relative Ni levels and high relative Cr levels when compared to serpentinites on a global level.
- Only Fe and Al were hyperaccumulated (more than 1 000 mg/kg) by plant species sampled from the catena in the study area.

- The following seven species accumulated high levels of Fe and Al in their roots and leaves: *Berkheya insignis*, *Dicoma gerrardii*, *Diheteropogon amplexans*, *Euclea linearis*, *Heteropogon contortus*, *Jamesbrittenia atropurpurea* and *Pterothrix spinescens*.
- Metal uptake by plants increases as the nutrient uptake decreases; metal concentrations in the plant material increases as the Ca in the plant tissues increases; Ca levels in the plant material is related to high nutrient levels in the tissue.
- Metal, nutrient and Mg/Ca levels in plant tissue are dependent on the availability of the elements in the soil.
- Metal, nutrient and Mg/Ca levels in plant tissue are dependent on the concentration of the elements in the soil.

Floristic analyses

- Identified taxa requiring conservation action, contributed towards reserve site selection on the basis of taxon richness and endemism, and provided a baseline inventory of plant resources with sustainable harvesting and bioprospecting potential—conforms to the Darwin Declaration (Environment Australia 1998).
- Fifty-eight SCPE endemic and approximately 67 SCPE near-endemic species/ infraspecific taxa were recorded for the study area. These taxa belong to 36 families.
- The SCPE has a species endemism of 5%; 115 endemic/near-endemic taxa out of a total number of 2 000 species/infraspecific taxa.
- Floristic links exist with various regions of South Africa, e.g. Karoo, Eastern Cape, Northern Cape etc.
- Currently the Flora for the region stands at 172 families, 757 genera and 1952 species/infraspecific taxa.
- The ten largest families in the SCPE in descending order are: Poaceae, Asteraceae, Fabaceae, Liliaceae, Asclepiadaceae, Lamiaceae, Acanthaceae, Schrophulariaceae, Euphorbiaceae and Cyperaceae/Rubiaceae
- There are three subcentres in the SCPE: Roossenekal, Leolo and Steelpoort.
- An assessment using the old IUCN Red Data List Categories identified 1 species as Endangered, 1 Vulnerable, 8 Rare, 2 Indeterminate, 15 Insufficiently Known and 10 Not Threatened in the SCPE, but in other provinces/countries of southern Africa (N).

- The major threats to the vegetation of the SCPE are communal lands, mining companies, commercial farming, residential development and a shortage of protected areas.
- The Grassland and Wetland Vegetation has 45 taxa of conservation significance, the Rock Outcrop Vegetation 36, the Open Mountain Bushveld 48, the Closed Mountain Bushveld 44 and the Arid Northern Bushveld 13.
- Priority plant communities for conservation are the *Tristachyo leucothricis*-*Cussonietum transvaalensis*, *Loudetio simplicis*-*Eucleetum linearis*, *Eragrosti lehmanniana*-*Hippobrometum pauciflori* and *Brachiario serratae*-*Melhanietum randii*.
- The largest number of endemic species, 18, occurs in the *Tristachyo leucothricis* - *Cussonietum transvaalensis*.
- The largest number of Red Data List taxa, eight, was recorded for the *Brachiario serratae*-*Melhanietum randii*.
- Most sensitive habitats include the seepage areas and Afromontane grasslands of the Roossenekal and Leolo Mountain Subcentres. These areas form the major catchment for large parts of the SCPE and should be protected.
- One national conservation reserve has been established in the study area, but is placed in the region with the least number of rare and threatened species.