THE EFFECT OF WOOL SHEEP FARMING ON THE LONG-TERM DIVERSITY OF THE VEGETATION OF THE KAROO

A REVIEW

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FOREWORD

South Africa is recognized for its species diversity and endemism as well as its diversity of ecosystems. These diverse ecosystems deliver services that are of benefit to people including the provision of basic services and goods such as clean air, water, food, medicine and fibre. This review considers the impact of wool farming on biodiversity in the Karoo region of South Africa. The agricultural industry in the Karoo has always been based on small stock, especially woolled and non-woolled sheep and historically sheep grazing have caused enormous damage to large parts of the Karoo. Most remnant Karoo areas and their current status is, to varying extents, a legacy of past grazing activities. However, notwithstanding the negative impact of earlier grazing regimes, there is increasing recognition that small stock grazing can have a positive impact on maintaining biodiversity in the future.

In order to report on the effect of wool farming on biodiversity in the Karoo an extensive review of literature on the subject was required and included the consultation of a diverse number of resources. Primary and secondary resources included publications/reviews/ inventories compiled by scientists in the fields of botany, rangeland management, biodiversity, ecology, soil science, agriculture, conservation and agricultural extension, as well as government reports. Historians' accounts and ecological and literary works by authors interested in the South African landscape and its peoples were also consulted. Archival material, such as historic photographs, old magazines and newspaper clippings proved invaluable material resources. Anecdotal information was also used where considered valuable, of interest and appropriate to the study's objectives.

Together with historic data, current data on rangeland and vegetation changes can provide a good assessment of the present state of vegetation diversity in the wool producing areas of the Karoo. In addition to the direct effects of grazing, some reference can also be made to the combined effects of climatic change, drought, grazing management, additional biological stresses, invasive species and fires on the diversity of vegetation. In this review the authors strive to present as broadly as possible the effect of wool sheep farming on vegetation diversity in the long-term, considering the various biotic and abiotic factors playing a role.

The review is subdivided into four sections: Section 1 deals with the concept of biodiversity, the threats to biodiversity as well as environmental legislation in South Africa pertaining to biodiversity. In Section 2 the area for review will be identified and described, the history of woolled sheep farming, different woolled sheep breeds as well as historical and current woolled sheep numbers in South Africa will also be alluded to. This history of grazing systems in the Nama Karoo will also be described in Section 2. Section 3 deals with the various natural and anthropogenic factors that could have influenced vegetal diversity in the past, present and future. This includes aspects such as grazing, rainfall and drought, climate change, fires, additional biological stresses as well as invasive plant species. In Section 4 strategies and approaches is discussed that have been introduced in the past to ameliorate the effects of livestock production in the Nama Karoo.

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INTRODUCTION

South Africa is recognized for its species diversity and endemism as well as its diversity of ecosystems. With only 2% of the planet's land area, the country is home to 6% of the world's plant and mammal species, 8% of bird species and 5% of reptile species, many of which are only found in South Africa. With nine biomes ranging from Desert to Grassland to Forest, South Africa has a huge range of habitats, ecosystems and landscapes. South Africa is recognized as one of 17 megadiverse countries (Figure 1).[1] These diverse ecosystems deliver ecosystem services that are of benefit to people including the provision of basic services and goods such as clean air, water, food, medicine and fiber.

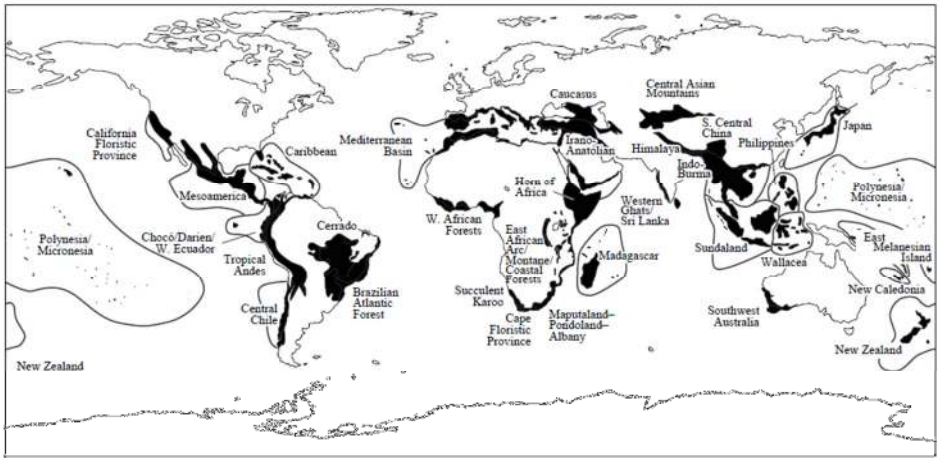

Figure 1. The 34 biodiversity hotspots currently recognized by Conservation International (redrawn from Mittermeier[2])

The pressure on biodiversity continues to increase. Globally habitat loss and degradation by agriculture and infrastructure development, overexploitation, pollution and invasive alien species remain the predominant threats. The drivers of loss of biodiversity and degradation of vegetation vary across the different ecological areas in South Africa, but the major drivers at a national level include overgrazing in terrestrial and wetland ecosystems, invasive alien species in terrestrial and freshwater ecosystems and mining in all ecosystems to name but a few.

The effect of grazing on vegetation diversity is a well-documented subject throughout the world but a general understanding of grazing effects (especially with regards to wool sheep farming) is still lacking, despite the extensive theoretical background.

Together with historic data, current data on rangeland and vegetation changes can provide a very good quantification of the present state of biodiversity in the wool production areas of the Karoo. In addition to the direct effects of grazing, some reference can also be made to the combined effects of climatic change, drought and grazing systems on the diversity of vegetation.

SECTION 1 – CHAPTER 1
WHAT IS BIODIVERSITY?

1.1 Defining the term

The official definition of biological diversity (i.e. biodiversity) is captured in Article 2 of the "Convention on Biological Diversity", signed by 156 nations and the European Community at the United Nations Conference on the Environment and Development, "The Earth Summit" in 1992:

"*Biological diversity* means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".[3]

"Biological diversity" has a long history of usage in a variety of contexts, but the start of its rise in the current sense can be traced to three publications which appeared in 1980.[4,5,6] The latter authors equated ecological diversity with species richness, i.e. the number of species in a community of organisms.

Biodiversity is commonly considered to include three components or levels: ecosystem diversity, species diversity and genetic diversity.[7,8,9] This review deals with diversity of vegetation at the ecosystem and species level, as well as with the ecological processes at the landscape scale which support this diversity. Noss[10] argued that ecological processes should be included in the definition of biodiversity, reasoning that although ecological processes are as much abiotic as biotic, they are crucial to maintaining biodiversity.

Biodiversity forms the backbone of healthy ecosystems, which in turn is important for providing us with invaluable ecosystem goods and services. These ecosystem goods and services, which include clean air, food, drinking water, energy resources, biological control, climate regulation, recreation, tourism, and protection from natural disasters, amongst many others, are considered to be vital to human well-being, health, and economic livelihoods.[11,12]

1.2 Quantifying and measuring biodiversity

On a global scale, species richness is the most widely used and intuitive measure of biodiversity.[13,14,15,16,17] Higher plant richness is widely used as a measure of biodiversity as plants are primary producers and provide habitat, hence the composition, diversity and structure of plant communities has a large effect on communities of other taxa.[10,18] Biodiversity can further be quantified and described in terms of the evenness of their distribution and their interactions.[15]

1.3 Biodiversity and farming

The Earth Summit in 1992 and the resulting Convention on Biological Diversity increased global awareness on the importance of sustainable farming for biodiversity conservation. Biodiversity in farming is useful to people in three broad ways: it has consumptive use value (in that nature provides products that can be consumed); it has productive use value (in that nature provides products that may be commercially harvested) and it has non-consumptive use value (in that indirect benefits may be derived from biodiversity, such as ecosystem functions).

Oldfield & Alcorn[19] and Götmark[20] argued that an important component of biodiversity is maintained by farming techniques. By consuming biomass, by controlling shrub growth and by dispersing seeds through their hooves and manure, sheep can contribute to plant diversity.[21] Controlled grazing activity of sheep could certainly favour the biodiversity of an ecosystem.[22]

Cowling[23] suggests that climatic factors determine local diversity and is supported by a number of authors who argue that diversity increases with increasing rainfall up to a maximum of about 400 mm/year, after which it declines.[24,25,26,27]

1.4 Challenge

Diversity comprises a broad spectrum of biotic scales and can generally be described as the number of entities, the evenness of their distribution, the difference in functional traits, and their interactions[28]. The precise (quantitative) effect on diversity of vegetation in a specific area would be extremely difficult to calculate as complete counts of organisms are impractical and almost impossible[29]. There is also no way to quantitatively compare diversity of vegetation at present with that of the past.

SECTION 1 – CHAPTER 2
THREATS TO BIODIVERSITY

Even in 1927 biodiversity was considered to be under threat: Statements such as *"In the drier areas, bareness of the soil becomes increasingly apparent owing to the vegetation having been killed by close grazing and too much tramping"* and *"A decrease of the desirable grasses, bushes and other plants most readily eaten by stock"* were published.[30] At present, the earth is experiencing an accelerated loss of biodiversity.[31] Habitat loss and fragmentation, climate change, over-exploitation, pollution and the spread of invasive alien species are widely accepted drivers of biodiversity loss.[32,33,34,35,36,37,38,39,40] The pressure on biodiversity continues to increase.[41] Climate change is increasing in importance and will have profound impacts, particularly in combination with other threats.[42]

The major threats to biodiversity in the Karoo are posed by pastoralism, exotic plants, mining and agriculture.[42,43] Both alone, and compounded by nitrogen deposition, atmospheric CO_2, climate change and biological invasions, land use change significantly affects local and global biodiversity. Agricultural activities have a universal impact, contributing to global climate change, the loss of biodiversity, water scarcity and alarming rates of soil erosion.[44]

Agricultural practices often seek to transform landscapes to increase productivity in terms of marketable commodities. Sustainable agriculture has received increasing attention because expanding agriculture is globally the principal driver of biodiversity decline.[39,45] Biggs[47] state that "the largest immediate threat to biodiversity is the expansion of degraded lands into areas currently under sustainable use".

Human activities have a direct impact on the land, its productivity as well as the diversity of the vegetation.[45] These activities include, poor management practices, overstocking (which leads to overgrazing), over-harvesting of medicinal plants and fuel wood (the main source of energy in many rural households), replacement of natural vegetation with extensive dry-land cropping systems, as well as mining and deforestation.[46]

Livestock grazing is one of the major threats to biodiversity in the Karoo.[48] Although well managed livestock grazing is compatible with biodiversity conservation, poor grazing management can lead to degradation and significant biodiversity loss at the landscape scale. It has been suggested that the threat to biodiversity from overgrazing is most severe on continuously grazed lands.[49] Changes in vegetation composition associated with grazing are frequently not obvious and as a result, grazing as a threat to biodiversity is often underestimated or overlooked. Furthermore, despite being reported as a threat to many vegetation types, the actual impact of livestock grazing is difficult to quantify at a broad scale and most assessments rely on remote sensing or anecdotal evidence to gauge grazing threat.

SECTION 1 – CHAPTER 3
ENVIRONMENTAL LEGISLATION PERTAINING TO BIODIVERSITY

3.1 International Environmental Legislation

International legislation governs the relationships between countries. International environmental commitments manage cross-boundary problems and provide a framework for political and scientific co-operation.[50] In section 231(1) - (5) of the Constitution of South Africa provision is made for cooperation and ratification of international commitments. According to this section commitments become part of national legislation, once it is enacted as legislation. The Minister may make a recommendation to Cabinet and Parliament pertaining to the accession and ratification of an international environmental instrument.[51]

Government can be bound to international commitments in the three different ways. When a commitment is signed the State is under an obligation of good faith to refrain from acts that do not comply with the objectives of such a commitment. The legal effect is however, influenced by whether a commitment is subject to ratification, acceptance or approval. The State is bound to a commitment when it is stipulated that signing of such a commitment has binding force. Ratification is the formal declaration of the State to be bound to a commitment. When the State has not signed a commitment it can only accede (or adhere) to a commitment, and cannot ratify such a commitment.[50]

International legislation central to the management and conservation of biodiversity in South Africa includes:

- United Nations Framework Convention on Climate Change (signed and ratified August 1997).
- Convention on Biological Diversity (ratified November 1995).
- United Nations Convention to Combat Desertification (signed 1995; ratified 1997).
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (ratified 1973).

3.2 National environmental legislation

Concern over environmental degradation has resulted in the promulgation of national legislation that contains directives to manage such issues. This is emphasised by Section 24 of the Constitution of the Republic of South Africa (1996) that states that Government should protect the environment against degradation. This also implicates that biodiversity that forms part of such environment should be protected. Under ideal conditions environmental legislation should make provision for the prevention of: biodiversity loss; disturbance to

ecological systems; land degradation; all forms of environmental pollution; landscape disturbance; and over-exploitation of renewable and non-renewable resources.[51]

National legislation central to the management and conservation of biodiversity in South Africa includes:

- The National Environmental Management Act (NEMA) (Act 107 of 1998, as amended) outlines measures that…. "prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development." Its associated EIA Regulations and Listing Notices identify activities deemed to have a potentially detrimental effect on natural ecosystems and outline the requirements and timeframe for approval of development applications.
- The National Environmental Management: Biodiversity Act (NEMBA) (Act 10 of 2004, as amended), provides for, *inter alia*, the management and conservation of South Africa's biodiversity, the protection of species and ecosystems that warrant national protection, and the sustainable use of indigenous biological resources.
- The National Environmental Management: Protected Areas Act (Act 57 of 2003, as amended) provides for; *inter alia*, the protection and conservation of ecologically viable areas representative of South Africa's biodiversity and its natural landscapes and seascapes. The Protected Areas Act provides for protected areas to be declared on private or communal land, with the landowner retaining title to the land. This has led to the development of biodiversity stewardship programmes, in which conservation authorities (such as provincial conservation agencies) enter into contractual agreements with landowners. Nature Reserves and Protected Environments declared through biodiversity stewardship programmes are considered formal protected areas, and are collectively referred to as contract protected areas (distinguished from state-owned protected areas).
- The National Water Act (NWA) (Act 36 of 1998) addresses, *inter alia*, the "protection of the aquatic and associated ecosystems and their biological diversity". The Act regulates all water uses, some of which are non-consumptive but which may impact on the integrity, functioning and biodiversity of wetlands and watercourses.
- The Conservation of Agricultural Resources (Act 43 of 1983) (CARA) (South Africa, 1983) states that the degradation of the agricultural potential of soil is illegal, and requires the protection of land against soil erosion and the prevention of waterlogging and salinization of soils by means of the construction and maintenance of suitable soil conservation works. The sustainable utilisation of marshes, water sponges and watercourses on agricultural land is also regulated in terms of the Act. The object of the CARA is divided into three core objectives, namely the maintenance of the production potential of the land; combating erosion and pollution of water resources; and the protection of vegetation through combating weeds and invader plants.
- BirdLife South Africa's Fiscal Benefits Project was launched in 2015 with the aim of testing biodiversity tax incentives as a benefit for landowners declaring Protected Areas,

through the Biodiversity Stewardship model. This was achieved on behalf of a landowner for the very first time in South Africa at the end of 2016.[52]

3.3 Critical biodiversity areas in South Africa

A Critical Biodiversity Areas map identifies a set of biodiversity priority areas, called Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs), which, together with protected areas, are important for the persistence of a viable representative sample of all ecosystem types and species as well as the long-term ecological functioning of the landscape as a whole.[53] Critical Biodiversity Area Maps are a form of strategic planning for the natural environment, providing a coherent and systematically identified set of geographic priorities to inform planning, action and decision-making in support of sustainable development (Figure 2). They should be used by a range of sectors, for example to inform land-use planning, environmental authorisations, agricultural authorisations, water use licencing, and other decisions that impact on the use and management of natural resources.

Figure 2. Critical Biodiversity Areas map for South Africa[53]

SECTION 2 – CHAPTER 1
DEFINING THE AREA OF THIS REVIEW

1.1 Historical descriptions of the Karoo area

One of the earliest references to the vegetation of the semi-arid interior of southern Africa is that of Thunberg.[54] In 1771 he mentions that, while travelling in the country behind the Swartberg range, the:

"plants stand very thin in the Carrow-veld; and, in such a burning hot climate, where not a drop of rain falls for the space of eight months at least, it is almost inconceivable how they can thrive at all. Their stems and branches likewise have the appearance of being brittle and quite dried up; but the leaves, on the other hand, are very thick and filled with briny fluid, and remain green all year through."

Sparrman[55] after his travels in 1776 mentions that the Camdeboo *"is an arid, flat, Carrow-like country inhabited by Christians who are chiefly employed in cattle rearing"*. This provides a hint of the grassiness of the vegetation which Sparrman probably encountered.

Francois Le Vaillant[56] describes the area from Pearston flats to the Voëlrivier as being covered with "coarse grass and weeds, with only small tufts of grass". These were amongst the first explorers to describe the conditions in the Camdeboo, and to use the name "Karoo".

Bolus[57] first recognized the Karoo as a distinct geographical unit, distinguishing it from that of the Kalahari and the Namib. Shaw[58] calls the Karoo a peculiar sub-province of plants. The Midlands (which forms part of the Karoo) was mentioned by Shaw[58] as being the great wool-producing country, and the country which is being changed in the character of its vegetation by overstocking. He furthermore describes the retrogression of Karoo rangeland as follows: "*When first introduced, sheep fed mainly on the grass; and in an area with its periodical or season rains, and under a high sun, the family soon began to give way and succumb. Shrubs alone could stand against the sheep*". In addition, as a result of the degradation of the vegetation, the animals were forced to move around all day looking for food, causing even more destruction by trampling resulting in compacted soils. Shaw[58] refers to *Chrysocoma ciliata* as being the prevailing plant of rangeland in a large part of the Karoo affecting the taste and smell of mutton.

Marloth[59] defined the vegetation of the region according to the presence of seven growth-forms, namely bushes and dwarf shrubs, leaf succulents, stem succulents, plants with underground water storage, bulbous monocotyledons, grasses and annuals. Bews[60] described the "Karroo" as a succulent sclerophyllous dwarf shrub type which is the product of a dry, continental climate on grassland.

In his description of the vegetation map of South Africa, Pole-Evans[61] referred to the "Karoo" as part of the "Desert shrub" but makes no mention of it being a vegetation type of its own.

1.2 Recent descriptions of the Karoo area

Acocks[62] emphasized the Karoo and suggested that it was the inextricable mixing of the "*Southern Fynbos and the forest of the winter rainfall area; with the tropical forest, savanna and grassveld of the summer rainfall area.*" He continued to describe units within the Karoo on the basis of their vegetation, and recognized twenty-two "Karoo and Karroid Veld Types". Based on the work of Acocks[62], Edwards[63] prepared a generalized floristic-physiognomic map of South Africa, which described the Karoo as a region occupied by dwarf and succulent shrubs.

With the advent of the biome approach to describing the vegetation of southern Africa, Werger[64] and White[65] preferred to regard the extensive arid and semi-arid areas of the south-western part of southern Africa as the Karoo-Namib biogeographical region. The Karoo-Namib region has been divided into three biomes by Rutherford & Westfall[66], namely Nama Karoo Biome, Succulent Karoo Biome and Desert Biome (Figure 3). Low & Rebelo[67] provided a very good description of the Nama Karoo Biome.

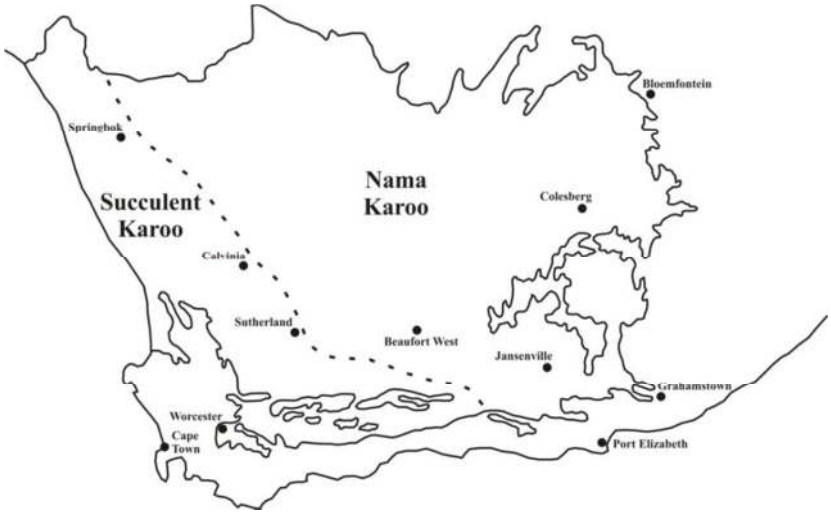

Figure 3. Map indicating the Succulent Karoo and Nama Karoo (adapted from Rutherford & Westfall[66])

Mucina and Rutherford[68] map nine biomes in South Africa: Fynbos Biome; Succulent Karoo Biome; Desert Biome; Nama Karoo Biome; Grassland Biome; Savanna Biome; Albany Thicket Biome; Indian Ocean Coastal Belt; Forests; and two on the subantarctic Prince Edward Islands: Subantarctic Tundra Biome and Polar Desert Biome.

For the purpose of this literature study the Nama Karoo Biome, as defined by Mucina & Rutherford[68], will be used as study area (Figure 4).

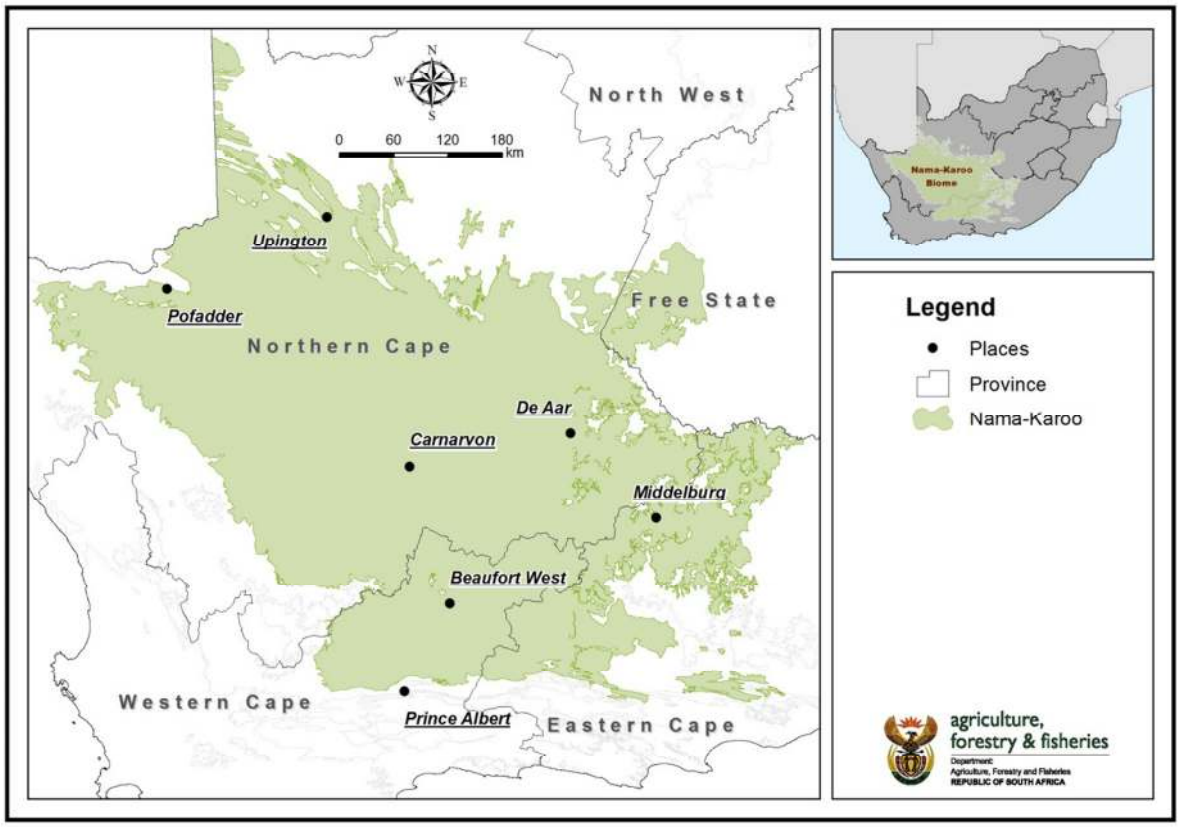

Figure 4. Nama Karoo Biome of South Africa[68]

1.3 The Nama Karoo - general

The Nama Karoo is a large, landlocked region on the central plateau of the western half of South Africa and extends into southeastern Namibia. It is flanked by six biomes and the biome boundary interfaces vary from gradual transitions to distinct boundaries.[68]

The Nama Karoo is an arid continental meseta (high altitude plateau) experiencing hot summers and cold winters (frosts occur often) as the entire region is situated between 1 000m and 1 600m above sea level, as a consequence of continental uplift (Figure 5). The Nama Karoo appears uniform, but the wide variety of parent materials and diversity of topographical features such as plains, dongas (erosion trenches), koppies (buttes) and flat-topped mountains (mesas)[67], contribute dramatically to landscape heterogeneity.[70]

Most of the rivers are non-perennial and only flow episodically after significant rainfall events. The few perennial streams that originate in the Nama Karoo are limited to the more mesic east, with the Great Fish River of note.[68]

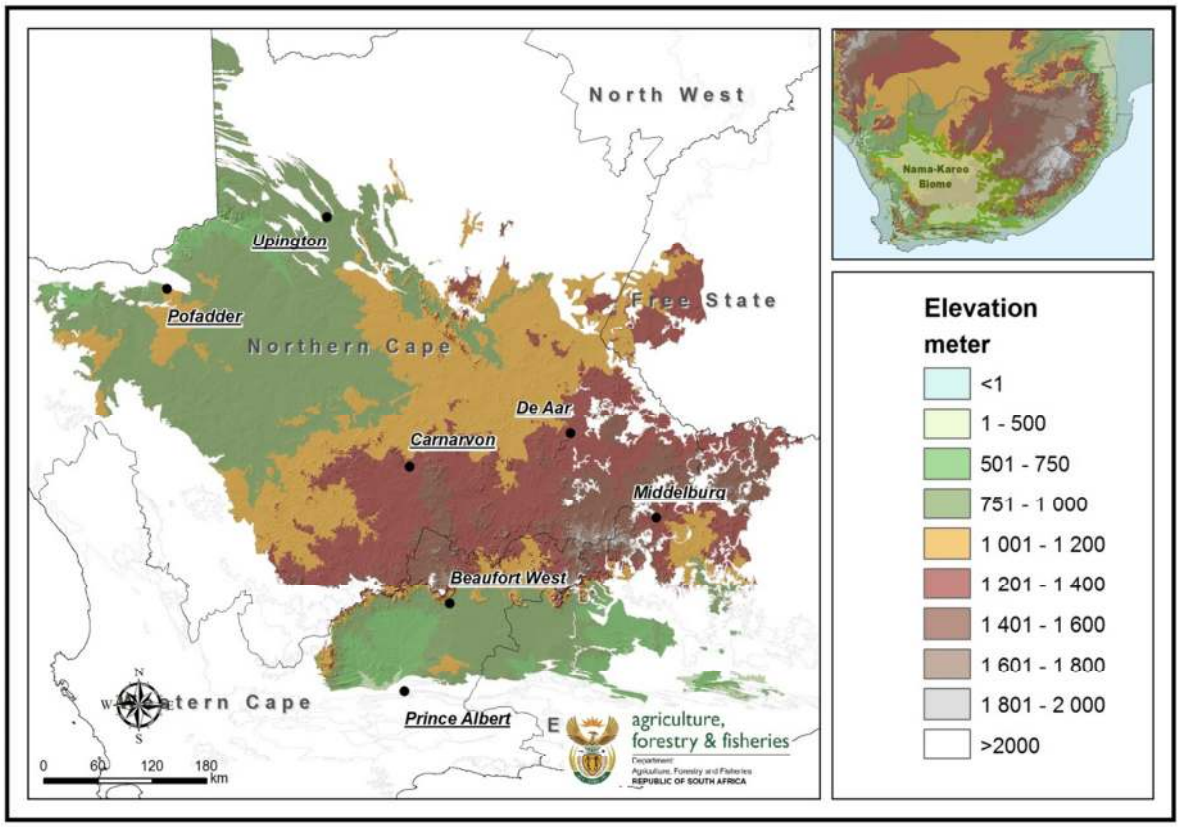

Figure 5. Elevation of the Nama Karoo

1.4 Vegetation

The vegetation of the Nama Karoo combines elements from the desert, arid and moist savannas, grasslands and, in sheltered sites, from the forest regions. It is normally a treeless environment.[68] Dwarf shrubs dominate the Karoo vegetation but the diversity in topography and climate has resulted in considerable variation in vegetation types in the region. Vegetation cover in these semi-arid vegetation types is clearly influenced not only by short- and long-term fluxes in rainfall but also by stocking rates, rotational grazing systems and land management practices.[71]

Acocks[62] defined a Veld Type as "a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potential" and in 1988 described 16 veld types in the Nama Karoo with five Veld Types falling almost entirely within the Nama Karoo (Central Upper Karoo, Central Lower Karoo, Orange River Broken Veld, Arid Karoo and False Arid Karoo). Low & Rebelo[67] regrouped most of these units and part-units to form six vegetation types in the Nama Karoo i.e. Bushmanland Nama Karoo, Upper Nama Karoo, Orange River Nama Karoo, Eastern Mixed Nama Karoo, Great Nama Karoo and Central Lower Nama Karoo. Mucina & Rutherford[68] described three broad vegetation units, i.e. Bushmanland & West Griqualand, Upper Karoo and Lower Karoo which include 16 vegetation types for the Nama Karoo Biome (Figure 6).

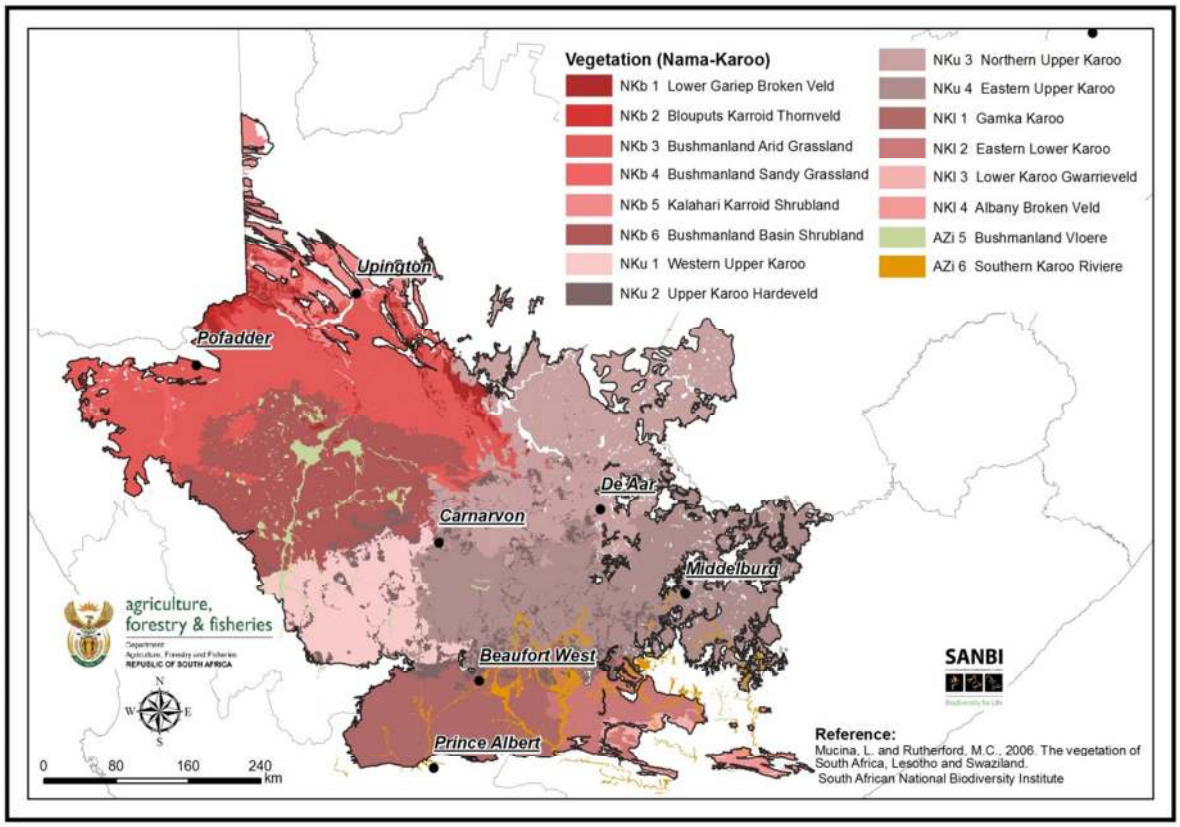

Figure 6. Vegetation types of the Nama Karoo[68]

1.5 Geology and soils

The soils of the Nama Karoo are typical of arid regions, slow to form, poorly developed with little organic matter and very sensitive to degradation.[72,73,74,75] Shallow, weakly developed lime-rich soils cover most of the region.[76] The soils are principally underlain by sediments of the Dwyka Formation, which are covered by the Ecca and Beaufort groups respectively.[77,78] The Karoo dolerite dykes and sills were formed when molten rock intruded into the pre-existing rocks of the Ecca and Beaufort shales.[78] Dolerite sills, generally more resistant to weathering than the surrounding sandstones and shales, can be seen as the flat topped hills typical of the Nama Karoo landscape.[76]

Watkeys[76] divides the Nama Karoo into several soil regions. In the north from Bushmanland to around Prieska, the most common soils are red and yellow sands to non-swelling clays, generally freely drained. Further south, in the belt running north of the Great Escarpment, eastwards of Calvinia, most soils are shallow (<300 mm) and weakly structured. Around Hanover and further east, duplex soils are dominant. The pattern of soils south of the Great Escarpment generally corresponds to that of the belt north of the escarpment, except that dolerite is absent southwest of Beaufort West. On the Great Escarpment from Fraserburg to around Middelburg, shallow lithosols predominate, with large areas of exposed rocks.

1.6 Rainfall

Rainfall has a key influence on the amount of plant material produced per hectare. In the Nama Karoo rainfall decreases uniformly westwards from the eastern escarpment across the plateau and also from north to south (Figure 7).[79,80] In the southwest, rain is brought by unpredictable late summer thunderstorms and occasional inland intrusions of winter high-pressure systems from the west, whereas convectional thunderstorms and southerly movement of the intertropical convergence zone bring reliable summer rain to the northeast of the region.[80]

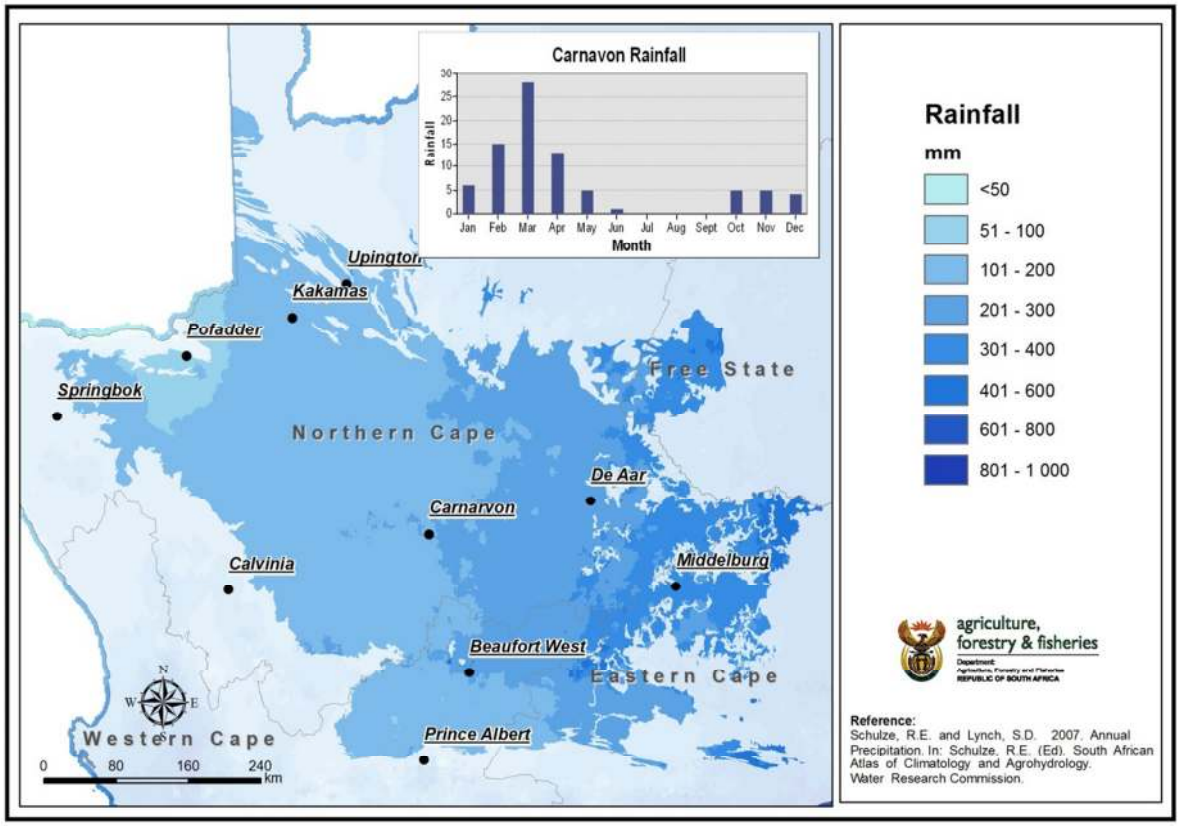

Figure 7. Rainfall in the Nama Karoo Biome

Rainfall is highly seasonal[81], peaking between December and March[79] and the area experiences a broad range in annual rainfall between 100 and 500 mm. The low rainfall is unreliable and droughts are unpredictable and sometimes prolonged.[82]

1.7 Temperature

Plants need an optimum temperature to grow and reproduce. It is, however, the adaptation to extreme temperatures, such as severe frost or extreme heat that often determines plant species composition. High temperatures, low relative humidity and little to no cloud cover is characteristic of the Nama Karoo and large ranges in annual and daily temperatures occur

(temperature extremes range from -5°C in winter to 43°C in summer) (Figure 8). According to Desmet & Cowling[80] the Nama Karoo is associated with higher maximum temperatures than other parts of South Africa.

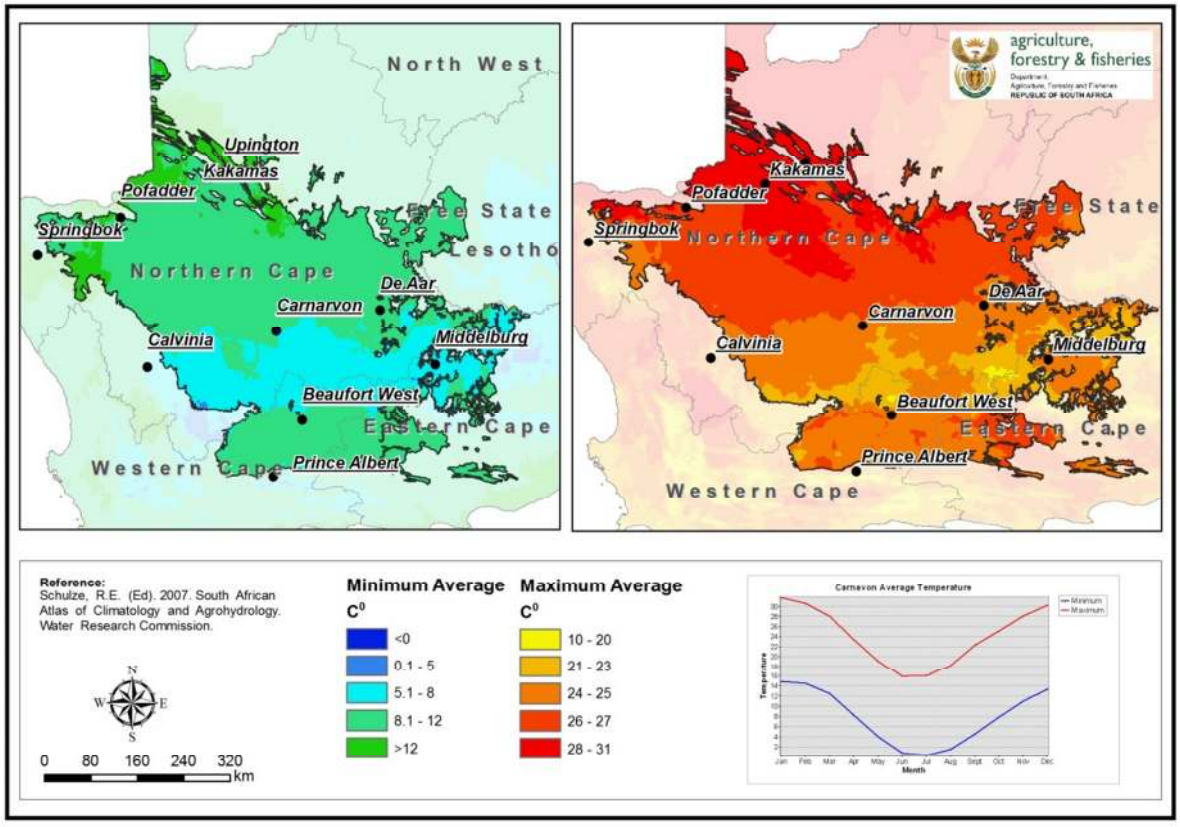

Figure 8. Average minimum and maximum temperatures measured in the Nama Karoo

1.8 Dew and frost

Dew is a more widespread phenomenon in the Nama Karoo than fog[83] and is highest in April/May. Frost occurs in all areas except in the extreme southeast of the Nama Karoo in winter from June to August.

1.9 Wind

In the western interior winds in summer are mainly from the south-west and in winter from the north. In the eastern interior they are south-easterly in summer and north-westerly in winter.[80] The winds are usually dry.

SECTION 2 – CHAPTER 2
THE NAMA KAROO AND VEGETATION DIVERSITY

There is little published data regarding species richness or endemism for the Nama Karoo flora, but floristic diversity was described for the Nama Karoo by Cowling[23] and Cowling & Hilton Taylor.[49] According to various authors the Karoo (including the Succulent and Nama Karoo) has a rich floristic diversity, consisting of up to 7000 different species,[49,65,84,85] but Gibbs Russell[86] estimated the number of plant species in the Nama Karoo at only 2 147. Cowling[87] and Cowling & Hilton-Taylor[49] found the diversity for the Nama Karoo biome to be the lowest in South Africa. There is however still no reliable estimate of the size of its flora.

Unlike other biomes of southern Africa, local endemism is very low (the highest number of local endemics is concentrated in the Upper Karoo Hardeveld). This could be a result of the geological and environmental homogeneity of the Nama Karoo.[68] The Nama Karoo with approximately 2,200 plant species is less rich and less unique (450 unique to the region) than the Succulent Karoo because many of the plant species are shared with the adjacent Succulent Karoo, Grassland and Savanna biomes.

Despite relatively low floristic diversity, the Nama Karoo vegetation has a high diversity of plant life forms. These include coexisting ephemerals, annuals, geophytes, C_3 and C_4 grasses, succulents, deciduous and evergreen trees.[68] Communities in the Nama Karoo constitute a matrix of long-lived shrubs, which are then interspersed by shorter-lived species such as grasses. Overgrazing may lead to a reduction or elimination of certain species or growth forms, thereby further reducing species richness.[88] Masubelele[89] found that at various sites in the Nama Karoo species richness declined in 2009 to values below those first recorded in 1961/2.

In spite of the low moisture availability many arid and semi-arid areas have high local diversities[24,87,90] i.e. small drainage lines support more plant species than surrounding plains.[91] Rubin & Palmer[92] found floristic patterns in the central Nama Karoo to correlate with coarse environmental variables such as elevation, rainfall, substrate and land type. It is generally accepted that rocky habitats are more diverse than adjacent plains habitats because of greater soil moisture heterogeneity and in turn a longer structural niche axis.

Topography generates habitat heterogeneity, which, in turn, serves to maintain diversity. The hills scattered all over the Nama Karoo landscape may create spatial heterogeneity resulting in unique assemblages of flora.[93,94] In addition, aspect has a major effect on insolation,[95,96] and can lead to substantial thermal differences between faces of slopes receiving differential insolation which may result in higher or lower diversity. South-facing slopes were found to have greater species diversity than north-facing slopes.[97] This was said to be caused by the more direct sunlight and resulting warmer and drier microclimate on the northern slopes.[97]

Todd[98] investigated species richness in a variety of habitats near Beaufort West and found the species richness differed for each of the surveyed habitats supporting the findings of differences in local diversities by Whittaker & Niering,[24] Cowling[87] and Aronson & Shmida[90] as mentioned above (Figure 9).

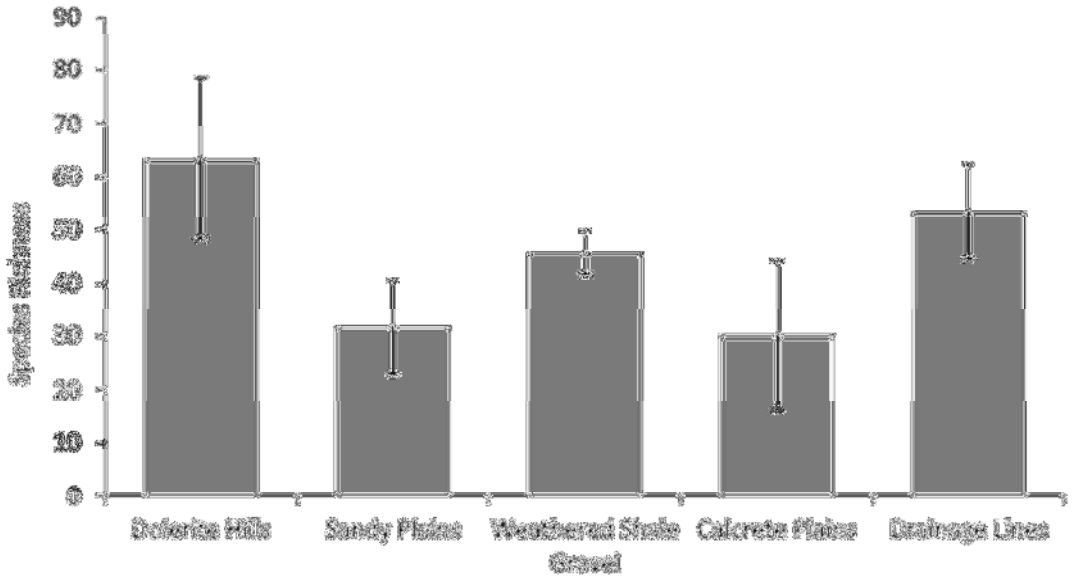

Figure 9. Mean species richness and standard deviation bars of five habitats within the Karoo near to Beaufort West[98]

The state of Nama Karoo vegetation, prior to the colonial introduction of domestic stock, is unclear but theories considering pre-degradation environments have evoked controversy[99] with some regarding the Nama Karoo as a perennial grassland.[62,100] There is generally a lack of understanding on how climate and land use change will affect major growth forms or biodiversity occurring within specific parts of the Nama Karoo landscape in the future.[101,102]