THE ASSESSMENT OF VARIABLE BUFFER ZONES TO MANAGE ROCKY RIDGES IN JOHANNESBURG, GAUTENG

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GLOSSARY

DEAT	Department of Environmental Affairs and Tourism
ECA	Environmental Conservation Act 1989
EIA	Environmental Impact Assessments
NEMA	National Environmental Management Act (Act 107 of 1998)
RIDGE	Essential characteristic defining a ridge is the slope of the site and includes any topographical feature with a slope of 5° or more (i.e. $\geq$ 8,8%, $\geq$ 1 in 11 gradient) (Pfab, 2001b)
GDACEL	Gauteng Department of Agriculture, Conservation, Environment and Land Affairs

ABSTRACT

In the pursuit of sustainable development, Environmental Impact Assessments (EIA) are acknowledged globally as a tool designed to assist governing authorities by providing the information required to make an informed decision regarding development proposals. South Africa has entrenched this EIA requirement in the presiding environmental legislation: the National Environmental Management Act (Act 107 of 1998).

In the effort to manage the negative impact of development on the rocky ridges of Johannesburg, the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs (GDACEL) has introduced a buffer zone requirement in the procedure of the EIA. The Red Data Plant Policy for Environmental Impact Evaluations for GDACEL described a buffer zone as a collar of land that filters out inappropriate influences from surrounding activities.

As a tool in the EIA, a buffer zone is a worthwhile concept. However, the determination of the dimension of the buffer zone on rocky ridges, is non-discriminatory between sites, and thus, presents potential contention between decision-making authorities and developers. There is a need for further research to establish a scientifically acceptable method of determining site-specific buffer zones for individual EIA applications.

The key objective of this paper is to suggest the possibility of determining a buffer zone that accommodates the unique environmental aspects of each site. This is achieved by determining the distance between the edge of existing developments and the point at which the successional climax community within the adjacent natural vegetation is established.

Three suitable study sites, consisting of developed residential estates on ridges adjacent to nature reserves, were identified within the greater Johannesburg metropolis. The three study sites identified for this assessment include Kloofendal (west), Morning Hill (east) and Kliprivier (south). Within each study site field surveys were conducted along transects starting 5m from the development edge and ending 75m within the nature reserve adjacent to each site. Quantitative (species density) and qualitative (Braun-Blanquet cover-abundance values) data analysis was employed to describe and evaluate the identified plant communities.

The data in this study provides clear indication that a 25-35m buffer zone would suffice for these specific plant communities to maintain a climax successional status if impacted on by residential development. This paper thus makes a case for permitting the determining of variable buffers zones, based on a gradient analysis of a plant community, as a potential panacea to the problem of resistance and reluctance to accept present standard buffer zones.

Key words

buffer zones, environmental impact assessments, Gauteng, plant species composition, plant succession rocky ridges.

UITTREKSEL

Omgewingsinvloedbepalings (OIB) word wêreldwyd aangewend om owerhede in staat te stel om ingeligte besluite te neem rakende ontwikkelingsvoorstelle deur die beskikbaarstelling van inligting. In Suid Afrika is die vereistes vir OIB verskans in die huidige omgewingswetging, naamlik die Wet op Nasionale Omgewingsbestuur, (Wet 107 van 1998).

In 'n poging om die negatiewe impak van ontwikkeling op die kliprante in Johannesburg te bestuur is die vereiste van bufferstroke deur die Gauteng Department of Agriculture, Conservation, Environment and Land Affairs (GDACEL) bekendgestel as deel van OIB prosedure. 'n Bufferstrook word in die Rooi Data Plant Beleid vir Omgewingsinvloedbepalings vir GDACEL beskryf as 'n gebied wat ongewensde invloede van omringende aktiwiteite uitfilter.

Die gebruik van bufferstroke as instrument by OIB is 'n waardevolle konsep. Die vasstelling van die afmetings van die bufferstrook by kliprante is nie-onderskeidend tussen gebiede en hou gevolglik moontlikheid in vir dispute tussen besluitnemende owerhede en ontwikkelaars. Daar is 'n behoefte na verdere navorsing ten einde 'n aanvaarbare wetenskaplike metode vas te stel vir die bepaling van bufferstroke in spesifieke gebiede vir OIB aansoeke.

Die doel van hierdie studie is om die moontlikheid te ondersoek om sodanige bufferstroke vas te stel wat die unieke omgewingseienskappe van onderskeie gebiede akkommodeer. Dit word bereik deur 'n vasstelling van die afstand tussen die grens van

bestaande ontwikkelings en die punt waar die opvolgende klimaksplantgemeenskappe binne die aangrensende natuurlike plantegroei voorkom.

Drie geskikte studiegebiede, naamlik ontwikkelde residensiële gebiede geleë op rante aanliggend tot natuurreservate, is geïdentifiseer binne die groter Johannesburg Metropool. Die drie studiegebiede vir hierdie opname sluit in Kloofendal (wes), Morning Hill (oos) en Kliprivier (suid). Binne elke studiegebied is veldopnames gedoen langs stroke wat 5 m van die rand van die ontwikkeling begin en 75 m binne die natuurreservaat naasliggend aan elke gebied lê. Kwantitatiewe (digtheid van spesies) en kwalitatiewe (Braun-Blanquet bedekkingswaardes) data-analise is gebruik om die plantgemeenskappe te identifiseer.

Uit die resultate blyk dit dat 'n 25 – 35 m bufferstrook nodig is vir hierdie spesifieke plantgemeenskappe om 'n klimakstoestand in stand te hou indien dit beïnvloed word deur residensiële ontwikkelings. Die studie motiveer die regulering van die ontwikkeling van bufferstroke by wyse van permituitreiking. Dit word aangevoer dat 'n gradiëntontleding van plantgemeenskappe 'n oplossing is vir die huidige teenkanting en teësinnigheid om die huidige standaard van bufferstroke te aanvaar.

Sleutelwoorde:

Bufferstroke, Gauteng, Kliprante, Omgewingsinvloedbepalings, plantspesie samestelling, plantsuksessie.

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Gauteng province has a higher population than any other province in South Africa, according to the State of the Environment Report of Gauteng (GDACEL, 2004). This province also has a far higher average population density (519 people/km^2) than the other provinces. This combined with a high population growth rate of 4.1% per annum, results in significant pressure on scarce resources and services most notably in the larger urban zones such as the Johannesburg Metropolitan Area. Johannesburg is the largest city in the Gauteng Province and forms the largest urban complex in South Africa. With an urbanization rate of 97%, a population of 2.83 million people and an approximate land surface area of 164 485ha, there is an urgent need to respond appropriately to development pressures in an environmentally sustainable manner in Johannesburg (SEF, 2002).

The provinces economic and population growth rate has increased by 4.1% per year since 1996 (GDACEL, 2004), and this poses significant environmental challenges to the relevant authorities. Pfab & Victor (2002) highlighted the fact that Gauteng has a relatively large percentage of South Africa's biodiversity in a small area but that habitat destruction, transformation and fragmentation through urbanization, is the most serious threat posed to the survival of threatened plants, birds, mammals, reptiles, amphibians and invertebrate species in the province. Biodiversity is regarded as the variability amongst living organisms and the ecological complexes in which these organisms occur, encompassing different levels of biological organization, including genes, individual organisms, populations, species, communities and landscapes as defined by Noss (1990) and Franklin (1993).

Although residential development along ridges is not a new phenomenon, the present rate of urbanization within these areas and the subsequent increased demand for land is a concern for the Department of Agriculture, Conservation, Environment and Land Affairs (GDACEL, 2004). The concern is that the city of Johannesburg is interspersed with unique geological ridges, which provide not only aesthetically pleasing environments that attract tourists and various recreational users, but also fulfill an essential role in ecosystem processes and biodiversity. Gauteng province represents a relatively large percentage of South Africa's biodiversity in a small area. More plant species occur per unit area in Gauteng than in any other province (Low & Rebelo, 1996). Gauteng is also important for biodiversity, as it is topographically diverse (diversity of habitats will support a diversity of species) and 71% of the province falls within the Grassland biome, which is second only to the fynbos in terms of species richness (Cowling *et al.*, 1991).

The quartzite ridges of Gauteng are extremely limited in their distribution. They are characterized by a unique plant species composition that is found nowhere else in South Africa or the world, known as the Bankenveld (Acocks 1988). Acocks (1988) described the Bankenveld as a False Grassland Type. The climax vegetation of this Veld Type should be an open savanna (Acocks, 1988), but it has changed to, and is maintained as grassveld by regular veld fires (Bredenkamp & Brown, 2002). Although much of the grassland area was disturbed by agricultural activities more than 50 years ago, it has recovered well by going through the natural succession process. It has reached a natural climax that is typical of the Bankenveld, with a diverse mixture of wild flowers, climax grasses and most of the biodiversity associated with a grassland ecosystem (Swartz, 2006).

As the Witwatersrand[1] is considered to be transitional between the Grassland and Savanna biomes, floristic elements from both these biomes contribute to the richness of Gauteng ridges. The Gauteng ridges, together with the Drakensberg Escarpment, should be regarded as one of the most important natural assets in the entire region of the northern provinces of South Africa (Bredenkamp & Brown, 1998a).

Authorities have been equipped to successfully manage the environmental challenges via The Environmental Impact Assessment (EIA) Regulations. These regulations, created under the Environmental Conservation Act 1989 (ECA), stated that before certain developments could be undertaken, an environmental impact assessment must be completed. Based on this assessment, the Department of Environmental Affairs and Development Planning judges the environmental feasibility of a development to allow or disallow it. The National Environmental Management Act (NEMA) now supersedes this Act, and whilst much of its contents have been repealed by the latter Act, certain pertinent provisions remain in force (King & O'Beirne, 2006).

Of particular relevance to the property industry are the provisions contained in Part V of the Act (regulating the control of activities which may have a detrimental effect on the environment) and section 31A (a Ministerial power to prevent degradation to the

[1] The Witwatersrand is also another name often used to describe the Greater Johannesburg Metropolitan Area, which spans the length of the gold-bearing reef. The metropolitan area is oblong in shape and runs from the area of Randfontein and Carletonville in the west to Springs in the east. It includes the vast urban areas of the East and West Rand, and Soweto.

environment). The former provisions are of great significance, as they constitute the legislative basis for requiring that EIA's be conducted (Glazewski & Witbooi, 2001).

GDACEL has motivated for the adoption of a strict no-go or low impact development policy for these ridges. All ridges in Gauteng have been classified into four classes based on the percentage of the ridge that has been transformed (mainly through urbanization) using the 1994 CSIR/ARC Landcover data (Pfab, 2001a). The four classes are:

Class 1 - 0 – 5% transformed

Class 2 - 5 – 35% transformed

Class 3 - 35- 65% transformed

Class 4 - 65- 100% transformed

If an individual owning land on or along a ridge wishes the government to deviate from this strict no-go policy for the purpose of development or sub-division, the competent authority requires the proponent to conduct a full EIA which must include a set of specialist reports which, amongst other stipulations, requires a minimum buffer zone of 200 m from any red data plant species found in the survey (Pfab, 2001b).

The competent authority administering these development proposals in Gauteng province is the Department of Agriculture, Conservation, Environment and Land Affairs (GDACEL). The ridges identified for this study fall into classes 2 and 3.

GDACEL together with the Directorate of Nature Conservation compiled the 'Red Data Plant Policy for Environmental Impact Evaluations' (Pfab, 2001b), and development

Guidelines for Ridges and in these documents a buffer zone is defined as 'a collar of land that filters out inappropriate influences from surrounding activities' (Shafer, 1999).

For the purpose of this study a "rocky ridge" will refer to hills, koppies and mountains with the characteristic defining topographical feature of a slope of 5° or more, as defined by Pfab (2001a).

1.2 Buffer Zones

Buffer zones are environmental and ecological management tools, which are used in a variety of ways to surround or shield a particular zone (core area) with the intention of insulating the important or threatened core area from negative external impacts. The definition used by Shafer (1999), includes the effects of invasive plant and animal species, physical damage and soil compaction caused through trampling and harvesting, abiotic habitat alterations and pollution. These are areas outside the boundaries of the core-protected area that are managed sympathetically to minimize the impacts of outside activities. Pressey (1997) stated that while doing all these things, buffer zones increase both the effective size of the protected area and the likelihood that all the life requirements of protected organisms will be provided in this larger area.

A buffer zone is essentially a boundary imposed on a specific habitat for a predetermined, specific objective. According to Strayer *et al.* (2003), ecologists use the term boundary to refer to a wide range of real and conceptual structures and it may be counterproductive to insist that all ecologists agree on a single rigid definition of a boundary. Strayer *et al.* (2003) states that this is apparent when reading ecological literature that ecologists attach a range of meanings to the term *boundary*, presumably to accommodate the systems and questions they are studying.

Ecological boundaries may differ in their origin and maintenance, their spatial structure, their function and their temporal dynamics. Therefore, these definitions are important when studying landscape ecology because this science deals with the spatially explicit relationships among patched types in complex mosaics (Turner 1989, Forman 1995, Wiens 1995).

Ideally, the prioritized end-use objective for a buffer zone is protection. Putwain & Pywell (1997) advised that one can protect remaining semi-natural habitats by creating buffer zones between them and an adjacent, potentially damaging land use. They go further to state that part of ecosystem management would be the establishment of buffer zones around protected areas, as Shafer (1999) pointed out, buffer zones can also provide more landscape needed for ecological processes such as fire.

Stephens (1998) illustrated that the advantages of buffer zones include increasing the available habitat area, decreasing the potential exposure to adverse impacts and absorbing the severity of impacts. Buffer zones may include areas ranging from almost full protection, to areas in the process of rehabilitation, and to those that may include small, low-density urban communities.

The characteristics of development (urban edges) along, or in close proximity to sensitive habitats are complex and pose management challenges and the situation is exacerbated when these areas abut protected areas. As has already been stated, the majority of literature and studies on buffer zones related to large conservation areas such as reserves, however Stephens (1998) observed that protected areas have been made available for conservation and must therefore coincide with the edges of pre-existing property.

Stephens (1998) further stated that boundaries of natural systems seldom coincide with those of privately owned property and it is therefore important to find a way of co-managing the urban fringe and natural areas in away that benefits both the built and natural environment. In line with Stephens (1998), the author of this study argues that a variable buffer zone model offers an effective means of co-managing the relationship between urban and natural areas.

Hansen & di Castri (1992) explained that the distinguishing feature of a landscape perspective is not just the recognition that a landscape is composed of elements of different quality, but the emphasis on relationships among patches – what happens between the elements in a mosaic. Differential movements or flows of nutrients, energy, organisms, or disturbances mediate these relationships across a landscape.

Once formulated and then implemented, a buffer zone essentially becomes a boundary. Cadenasso *et al.* (2003) stated that boundaries are the zones of contact that arise whenever areas are partitioned into patches and that the understanding of how boundaries influence the functioning of ecological systems is poorly developed. Cadenasso *et al.* (2003) further stated that when, where and how boundaries affect ecologically important flows across heterogeneous space are not well known.

An area where buffer zones have proven very effective is in the management and protection of biosphere reserves, Birckhead *et al.* (1997) stated that the biosphere reserve model rests heavily on the concept of buffer zones. Biosphere reserves are models whereby environmentally sound and sustainable development can be promoted in areas adjacent to the more strictly protected areas. Although biosphere reserves are concepts on a larger scale than residential development the principles are the same and the successful creation of biosphere reserves refers back to the mid 60's, and these have included the implementation of buffer zones which provide a transition between areas used primarily for conservation purposes, and areas that are used for purposes not well suited to conservation (Birckhead *et al.*, 1997).

Again, with more specific relevance to national parks and biosphere reserves, Sayer (1991) defined a buffer zone as 'a zone, peripheral to a national park, or equivalent reserve, where restrictions are placed upon resources use or special development measures are undertaken to enhance the conservation value of the area'.

What is important to take note of in this definition is that Sayer (1991) recognized that development activities may take place, as long as they are environmentally sustainable and enhance the conservation value of an area. Having said this it is important to acknowledge that patches and boundaries must be defined, as they are the structural and functional components of landscapes. It is not the purpose of this study to evaluate edge effects, ecological boundaries and patches.

1.3 Shortcomings in determining buffer zones

Lucas (1992) stated that the incorporation of human societies, behaviour and welfare into planning and design of conservation areas is currently lacking, but is destined to become a vital component of conservation management. Considering the aggressive rate of development in Johannesburg and the sociopolitical pressure from government and the private sector to elevate poverty by job creation, the need to establish cooperation between development and conservation is of utmost importance.

Development has historically enjoyed priority over conservation in Gauteng (GDACEL, 2004). There is, however, growing uncertainty and confusion amongst developers and planners regarding the justification and implementation of the present buffer zone requirements, especially on ridges. Discussions between developers and EIA consultants have highlighted this uncertainty. For example if a proposed development requires a 200m buffer zone but the property boundary is only 100m and the adjacent property is fenced off by a wall, why was the species concerned surviving in the <200m area prior to the assessment?

It is understandable that the departmental authorities presently recommend a strict no-development status, as well as requiring the present buffer zones because of injudicious development. This development has included residential and business purposes as well as industrial expansion, population growth and invasion of open spaces, and has often been allowed to take place in close proximity to sensitive environments and especially wetlands through inappropriate land-use planning (GDACEL, 2004). It is this modern view of prioritizing societies developmental needs (economics) in a manner that is environmentally respectful, which aspires to sustainable development.

There are different definitions for sustainable development and can be addressed on global, national and regional levels. The South African Development Community's goals for sustainable development emphasized the importance of a people-centered approach in the context of developing countries.

Definitions of Sustainable Development (DEAT, 2004):

Global

Our Common Future (WCED, 1987) defines sustainable development as:

Development that meets the needs of the present without compromising the ability of future generations to meet their needs and aspirations.

Regional

The sustainable development goals of the Southern African Development Community (SADC, 1996) are to:

Accelerate economic growth with greater equity and self-reliance;
Improve the health, income and living conditions of the poor majority; and
Ensure equitable and sustainable use of the environment and natural resources for the benefit of present and future generations.

National

The South African National Environmental Management Act (NEMA, Act 107 of 1998) defines sustainable development as follows (section 1(1) (xxix)):

Sustainable development means the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations.

The shift in emphasis on defining sustainable development was echoed in the outcomes of the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002. Furthermore, the fundamental principles of sustainable development are entrenched in the Constitution of the Republic of South Africa, 1996.

Environmental rights of people in the South African Bill of Rights (DEAT, 2004) included the following important statements:

In terms of Section 24 (a) of the Bill of Rights in the South African Constitution (Act 108 of 1996), everyone has the right:

(a) to an environment that is not harmful to their health or well-being; and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other 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.

The essence of the environmental management legislation is to promote and attain sustainable development.

From the previous paragraph it is clear that DEAT (2004), acknowledged that although there are numerous and varied definitions of the term sustainable development, the common elements included the need to integrate social, economic and environmental features as well as to address intra-and inter-generational equity.

According to Bredenkamp & Brown (2001), it is becoming more accepted that sustainable development can provide the needs of the present generation without jeopardizing the right of future generations to experience and enjoy nature, in the form of natural and unspoilt ecosystems where biodiversity has been preserved as a component of their quality of life. Furthermore, due to increased development as a result of growing urbanization and declining urban environmental quality, more attention is being paid to ecological principles as the basis for development planning.

It has become critical that development should be planned in such a way as to make the best possible use of natural resources whilst avoiding degradation and allowing for conservation of natural ecosystems.

Bredenkamp & Brown (2001) further stated that it is crucial to find ways to maintain plant and animal species, biodiversity and ecological processes within the sustainable development process. Hence, explicit attention must be given to the inclusion of the environment, its biota and the associated habitats in the decision-making and planning process. For this reason it has become essential to develop procedures that can evaluate and assess the impact of new developments on the environment and to include this knowledge in the planning of new developments.

There have been problems between the main components, being authority (national government & local and provincial authorities), industry (commercial developers, business) and the environmental consultants (independent facilitators). It was felt that the term EIA was inappropriate because of connotations of being anti-development and being associated with legal conflicts and costly delays (DEAT, 2004). King & O'Beirne (2006) stated that of particular concern in South Africa is that significant socio-economic problems are leading to fast-tracking of economic growth policies, with environmental concerns, being accused of unnecessarily delaying or even preventing much needed development.

The general public also has their doubts as to the true nature of certain development authorizations. Claase (2004) highlighted this by finding that in spite of the vocal support of Environmental Affairs Minister, Marthinus van Schalkwyk, for placing "people firmly at the center of conservation", there is an increasing perception that these developments are not for the community but for corporate profits.

In Gauteng there is presently only one authoritative buffer zone requirement, which is a 200 m "no development zone" emanating from any Red Data species found within any survey area along a ridge. There is presently much debate as to what a minimum buffer zone should be.

Due to the lack of literature available on determining buffer zones, GDACEL posted a request for buffer zone recommendations on the listserve of the Ecological Society of

America, to which scientists from all over the world subscribed (Pfab, 2001b), in order to gain broader insight into present opinions. The responses were mixed and indicated little or no consensus as to a recommended width as they varied from 3.5m to 1.6km.

Table 1. Responses received from ecologists subscribing to the listserve of the ecological Society of America regarding buffer zone widths (Pfab, 2001b).

RESPONSE FROM	GUIDELINE INFORMATION
Daniel Press, Associate Professor, Environmental Studies Department, University of Santa Cruz, USA	• No widely applicable formulas for buffer zones; varies from species to species and case to case.
William Null, Wetlands Biologist, Washington State Department of Transportation, USA	• No known established widths for threatened plant populations. • Wetland buffer zones recommended in USA range from 8m to 530m. • Riparian buffer zones recommended in USA range from 3.5m to 305m. • Buffer zones for endangered/threatened species recommended at 50m by Ontario Ministry of Natural Resources. • Buffer zone needs of fish and wildlife range between 9m (for muskrat feeding and denning) to 183m (for some bird species)
Carlo Popolizio, U.S. Fish and Wildlife Biologist, USA	• Reluctant to set standard buffer zones. • Depends on autecology of species.
Vincent Tepedino, USDA ARS Bee Biology & Systematics Lab, Utah State University, USA	• U.S. Fish and Wildlife Service opt for a rough (and rather liberal) buffer zone of 4.8km around plant populations based on maximum distance a bee may fly from nest-site to foraging area and based on distances that crop growers clear around some crops to prevent unwanted hybridizations with wild conspecifics or congenerics – estimate not based on reliable data. • Depends on habitat, type of pollinator, nest site availability, density of flowering plants, etc. • Recommends a minimum buffer of 1.6km. • Resources for pollinators must be provided, e.g. a variety of nesting sites (e.g. dead wood, south-facing semi-bare partially compacted soil, vertical embankments), a source of water and/or mud if none is readily available, alternative blooming plants, sources of leaf, resin, plant hairs, etc. Developers should be required to include open spaces for such "pollinator amenities".

Patricia Gordon-Reedy, Senior Botanist, Conservation Biology Institute, California, USA	• Is also looking for information on buffer requirements for endangered or threatened plant species.
Karen Holl	• Maintenance of ecosystem processes must be ensured. • Depends on what one is trying to buffer against.
Anna Ballance, CSIR, South Africa	• Ecosystem processes must be maintained.
Ingrid Parker, Assistant Professor, University of California, USA	• As long as pollinators are available, small patches of plants can be self-sustaining without a huge buffer, but patch itself must be completely protected. • Fence in the impact rather than fencing in the rare species.
Dan Doak	• Abiotic changes in forest can extend up to at least 200-300m from the edge. • Abiotic effects likely to decline much more rapidly in grassland. • A buffer zone of 200m in grassland seems reasonable since abiotic effects are going to be low at this distance, it is beyond the normal home range size of most pollinators, it is far enough to give some warning of important exotic invasions.
Malcolm Hodges, Stewardship Ecologist, the Nature Conservancy of Georgia	• Buffer needs will vary according to the species. • Ecological processes need to be considered. • Fire may require a fairly large buffer while the maintenance of hydrological processes will require a smaller buffer.

Unfortunately, determining buffer zones has not received in-depth investigation and analysis, as observed by Arthur Ebregt (IAC, 2001) who stated that a methodical assessment of strengths and weaknesses of the buffer zone concept had hardly been carried out. Buffer zones have mostly been viewed for their potential benefits to water quality, and numerous studies have addressed the influence of buffer zones on reducing non-point source pollution in watershed runoff. Recommended design criteria are highly variable, and relatively few studies have addressed the compatibility of recommended buffer strip widths for water quality with other important ecological functions (Upper Raritan Watershed Association, 2002).

1.4 Research aims and objectives

The main research aim of this study is to determine whether a pre-determined buffer zone of for example 200 m is applicable to all plant communities, by investigating the effect of development on plant species composition and plant density within selected developments on rocky ridges.

The objective is to study the changes in vegetation from the boundary of development into the less disturbed areas using qualitative data (cover-abundance scale) and quantitative data (plant density). The distance between the disturbed development edge and the point at which the climax community has been established, or is still present, will indicate (represent) the ecologically defined buffer zone required for each specific habitat type based on the succesional status of species.

The important questions to be answered are:

- Is the present blanket application of a 200m buffer zone on rocky ridges scientifically justifiable? Is this buffer zone actually too small or too large to allow environmentally responsible development that does not negatively impact its surroundings?
- Could plant community based surveys provide an easy and efficient method of determining ecologically defendable buffer zones

Bredenkamp & Brown (2006) stated that the management of savanna ecosystems in southern Africa has for many years been based on the assumption that the dynamics of these ecosystems are by conventional succession, and therefore, that these systems are stable and in equilibrium. Ecosystems are considered to be in equilibrium when plant growing conditions are relatively favorable and stable over time, with low inter-annual variation in rainfall and predictability in timing and magnitude of rainfall (Bredenkamp & Brown, 2006).

These systems fluctuate around one or more points of equilibrium, to which they return after recovery from a disturbance. Therefore, each study area was investigated by assessing the successional sequence beginning 5m from the development edge and ending 75m within the pre-selected homogenous plant community. It is proposed that the distance between the primary successional stage (closest to the development edge) and the established climax community will indicate the distance required to serve as a buffer zone on these specific ridges.

Bredenkamp & Brown (2002) described the climax community of the study area as open savanna that is bushveld vegetation, but has been changed to, and maintained as grassveld by regular veld fires. Therefore, the climax community will be determined by the presence of species identified by Bredenkamp & Brown (2002). This will provide some indication of the extent to which the present buffer zone requirements of 200m in the Gauteng Province (Pfab, 2001a) are realistic.

Succession as described by Tainton (1999) is the progressive development of vegetation in any area, through a series of different plant groupings or communities. Because secondary succession occurs wherever a plant community has been disturbed and is no longer in equilibrium with its environment, this will be an indication as to the distance required for communities bordering developments to attain equilibrium (climax community). Therefore, by using vegetation as the most physical representation of the environment, the study intends to investigate at what distance from the development does the climax community as described for the specific study areas by Bredenkamp & Brown (2002) dominate. A successional climax community will be characterized by a high density of climax species and conversely a high density of weedy and pioneer species will indicate a successional pioneer community. Kent & Coker (1992) stated that information on vegetation may be required to help solve an ecological problem: for biological conservation and management purpose; as an input to environmental impact statements; to monitor management practices or to provide the basis for prediction of possible future changes. These findings could then be used as a scientific base to defend buffer zones imposed on developers.

1.5 Hypothesis

It is possible to develop scientifically based guidelines to assist environmental assessors on establishing ecologically acceptable buffer zones on rocky ridges and hills. A 200m buffer zone is not necessarily applicable to all plant communities on rocky ridges.

1.6 Contents of this mini-dissertation

In chapter 1 an introduction to the topic is presented and includes a problem statement, an introduction to buffer zones, shortcomings in determining buffer zones, research aims and objectives and the hypothesis.

In Chapter 2 an overview of the study area is given with particular reference to the climate, geology and the vegetation type of each study site. Chapter 2 also includes 1: 50 000 topographical maps of each study site indicating the placement of transects.

Chapter 3 discusses the scientific methods that were implemented in the execution of this study. The quantitative (species density) data analysis includes multivariate analysis using CANOCO (Ter Braak & Šmilauer, 2002) and qualitative (Braun-Blanquet cover–abundance values) data analysis and description which includes site selection, data collection, transects and sample plots.

Chapter 4 presents the results which include the classification, description and phytosociological table for the vegetation types, the density of successional groups of species and the CCA triplots for each study site.

Finally, Chapter 5 concludes this dissertation with an overview of, and remarks concerning, the study as a whole.

CHAPTER 2

STUDY AREA

2.1 General information

Gauteng is the countries smallest Province (only 1.7 million hectares in extent), and is 97% urbanized (Figure 1). Gauteng is also the economic hub of South Africa and accounts for 33% of South Africa's GDP and is also the largest sub-national African economy. Economically Gauteng is also responsible for 49.6% of all employee remuneration in the country and 52% of all turn- over of institutions.

Gauteng has the highest population density in South Africa, which grew from 432 people per square kilometer in 1996 to 522 people per square kilometer in 2001 with densities as high as 100 people per hectare in some areas (Gauteng Provincial Government, 2005). One of Gauteng's greater land use challenges lies in the fact that Gauteng has approximately 40 000 hectares of highly arable land of which only 67% is farmed, and more than 15 000 hectares having been sterilized by 160 slimes dams. It is interesting however to note that with high levels of industrial activity, urbanization and economic growth, more plant species occur per unit area in Gauteng than any other Province (Low & Rebelo, 1996) and the grassland biome, which accounts for 71% of Gauteng, is second only to the fynbos in terms of species richness (Cowling *et al.*, 1991).

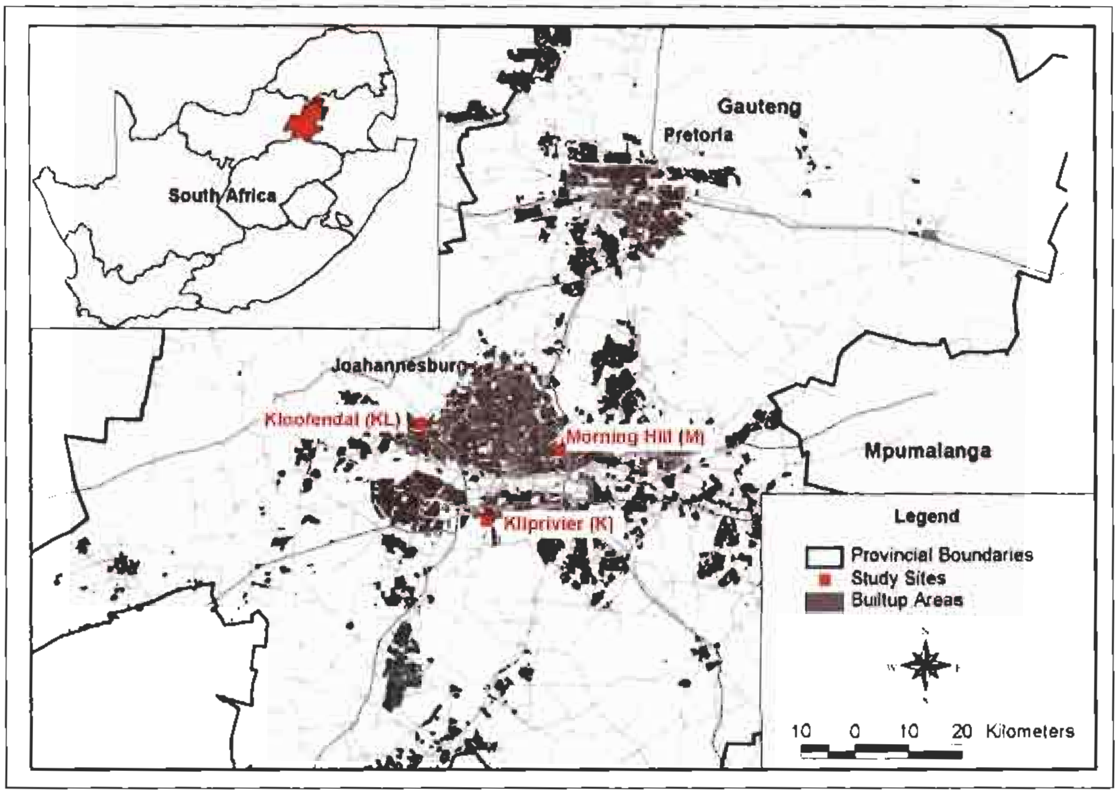

Figure 1. Map of Gauteng Province indicating the study sites

Gauteng lies S 26°11' 10,62" and E 027°59' 47,08" latitude and longitude and falls within a summer rainfall area where the days are usually warm to hot with clear blue skies often giving way to brief late afternoon thunderstorms. The Highveld Plateau, on which the sites are located, has warm to hot summers with fairly high rainfall, and cool to cold winters with little or no rain. On average January is the hottest month (average maximum temperatures recorded at 26° C to 29°C) with June/July being the coldest months in the year (average maximum temperatures recorded at 16° C to 19°C).

Only about 7% of South Africa has a mean annual precipitation (MAP) exceeding 800mm, however, Gauteng does not fall within the 7% as recordings indicate a mean annual rainfall of 668mm. Rain falls mainly within the months of November to January over the Highveld with the highest rainfall in January and February (Figure 2).

Johannesburg is the largest city in Gauteng and was founded in 1886 after the discovery of gold and has for over a century been the center of South Africa's gold-mining industry (Greater Johannesburg, 2006). It is one of the youngest major cities in the world and has the status of the country's chief industrial and financial metropolis. The Greater Johannesburg Metropolitan area forms the largest on the African continent comprising a total of 2.5 million people of which 400 000 are in informal settlements (Greater Johannesburg, 2006). Johannesburg is situated on the Highveld, the broad grassland dominated plateau that traverses the South African interior. The plateau's elevation ranges from 1500m to 1800m and constitutes the watershed between the sub-continental drainage divide into the Indian and Atlantic Oceans.

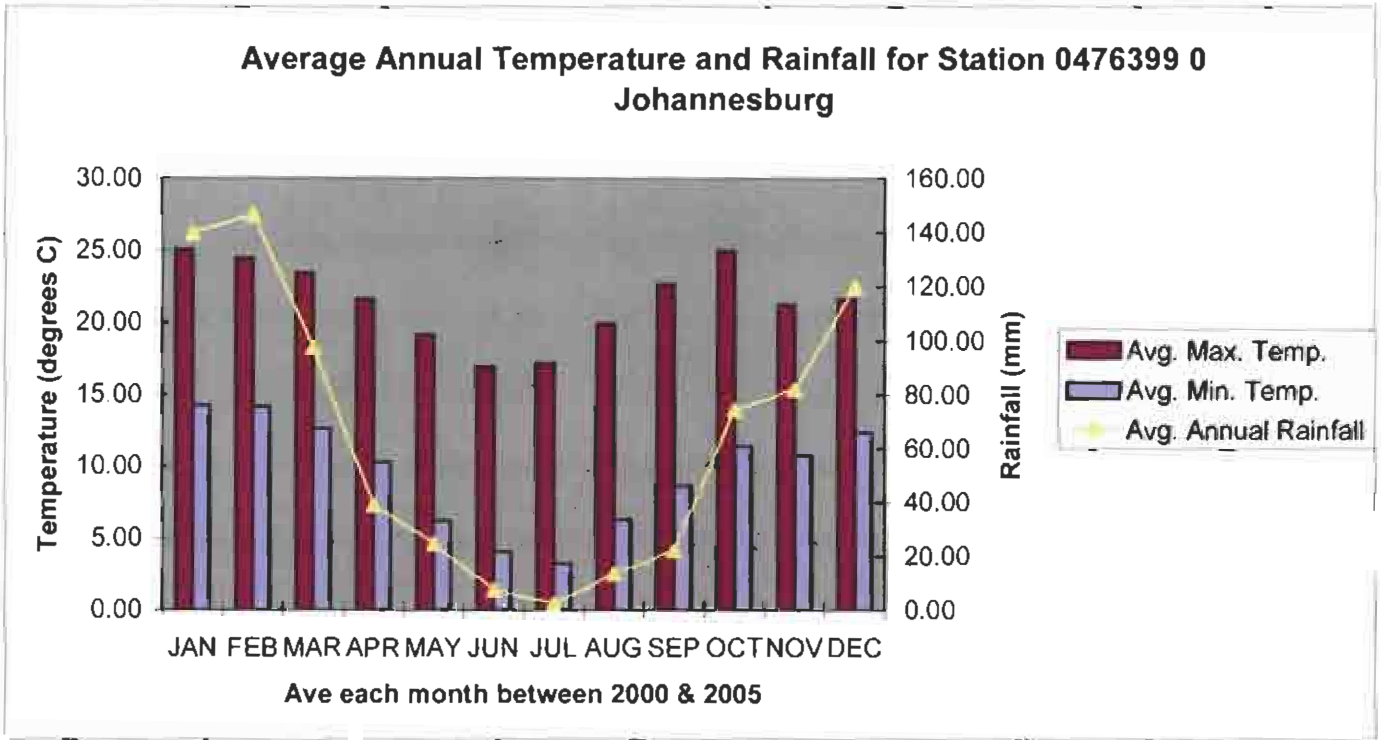

Figure 2. Average climatic conditions in Gauteng between 2000 – 2005 (data supplied by the South African Weather Services).

Of the thee ridges identified for this study two sites; Kloofendal (sample site 1) and Morning Hill (sample site 2), are both south facing ridges composed of *Protea roupelliae* Cool Temperate Mountain Bushveld (Bredenkamp & Brown 2002) and the two sites are also founded on the same geological formations, and have therefore been described together.

2.2 Location

2.2.1 Sample site 1: Kloofendal &Sample site 2: Morning Hill

The Kloofendal site is situated at S 26°07' 24,4" and E 027°52'49,3" (Figure 3). This study site is located along the eastern boundary of a secure up-market residential estate north east of Wilgerood road. The study area extends from the development boundary into the Krans Alwyn Nature Reserve Trail. Access to the site was via a private gate from within the estate. The general area can be described as an established, up-market suburb composed of residential developments along the slopes of a prominent ridge.

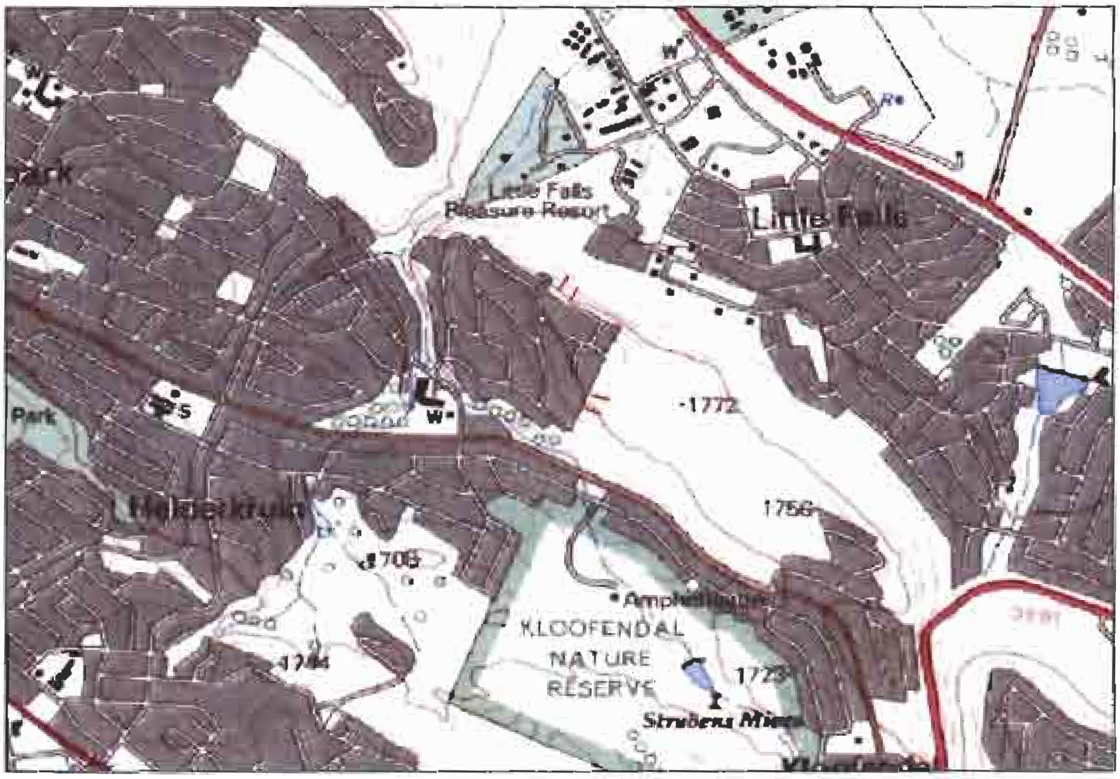

Figure 3. Map showing the Kloofendal study area with transects in red (scale:1:50 000).

The Morning Hill study site is situated S 26°10'05,1" and E 028°07'15,3". This study site is located on the northern boundary of an up-market residential estate north of the R40 approximately 3km north east of Eastgate shopping mall (Figure 4). Access to the study site was through the estates security entrance, as the undeveloped ridge forms part of a protected open space. The entire ridge is surrounded by middle to up-market residential development and lies to the east of the Harvey Nature Reserve.

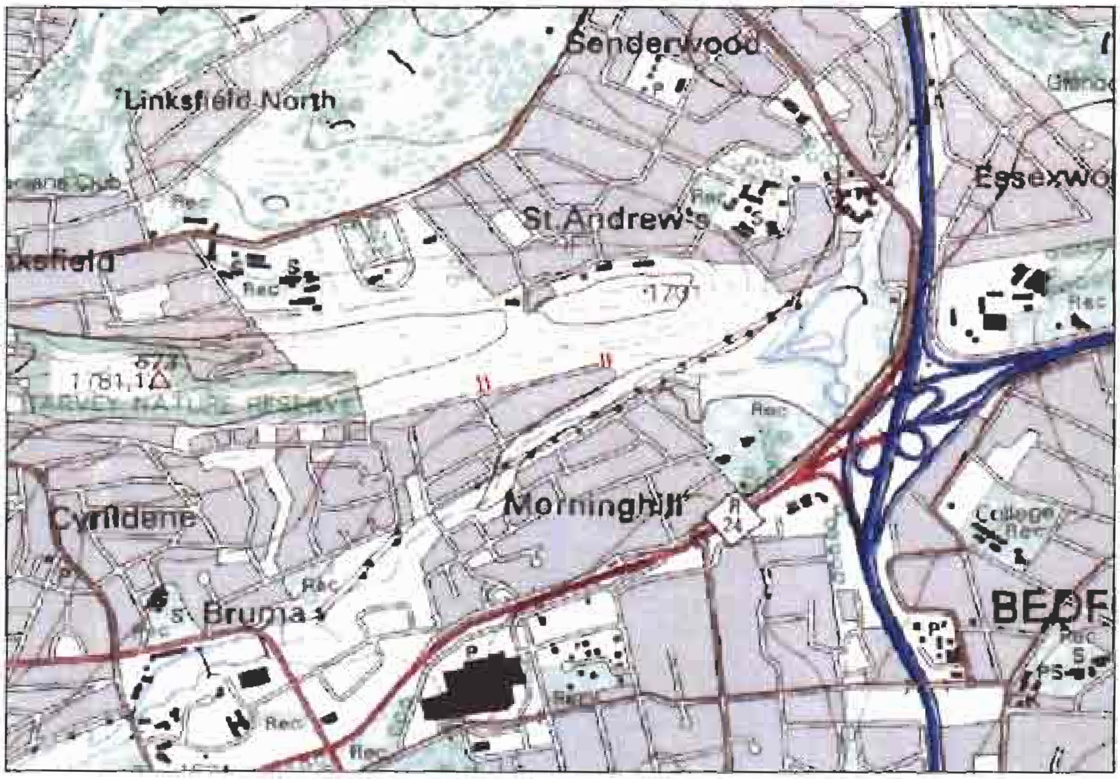

Figure 4. Map showing the Morning Hill study area with transects in red (scale: 1:50 000).

2.2.2 Geology

The geological formation in these particular sites is the Orange Grove formation of the West Rand Group of the Witwatersrand Super Group (ENPAT, 2000). The Witwatersrand group is a thick sequence of shales, quartzites and conglomerates. Principle subdivision is into a lower, predominantly argillaceous unit, and an upper unit, composed almost entirely of quartzites and conglomerates. The lower unit is subdivided into three lithologically: the Hospital Hill, Government Reef and Jeppestown; the upper unit into the Main-Bird and Kimberley-Elsburg (Truswell, 1977).

The Orange Grove Quartzite forms the actual Witwatersrand, and rests noncomformably on the Halfway house granite. The quartzite itself is a light-coloured, dense, recrystallized rock. It contains little other than quartz and is thus an orthoquartzite. A simplified geological map derived from the Environmental Potential Atlas (ENPAT 2000) (Figure 5) indicates the specific geology underlying these sites.

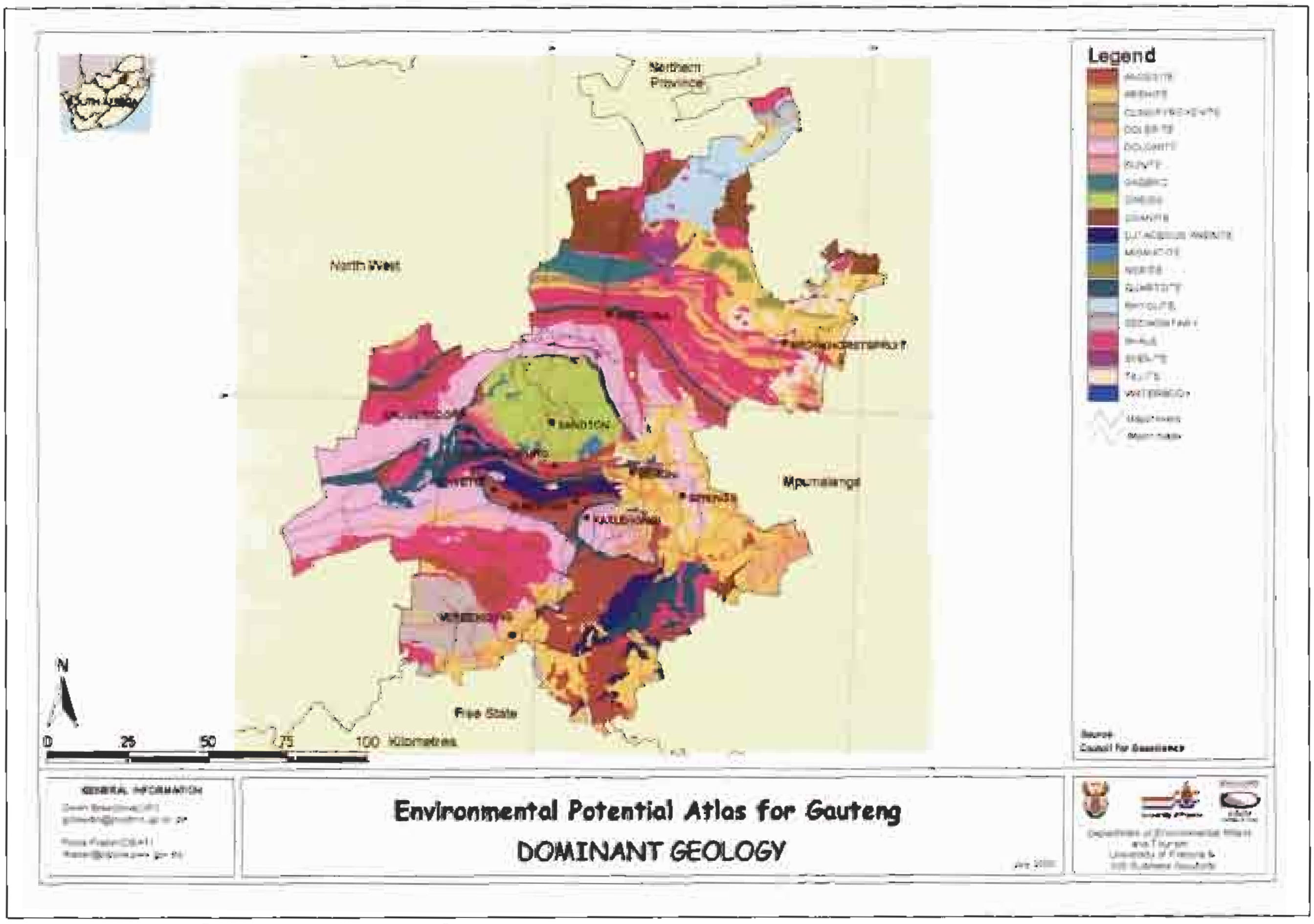

Figure 5. Geological map of Gauteng.

2.2.4 Vegetation type

The two study sites are both included in the *Protea roupelliae* Cool Temperate Mountain Bushveld (Bredenkamp & Brown, 2003).

This cool temperate bushveld is mainly found at high altitudes on relatively steep southern mid-slopes of rocky quartzite ridges (1b land types) and is restricted to the western and southern parts of the Gauteng region (Bredenkamp and Brown 1998a, 1998b, Grobler *et al.* 2002). The slopes normally have a high rock cover with shallow sandy soils. These represent the relatively moist and cool habitats (Bredenkamp & Brown 2003).

Low & Rebelo (1996) define these sites as part of the Rocky Highveld Grassland, which is the transition type between typical grasslands of the high inland plateau, and the bushveld of the lower inland plateau (Figure 6). It stretches from Lichtenburg to Middleburg in the east, including the southern slopes of the Magaliesberg, the ridges of the Witwatersrand and the dolomite plains of Gauteng, mainly between 1500 to 1600m in altitude.

The diagnostic plant species of this vegetation type include the tree *Protea roupelliae*, the grass *Eragrostis micrantha* and the forbs *Crassula nodulosa, Gnidia sericocephala, Graderia subintegra, Indigofera hilaris, I. melanadenia, Lotonosis eriantha, Nemesia fruticans, Tephrosia rhodesica, Tritonia nelsonii* and *Selago tenuifolia* (Bredenkamp & Brown, 2002).

The vegetation is dominated by the trees *Protea roupelliae*, *Protea caffra* and the grasses *Loudetia simplex*, *Trachypogon spicatus* and *Tristachya leucothrix*. Other woody species also present include the trees *Rhus leptodictya*, *R. lancea*, *R. pyroides*, *Euclea crispa*, the shrubs *Grewia occidentalis*, *Lippia javanica* and the grasses *Monocymbium ceresiiforme*, *Panicum natalense*, *Urelytrum agropyroides*, *Themeda triandra* and the forb *Vernonia oligocephala* (Bredenkamp & Brown, 2002).

Examples of this vegetation type were described by Bredenkamp and Brown (1998a, 1998b) and Grobler *et al.* (2002). In the Bankenveld relatively little has been published on the distribution of this relatively rare community and it has been included as part of the larger *Protea caffra* plant community descriptions.

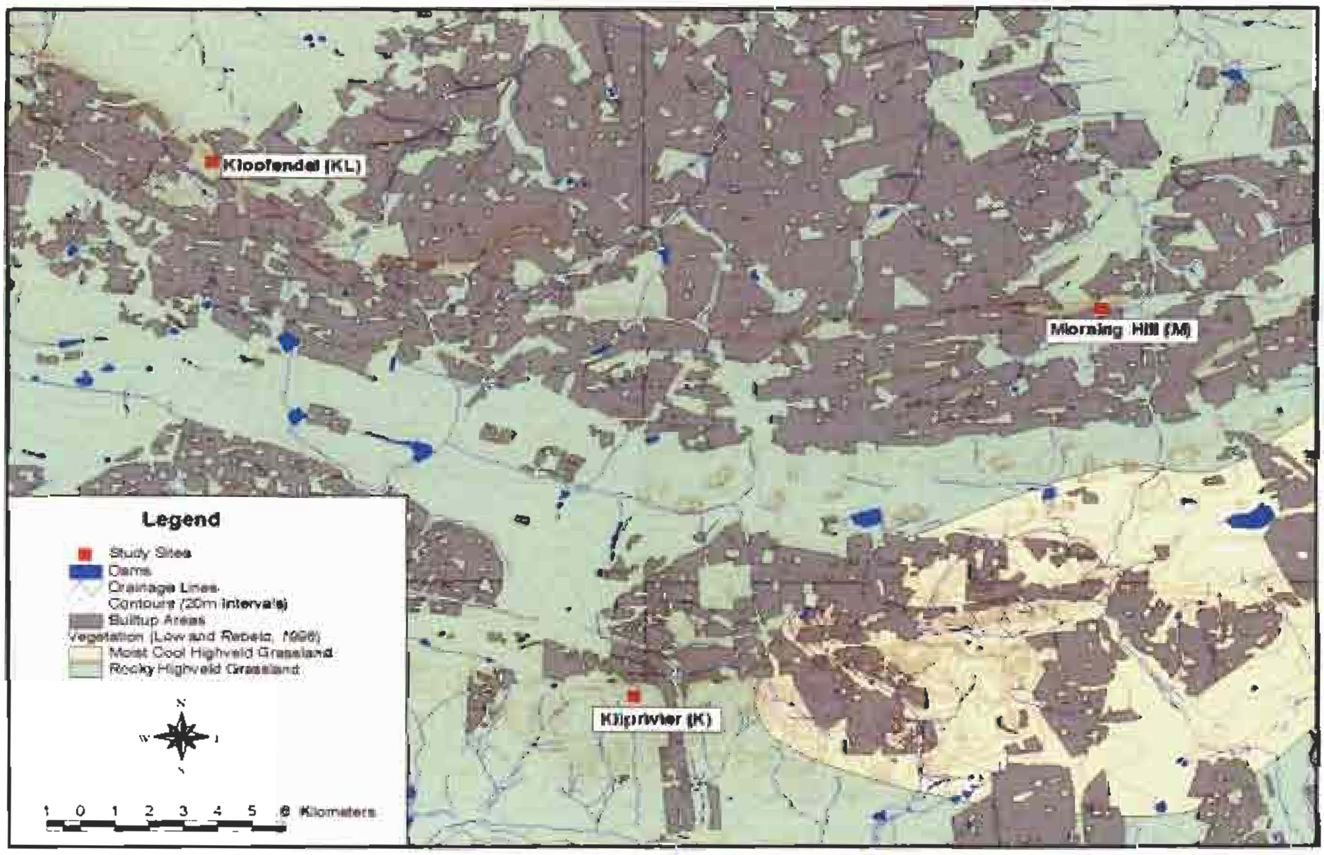

Figure 6. Vegetation map of study sites (Low & Rebelo, 1996).

The presence of the trees *Protea roupelliae, Protea caffra* and the grasses *Loudetia simplex, Trachypogon spicatus, Tristachya leucothrix, Monocymbium ceresiiforme, Themeda triandra, Diheteropogon amplectens* and *Hyparrhenia hirta* indicates a definite affinity to the Drakensberg vegetation (Afro-montane phytochorium) (Acocks 1988, Smit *et al.* 1992, 1995a, Eckhardt *et al.* 1996).

2.3 Sample site 3: Kliprivier Nature Reserve

2.3.1 Location

The Kliprivier site is situated at S 26°16'47,3" and E 027°59'35,7" (Figure 7). The study site lies to the east of the R82 in the southern suburbs of Johannesburg. The general area can be described as middle to lower income residential suburbs with well-established infrastructure and services. The transects start on the southern boundary of Alan Manor and extend into the Klipriviersberg Nature Reserve.

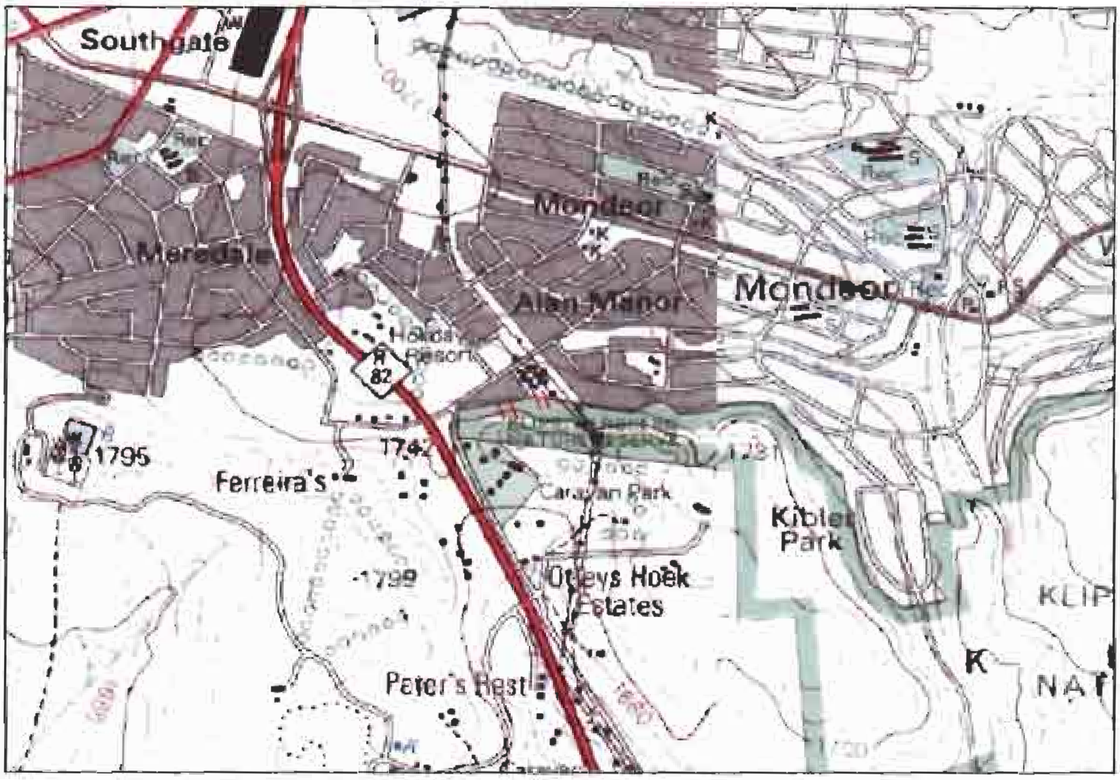

Figure 7. Map showing the Klipriver study area with transects in red. (scale: 1:50 000)

2.3.2 Geology

This site lies on the transition between the Alberton and Westonaria formations of the Klipriviersberg Group of the Ventersdorp Super Group (ENPAT, 2000). Truswell (1977) described the Ventersdorp Super group as a mass of predominantly volcanic rocks that are younger than the Witwatersrand but older than the succeeding Transvaal.
The Ventersdorp outcrops are over an extensive area within and around the Witwatersrand basin, especially to the west and southwest (Figure 5).

Other outcrops occur around the northwestern rim of the Vredefort Dome, in Johannesburg and to the south of it in the Klipriviersberg, and further south again down to the Vaal River between Vereeniging and Villiers (Truswell, 1977).

Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. Exposures are generally poor and sedimentary intercalations are lenticular in nature. Truswell (1977) identified two unconformities with the Ventersdorp; that the rocks from the Klipriviersberg Group may rest conformably on Witwatersrand strata, as they do in the Klipriviersberg south of Johannesburg (the study area), and the distribution of this group is indeed closely related spatially to the underlying Witwatersrand strata. The suggestion has been made that the Klipriviersberg Group should be regarded as part of the Witwatersrand basin.

<u>Ventersdorp lava</u>

These andesitic lavas mostly form flat plains with deep, nutrient-rich soils and with *Cymbopogon – Themeda* Graasveld, often utilized for maize cultivation. In ridges within the Heidelberg, Alberton and Gatsrand areas, however, the lavas form smooth hills and ridges with woodland communities at sheltered sites, with grassland on exposed high altitude slopes and plateau (Bredenkamp & Brown, 2002).

2.3.3 Climate

Low & Rebelo (1996) indicate the summer rainfall between 650 to 750mm per year and temperatures varying between -12°C and 39°C, with an average of 16°C.

2.3.4 Vegetation type

This study site is included in the *Themeda triandra-Acacia karoo* Microphyllous Woodland (Bredenkamp & Brown, 2003).

Bredenkamp & Brown (2003) stated that in the Bankenveld area this type of woodland is found on colluvial soils on foot-slopes, in bottomland plains and as riparian vegetation along streams and rivers (Bezuidenhout & Bredenkamp, 1991). Low & Rebelo (1998) also include this site within the Rocky Highveld Grassland (Figure 6). This vegetation type occurs over a wide range of geology, land types, soils and terrain types with low rock cover, but is mostly associated with moderately deep and often clayey, high nutrient, alluvial soils derived from andesite shale, karoo sediments or dolomite (figure 6).

According to Bredenkamp & Brown (2003) this woodland may be open to quite dense and is characterised by the diagnostic trees *Acacia karoo* and *Ziziphus mucronata* which dominate the woody layer. The diagnostic multi-stemmed shrubs *Asparagus* *suaveolens* and *Asparagus laricinus* and the forb *Teucrium trifidum* are almost always associated with this vegetation type. The herbaceous layer is dominated by the grasses *Themeda triandra*, *Setaria sphacelata* while the grasses *Eragrostis curvula*, *Heteropogon contortus*, *Digitaria eriantha* and *Elionurus muticus* are also abundant locally.

On lower mountain slopes this vegetation type and Acacia caffra –dominated vegetation often merge to form an ecotonal mixed microphyllous woodland.

Examples of this vegetation were described by *inter alia* Coetzee (1975a) from the Rustenburg Nature Reserve, Bredenkamp & Theron (1980).

CHAPTER 3

METHODS

3.1. Introduction

Vegetation can be defined as an assemblage of plants growing together in a particular location. It may be characterized by either its component species or by the combination of structural or functional characters that characterize the physiognomy of vegetation. This is an important distinction that is reflected by the range of methods available for describing vegetation (Kent & Coker, 1992).

Vegetation ecology is important for three reasons. Firstly, in most terrestrial parts of the world, the most physical representation of an ecosystem is vegetation. Secondly, primary production usually results in vegetation. This is where solar energy is transformed through the process of photosynthesis into green plant tissue. Thirdly, vegetation provides the habitat within which organisms live, grow, reproduce and die (Kent & Coker, 1992).

Individual plants form the building blocks of vegetation. Each plant is classified according to a hierarchical system of identification and nomenclature, using carefully selected criteria of physiognomy and growth form. A population is made up of several individual plants of the same species and within the local area, groups of plant populations found together, form plant communities. Plant communities are dynamic in nature and therefore community composition will often change over time according to the principles of succession and climax (Kent and Coker, 1992). Succession involves the immigration and extinction of species together with changes in their relative abundances. The end product of succession is the climax community, which is based on the idea of relative stability (Kent and Coker, 1992) and will be used to determine the outer limit of the buffer zone.

3.2. Methodology used in this study

The phytosociological method namely the Zürich-Montpellier or Braun-Blanquet method was used to ecologically classify the vegetation of each sample site. The Braun-Blanquet method is a useful tool in providing a framework within which to classify vegetation. This method is widely accepted and has been successfully used within the various biomes of South Africa by amongst others Werger (1973), Coetzee (1974a&b), Bezuidenhout & Bredenkamp (1991), Du Preez & Bredenkamp (1991), Mathews (1991), Smit *et al.* (1995a and b), Brown *et al.* (1997), De Frey (1999), Janecke (2002) and Müller (2002).

According to Werger (1974), the Braun-Blanquet approach meets three essential requirements that make this approach one of the most significant tools in the study of the environment:

- The method is scientifically sound.
- It fulfills the necessity of classification at an appropriate level.
- It is the most efficient and versatile amongst comparable approaches.

These qualities make the Braun-Blanquet approach one of the most significant tools in the study of the environment. Westhoff & Van der Maarel (1978) summarizes the essence of the Braun-Blanquet approach as follows:

- Recognized by their floristic composition, plant communities are conceived as types of vegetation. The full species composition of communities better express their relationship to one another and the environment than any characteristic.
- Amongst the species that make up the floristic composition of a community, some are more sensitive expressions of a given relationship than others. The approach seeks to use those species whose ecological relationships make them most effective indicators. These are called diagnostic species.
- Diagnostic species are used to organize communities into hierarchical classification of which the association is the basic unit. The hierarchy is not merely necessary, but invaluable for the understanding and communication of community relationships.

The Braun-Blanquet method can be separated into two phases namely the analytical and synthetic phases.

3.2.1 Braun-Blanquet method: Analytical phase

This phase involves the acquiring of all the vegetation information needed for the study, which is represented in relevés. The process begins with the identification and selection of suitable sites.

3.2.1.1 Site selection

The hypothesis wishes to test whether it is possible to develop scientifically based guidelines to assist environmental assessors on establishing ecologically acceptable buffer zones on rocky ridges and hills. The following criteria where used to assess possible sites for investigation:

- Development occurred on a ridge
- The vegetation emanating from the development had not been developed and/or visually impacted.
- The remaining ridge habitat was in a protected environment and could therefore be used as the climax control habitat.

A desktop survey of Gauteng was conducted and possible sites of developed areas were identified. These potential sites were then physically investigated and the three study areas were finally selected based on the above-mentioned criteria. The ridges identified for this study fall into classes 2 and 3 as described by Pfab (2001a).

3.2.1.2 Data Collection

Surveys were conducted during the summer months of December 2005, January and February 2006. Developed areas adjacent to natural open areas were subjectively chosen during field trips in September-November 2005 to ensure that representative sample sites were selected. During the survey sample plots were sampled in areas where the vegetation composition was homogenous and representative of the specific area to be surveyed. This was done in accordance to Bredenkamp & Brown (2003).

When a disturbance takes place in an area, the area is recolonised by a new, better-adapted plant community. This new community improves the growth conditions, and a plant community that is better adapted to the new, improved growth conditions replaces the existing plant community. This progressive succession of plant communities is called plant succession and continues until climax community has been established (Kent & Coker, 1992).

When the succession process is disturbed once more, the veld will revert to the first stage, the pioneer stage (van Oudtshoorn, 1999). All species identified within the sample plots were allocated a successional value according to their successional stage as defined for grasses by van Oudtshoorn (1999) and for forbs by Van Wyk & Malan (1998). The primary importance is the presence or absence of particular species. At this point, the abundance of each species present becomes important (Kent & Coker, 1992).

According to McIntosh (1980) there are major problems in developing any universal model of succession, and this is partly due to a lack of consistent generalizations to allow any compact overview. Pickett *et al* (1992) argued that the equilibrium paradigm focused on the stable point equilibrium of ecological systems, indicating that succession is the attainment of the climax state. Therefore, the processes involved lead to the climax state and deviations from this are of little fundamental interest. Pickett *et al.* (1992) concluded that the classical paradigm in ecology, with its emphasis on the stable state, that natural systems are closed and self-regulating can no longer serve as adequate foundation for conservation. Instead, the new paradigm that recognizes episodic events and openness of ecological systems is more realistic as a basis for conservation planning and management.

Therefore, the reason for pursuing the classical paradigm model for this assessment is based on the findings of Hardy *et al.* (1999) who stated that in the grasslands of southern Africa the methods most commonly used apply the classical successional theory, i.e. vegetation state moves in sympathy with the environment between a pioneer and climax community. Ultimately, in any assessment of the general views of succession, interpretation depends on the nature of the environments and the times in which they are applied. According to Hardy *et al* (1999) methods based on ecological principles index veld condition according to a response of vegetation to abiotic environmental impacts, which is what was being tested in this investigation.

The following plant successional groups were used as described by Van Oudtshoorn (1999):

Climax species – These are strong perennial plants that are adapted to normal, optimal growth conditions and will grow in an area as long as these conditions prevail. The climax stage is the basic stage towards which the plant succession process automatically progresses. Van Wyk & Malan (1998) described climax as a plant species forming part of a plant community at the terminal stage of ecological succession, i.e. a relatively stable (climax) community which is in dynamic equilibrium with its environment.

Subclimax species – Subclimax plants are denser than pioneer plants and offer more protection to the soil. These plants are mainly weak perennials and as growth conditions improve, sub-climax species are replaced by climax species.

Pioneer species – These plants are hardened, annual plants that can grow in very unfavorable conditions. Pioneer plants improve the growth conditions for the future plants. As the growth conditions improve, the conditions become more favourable for perennial grasses. For the purpose of this study the author further distinguishes the exotic pioneers as weeds.

Weeds– Secondary succession is most commonly encountered on abandoned farmland and noncultivated ruderal sites (waste places) such as fills, spoil banks, railroad grades, and roadsides, all artificially disturbed and frequently subject to erosion and settling movements. Species most likely to colonize such places are regarded as weeds. Although difficult to define, weeds have one characteristic in common; they invade areas modified by human action (Smith, 1990). Therefore, for the purpose of this investigation a further distinction will be made to pioneer species that are described as weeds by Van Wyk & Malan (1998).

The methodology used to obtain the vegetation data in each site was uniform and included:

- **Transects**

Kent & Coker (1992) described the transect approach as very popular in vegetation work. Transects are effective as they can be deliberately set up across areas where there are rapid changes in vegetation and marked environmental gradients. Kent & Coker (1992) also stated that classic examples of laying transects across gradients are up hillsides, where slope angle, drainage and altitude combine, as was the case within the sample site. During the data collection four 75m transects were randomly placed

50m apart along the length of the developments edge boundary and emanated from the development towards the undeveloped protected area (Figures 8,9 &10). The stated 75m transect was determined to prevent the transect entering a different plant community. A 100m coloured nylon rope functioned as the transect and was secured to the ground with tent pegs.

Each 10mx10m plot was placed at 10m intervals not exceeding the range of the studied plant community. Each transect only started 5m from the properties physical boundary to exclude the possible impact that the physical wall or fence imposes on the immediate vegetation.

- **Sample Plots**

Four 10m x 10m sample plots were placed along each transect with a 10m interval between each sample plot. Inserting large wooden stakes created the 10m x 10m sample plots, with coloured tips for easy boundary identification, and then enclosing the plot with a nylon rope. Every plant within the plot was identified and documented in the respective data sheet. The abundance of each taxon present in the sample plots was allocated according to the Braun-Blanquet cover-abundance scale (Table 1). The taxon names in this mini-dissertation correspond to those of Arnold & De Wet (1993) and the PRECIS Data Base (updated March 2002). Environmental data, such as aspect, slope, topography, and percentage area covered by rock, biotic influence and longitude and latitude-using GPS (Global Positioning System) was acquired and recorded for each sample plot.

Table 2. The Braun-Blanquet cover values used in this study according to Kent & Coker (1992).

COVER VALUES	DESCRIPTION
R	One, or few individuals, rare occurrence.
+	Cover less than 1% of total plot area
1	Cover less than 5% of total plot area
2a*	Cover between 5-12.5 % of total plot area
2b*	Cover between 12.5- 25 % of total plot area
3	Cover between 25-50 % of total plot area
4	Cover between 50-75 5% of total plot area
5	Cover between 75-100 % of total plot area

* After Bredenkamp *et al* (1993).

The usual means of sampling vegetation for floristic description is the quadrat (Kent & Coker, 1992). Quadrat size is very important and will vary from one type of vegetation to another. In order to analyze and describe the vegetation with a high degree of statistic probability 1m x 1m quadrants were used. Nine 1m x 1m quadrats were placed within each 10m x 10m sample plot and all herbaceous plants within the quadrats were identified and counted in order to investigate species frequency and density. This data, recorded on field research sheets was then processed for interpretation by the methods described in the synthetic phase.

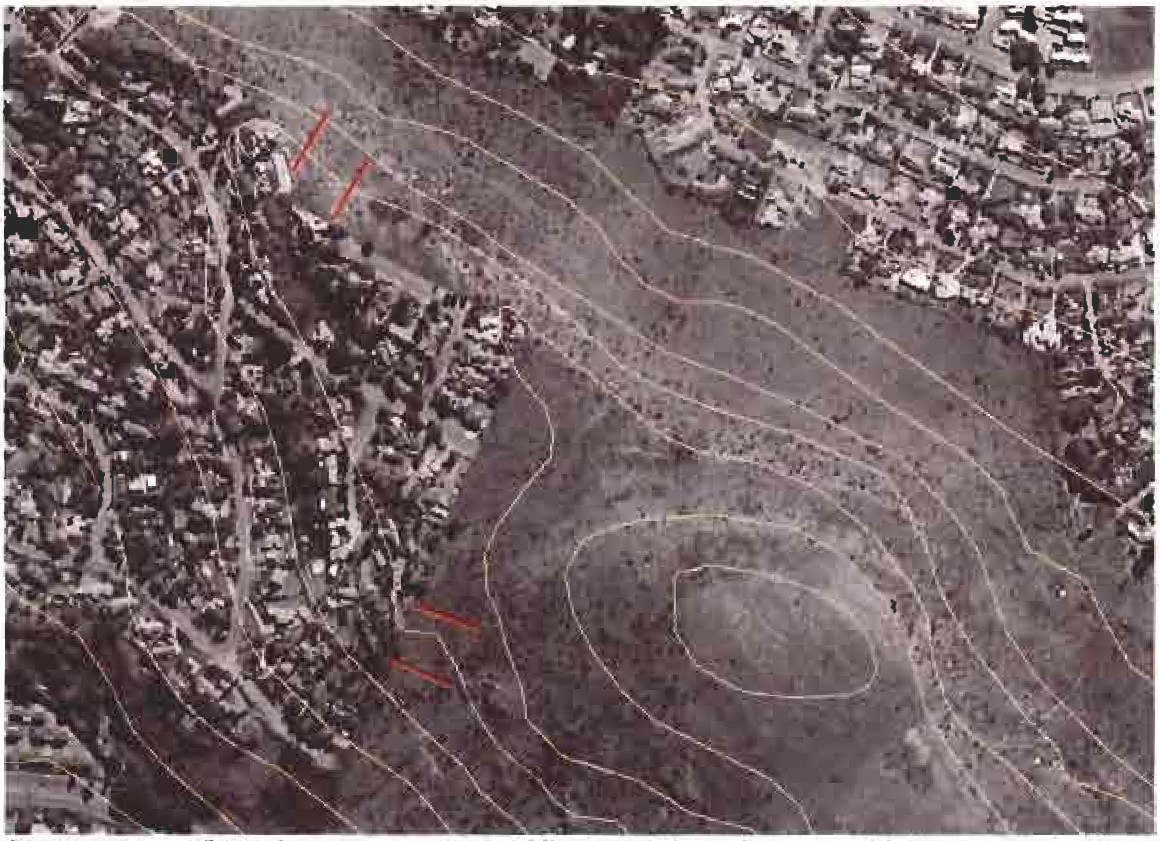

Figure 8. Ortophoto showing the Kloofendal study area with transects indicated in. Red (KL T1-4; P1-4).

Figure 9. Ortophoto showing the Morning Hill study area with transects in red (M T1-4; P1-4).

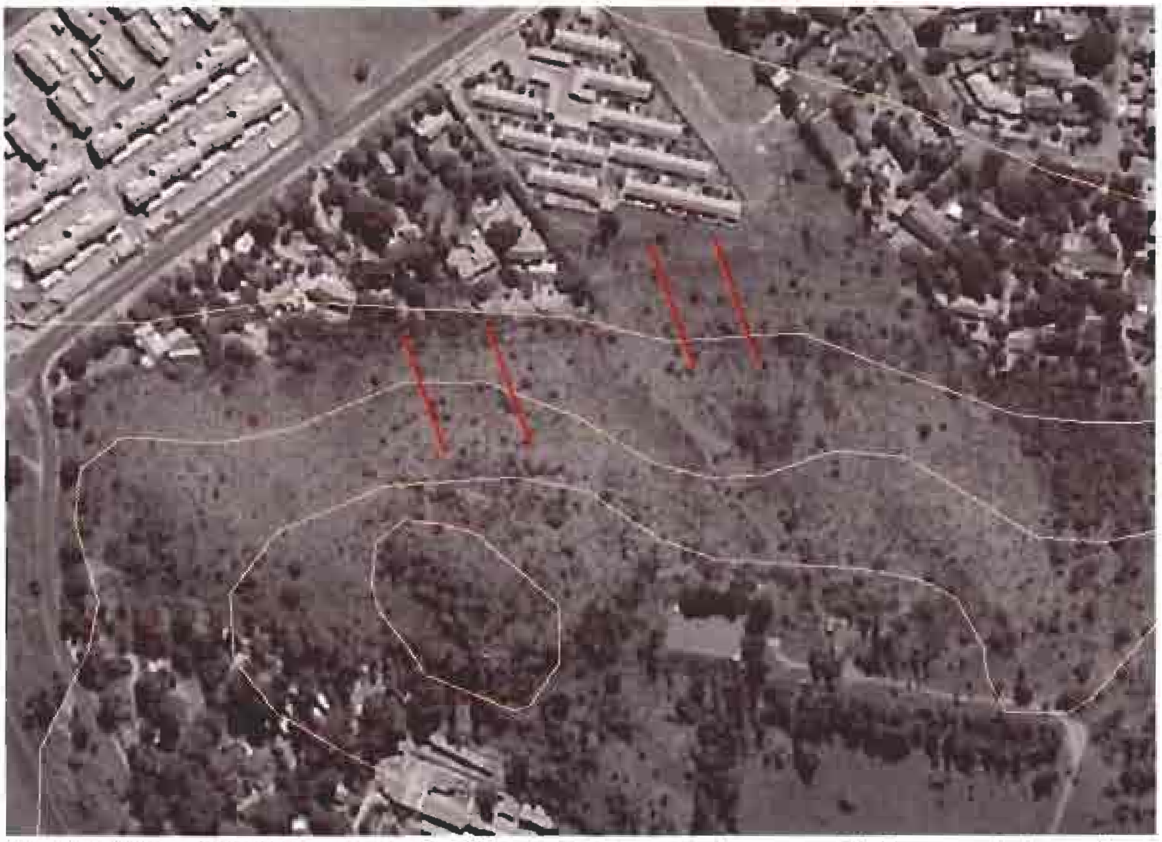

Figure 10. Ortophoto showing the Kliprivier study area with transects in red (K T1-4; P1-4).

3.2.2 Braun-Blanquet method: Synthetic phase

All relevé data was imported into the database TURBOVEG (Hennekens, 1996a). The numerical classification technique TWINSPAN (Hill, 1979a), which is regarded as a successful approach for classification by several phytosociologists (Mucina & Van Der Maarel, 1989; Bredenkamp & Bezuidenhout, 1995; Cilliers, 1998) was used as a first approximation for the floristic data. Subsequently, Braun-Blanquet procedures (Bezuidenhout et al. 1996) were used to refine data and construct a phytosociological table using a visual editor, MEGATAB (Hennekens, 1996b).

The arrangement of species and relevés in the phytosociological table leads to a comprehensive classification system of plant communities. This can be used as the basis for further ecological studies. Species act as indicators for the habitat typical for the community and the Zürich-Montpellier approach determines that patterns in the floristic composition correspond with patterns in the environment (Werger, 1974). The importance of this method is that it identifies the vegetation unit as the association, which is an abstraction obtained by floristic comparison of a number of stands and defined by the diagnostic species groups (Werger, 1974).

Multivariate analyses were done using CANOCO (Ter Braak & Šmilauer, 2002). Ordination or scaling, allows one to plot these objects in multidimensional space, with the objects ordered along each axis, with the Euclidean distance between objects representing their biological dissimilarity (Quinn & Keough, 2002).
The variation in the species data is explained via the ordination axes, which represent a theoretical explanatory variable (theoretical environmental variable or underlying gradient).

A number of values are associated to each axis, one being the eigenvalue, which is an importance measure of that ordination axis. In matrix algebra an eigenvector $\underline{u}$ multiplied by a scalar value λ (lambda) satisfies the matrix equation of the square matrix $\underline{A}$. Another is the gradient length, which represents a latent (theoretical) environmental variable, estimated in standard deviation (SD) units of species turnover.

While species data are response variables (variables to be explained), environmental variables act as explanatory variables (predictors) to this data. Hence, the ordination axes explain species data, and the environmental data are used to interpret or define these axes (Quinn & Keough, 2002).

An ordination diagram with both samples and species can display either the relationships among samples or species in an optimal way, but not both; as the ordination axes of one are a linear rescaling of those of the other i.e. that the sample scores are weighted averages of the species scores. Hence, in the ordination diagram, species that occur in a sample lie around that sample's point.

The variance of the sample score on each ordination axis reflects the importance of the axis as measured by the eigenvalue (the variance of the linear function of the variable in question), whereas the variances of the species scores along the axes are equal. The objective was to interpret relationships among samples from the ordination diagram. Inter-sample scaling allows one to better infer environmental effect sizes. Irrespective of the scaling chosen the ordination diagram displays the major patterns in the species data table, the table of correlations between species and quantitative environmental variables (Ter Braak & Šmilauer, 2002).

The following environmental variables were used in the Canonical correspondence analysis (CCA), in order to determine their association with different plant communities and plant species:

- Distance from development edge. A 5m buffer was measured from the development edge and then each transect started from this point and continued for 75m.
- The percentage of bare patches within each sample plot.
- The percentage of exposed rock in each sample plot.

Chi-square (χ^2) is used as a measure of the degree of association between species in a set of samples (Kent & Coker, 1992). This involves the use of 2 x 2 contingency tables and χ^2 to determine significant associations between species. Bailey (1995) advised the best way to carry out a reliable statistical test is to calculate a Chi-squared. This statistical test is a measure of the extent to which the observed numbers in the cells of a contingency table depart from the values we should have if the rows of percentages mentioned were all identical. Reference is then made to tables of the χ^2 distribution to see whether the observed value is larger than would be expected by chance on a null hypothesis that postulated no association whatsoever between the two classifications.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Kloofendal study area

4.1.1 Description of plant communities

This study site is representative of the *Tristachya biseriata-Protea caffra* Cool Temperate Mountain Bushveld as described by Bredenkamp & Brown (2003).

4.1.1.1. Transects 1&2 (Table 3)

The phytosociological descriptions below for transects 1 & 2 are all relevant to Table 3. Reference to Table3 will therefore not necessarily be made when referring to the different species groups.

1. *Protea caffra-Themeda triandra* Open Woodland

The vegetation of the total area within which these transects were laid is classified as *Protea caffra-Themeda triandra* Open Woodland and is characterized by the prominence of the tree *Protea caffra* and the grass *Themeda triandra* (species group F). Species from species group F are characteristic for the study site. These include tree *Protea caffra*, grasses *Themeda triandra, Panicum natalense, Brachiaria serrata, Melinis repens, Trachypogon spicatus,* and the forbs *Tagetes minuta, Senecio venosus,* *Pearsonia sessilifolia, Sphenostylis angustifolia, Ipomoea ommaneyi, Tephrosia longipes, Conyza podocephala* and *Indigofera filipes.*

This community can be divided into two subcommunities (one with three variants) namely (Table3):

1.1 *Acacia melanoxylon-Themeda triandra* Open Woodland

1.2 *Themeda triandra-Panicum natalense* Open woodland

 1.2.1 *Themeda triandra* Variant

 1.2.2 *Diheteropogon amplectens* Variant

 1.2.3 *Enneapogon scoparius* Variant

1.1 ***Acacia melanoxylon-Themeda triandra*** Open Woodland

This subcommunity is characterized by the presence of species from species group A and includes the declared alien invasive tree *Acacia melanoxylon* (Henderson, 2001), the weedy invasive grass *Pennisetum clandestinum* and the weed *Bidens pilosa.*

The vegetation is dominated by the climax grass *Themeda triandra* (species group F), while the weedy invasive grass *Pennisetum clandestinum* (species group A), the pioneer grass *Melinis repens* (species group F), and the weeds *Bidens pilosa* (species group A) and *Tagetes minuta* (species group F) are prominent throughout this subcommunity.

The woody layer is not well-developed and only covers 5% of the area while the herbaceous layer has a 80-90% cover.

This subcommunity (relevés 1 & 4 – Table3) is representative of the vegetation of the sampling plots KLT1P1(transect 1,plot1) and KLT2P1(transect 2, plot1) and are both located within the 5-15 m zone from development boundary. The vegetation of this subcommunity comprises a large number of pioneer and weedy species. The area has a slope of 4-6°, shallow soils and an estimated rocky cover of 3-5%. There is a well-worn footpath bisecting the site as well as minor erosion and small piles of domestic garden refuse and building rubble.

1.2 *Themeda triandra-Panicum natalense* Open woodland

This subcommunity is characterized by species from species group B and includes the climax grass *Eulalia villosa,* the sub-climax grass *Eragrostis racemosa* and the weedy forb *Nidorella hottentotica*.

The woody layer with a 20-30% cover is dominated by the climax tree *Protea caffra* (species group F) while the grass layer with a cover of 60-70% is dominated by the climax grasses *Panicum natalense* and *Themeda triandra* (species group F) dominate the herbaceous layer. Other species also prominent include the sub-climax grass *Eragrostis racemosa* (species group B), the climax grass *Diheteropogon amplectens* (species group E) while the climax forb *Senecio venosus,* the weedy forb *Tagetes minuta* and the sub climax forb *Sphenostylis angustifolia* (species group F) are also present.

This subcommunity (relevés 2, 3, 5, 6 & 7) is representative of the vegetation plots between 25-75 m (KLT1P2-P3 (transect 1, plots 2 &3) and KLT2P2-P4 transect 2, plots

2-4) from development and mainly consists of sub-climax and climax species though some pioneer species are also present. The area has a slope of 4-6° shallow soils and a rocky cover of 5-10%. There is a well-worn footpath bisecting the site with no visible erosion and no domestic garden refuse or building rubble.

This subcommunity can be divided into three variants namely the *Themeda triandra* variant, the *Diheteropogon amplectens* variant and the *Enneapogon scoparius* variant.

1.2.1 *Themeda triandra* Variant

This variant comprises only one relevé that is located 25-35 m from the edge of the development. The vegetation is characterized by the presence of species groups B & C and the absence of species groups D & E.

The vegetation is dominated by the climax tree *Protea caffra* (species group F) and the climax grasses *Panicum natalense* and *Themeda triandra* (species group F).

1.2.2 *Diheteropogon amplectens* Variant

This variant comprises three relevés of which one (relevé 5) is located 25-35 m and relevés 3 & 6 within 45-55 m from the edge of the development. Species group D is the diagnostic species, and it is further characterized by species group B, C & E.

The vegetation is dominated by the climax grasses *Panicum natalense* (species group F) and *Diheteropogon amplectens* (species group E).

1.2.3 *Enneapogon scoparius* Variant

This variant represents the sampling plot furthest from the development (65-75 m) and consists mainly of climax plant species. The soil is shallow with a slight 3-4° slope and an estimated 2-5% rock cover. The vegetation is characterized by the presence of species from species groups B and E and the absence of species from species groups C and D.

The vegetation is dominated by various climax grasses namely *Panicum natalense* (species group B), *Eulalia villosa* (species group B) and *Enneapogon scoparius* (species group E). The sub-climax grass *Eragrostis racemosa* (species group B), climax grass *Themeda triandra* and the pioneer grass *Melinis repens* (species group F) are prominent.

Table 3. Phytosociological table of Kloofendal Transects 1 & 2

Community	1						
	1.1		1.2				
			1.2.1	1.2.2			1.2.3
Relevé	1	4	2	3	5	6	7
Species group A							
Bidens pilosa	+	b	.	.	.	+	+
Acacia melanoxylon	+	a	.	.	.	.	.
Pennisetum clandestinum	4	.	.	.	.	.	.
Species group B							
Eragrostis racemosa	.	.	+	+	a	1	1
Eulalia villosa	.	.	+	+	+	+	a
Nidorella hottentotica	.	.	+	+	1	1	+
Species group C							
Loudetia simplex	+	.	+	+	+	1	.
Pseudognaphalium luteo-album	.	.	+	+	+	+	.
Andropogon chinensis	.	.	+	+	+	.	.
Polygala uncinata	.	.	+	+	+	.	.
Species group D							
Tristachya leucothrix	.	.	.	+	+	+	.
Vernonia natalensis	.	.	.	+	+	.	.
Pentanisia angustifolia	.	.	.	+	+	.	.
Species group E							
Cyperus rupestris	.	.	.	+	+	.	+
Diheteropogon amplectens	.	.	.	1	3	1	+
Indigofera hedyantha	.	.	.	+	+	+	+
Thesium utile	.	.	.	+	+	+	+
Enneapogon scoparius	.	.	.	+	.	+	b
Hemizygia pretoriae	.	.	.	.	+	+	1
Species group F							
Themeda triandra	a	1	a	b	.	a	a
Panicum natalense	+	.	1	1	3	a	3
Tagetes minuta	+	b	.	+	+	+	1
Brachiaria serrata	+	+	+	+	1	+	r
Senecio venosus	+	+	+	+	+	+	a
Protea caffra	+	.	1	b	+	1	+
Melinis repens	+	1	1	.	+	.	1
Pearsonia sessilifolia	+	.	+	.	+	.	+
Sphenostylis angustifolia	+	.	+	+	+	+	+
Ipomoea ommaneyi	.	+	.	+	.	+	.
Tephrosia longipes	.	+	.	.	.	+	.
Conyza podocephala	+	.	+	+	.	.	+
Indigofera filipes	+	.	+	+	.	.	.
Trachypogon spicatus	+	.	+	+	.	.	.

4.1.1.2 Transects 3&4

The phytosociological descriptions below for transects 3 & 4 are all relevant to Table 4. Reference to Table 4 will therefore not necessarily be made when referring to the different species groups.

1. *Protea caffra-Themeda triandra* Open Woodland

The vegetation of this Open Woodland is characterized by the prominence of the tree *Protea caffra* and the grasses *Themeda triandra* and *Eragrostis racemosa* (species groups G). Species from species group G (Table 4) are characteristic for the study site. These include the grasses *Themeda triandra, Eragrostis racemosa, Diheteropogon amplectens, Panicum natalense, Brachiaria serrata, Melinis repens, Trachypogon spicatus, Tristachya spicatus* and the forbs *Cyperus rupestris, Vernonia natalensis.*

This community comprises following three subcommunities, one with three variants (Table 4):

1.1 *Bidens pilosa-Themeda triandra* Open Woodland

1.2 *Panicum natalense-Themeda triandra* Open Woodland

- 1.2.1 *Eulalia villosa* Variant
- 1.2.2 *Loudetia simplex* Variant
- 1.2.3 *Protea caffra* Variant

1.3 *Themeda triandra-Eragrostis racemosa* Open Woodland

1.1 *Bidens pilosa-Themeda triandra* Open Woodland

This subcommunity is characterized by the presence of the weedy forbs *Bidens pilosa, Tagetes minuta* and includes the declared alien invasive tree *Acacia melanoxylon* and *Bidens pilosa* (species group A).

The vegetation is dominated by the climax grass *Themeda triandra* (species group G) while the climax tree *Protea caffra* (species group G), the weedy dwarf shrub *Seriphium plumosum* (species group C), and the sub-climax grass *Eragrostis racemosa* (species group G) are prominent locally. The woody layer is not well-developed and only covers 1-10% of the area while the herbaceous layer has a 80-90% cover.

This subcommunity (Relevés 8 & 12) is representative of the vegetation of the plots KLT3P1 (transect 3, plot 1) and KLT4P1 (transect 4, plot 1) and within the 5-15 m zone from development and comprises a large number of pioneer and weedy species. The area has a slope of 4-6° shallow soils and a rocky cover of 3-5%. There is a well-worn footpath bisecting the site and small piles of domestic garden refuse and building rubble are also present.

1.2 *Panicum natalense-Themeda triandra* Open Woodland

This subcommunity is characterized by the presence of species group D and includes the climax grass *Loudetia simplex* and the weedy forb *Pseudognaphalium luteo-album,* climax forbs *Polygala uncinata* and *Pentanisia angustifolia* (species group D).

The vegetation is dominated by the climax grasses *Loudetia simplex* (species group D), *Themeda triandra* and the sub-climax grass *Eragrostis racemosa* (species group G). Prominent species include the climax tree *Protea caffra* (species group G), the climax grasses *Panicum natalense, Brachiaria serrata, Diheteropogon amplectens* and the climax forb *Cyperus rupestris* (species group G). The woody layer with a 5-20% cover is represented by the climax tree *Protea caffra* (species group G) while the grass layer covers between 90-95% of the area.

This subcommunity (relevés 13, 10, 15, 11, 14) is representative of the vegetation plots between 25-65 m (KL T3P3-P4 (transect 3, plots 3 &4) and T4P2-P4 (transect 4,plots 2-4) from development and mainly consists of sub-climax and climax species though some pioneer species are also present. The area has a slope of 5^{o}, shallow soils and a rocky cover of 0.5-1%. There is no visible erosion and no domestic garden refuse or building rubble was found to be present.

This subcommunity can be divided into three variants namely the *Eulalia villosa* Variant, the *Loudetia simplex* Variant and the *Protea caffra* Variant.

1.2.1 *Eulalia villosa* Variant

This variant is characterized by the presence of species from species groups B, C & D and the absence of species group E. This variant represents the sampling plot (relevé 13) that is located in the 25-35 m buffer zone from the development.

The vegetation is totally dominated by the climax grasses *Themeda triandra* (species group G) and *Eulalia villosa* (species group F) prominent species include the climax grasses *Diheteropogon amplectens, Brachiaria serrata* and the sub-climax grass *Eragrostis racemosa* (species group G).

1.2.2 *Loudetia simplex* Variant

The *Loudetia simplex* Variant is characterized by the presence of species from species groups C, D & E and the absence of species group B. This variant represents a sampling plot (relevé 10) between 45-55 m and a sampling plot (relevé 15) located at the 65-75 m zone from development.

The vegetation is dominated by the climax grasses *Loudetia simplex* (species group D), *Themeda triandra, Panicum natalense* and the sub-climax grass *Eragrostis racemosa* (species group G). The climax grass *Brachiaria serrata* and the climax forb *Cyperus rupestris* (species group G) are also prominent.

1.2.3 *Protea caffra* Variant

This variant is characterized by the presence of species groups D, E & G and the absence of species groups B & C. This variant represents a sampling plot (relevé 14) between 45-55 m and a sampling plot (relevé 11) located at the 65-75 m zone from development.

The vegetation is dominated by the climax tree *Protea caffra* and the climax grasses *Themeda triandra* and *Panicum natalense* (species group G).

1.3 *Themeda triandra-Eragrostis racemosa* Open Woodland

This sub community is characterized by species from species group G and the absence of species groups B, C, D, E and F (Table4).

The woody layer is represented by the climax tree *Protea caffra* (species group G), but the vegetation is dominated by sub climax grass *Eragrostis racemosa* and the climax grass *Themeda triandra* (species group G) while the climax grass *Brachiaria serrata* (species group G) is also prominent.

This community is representative of the vegetation plot (relevé 9) between 25-35 m (KL T3P2 (transect 3, plot 2) from development and mainly consists of sub-climax and climax species though some pioneer species are also present. The area has a slope of 4-6° shallow soils with no rocky cover. There is also a well-worn footpath bisecting the site but with no visible erosion or domestic waste.

Table 4. Phytosociological table for Kloofendal transects 3 &4

	1							
	1.1		1.2					1.3
			1.2.1	1.2.2		1.2.3		
Relevé	8	12	13	10	15	11	14	9
Species group A								
Bidens pilosa	+	+	.	+	.	.	.	.
Tagetes minuta	+	+	.	+	.	.	.	.
Acacia melanoxylon	+	.	.	.	.	.	.	.
Species group B								
Senecio erubescens	+	+	+	.	.	+	.	.
Polygala transvaalensis	+	+	+	.	.	.	.	.
Indigofera comosa	.	+	+	+	.	.	.	.
Species group C								
Oxalis depressa	+	+	+	+	+	.	.	.
Nidorella hottentotica	1	.	+	.	+	.	.	.
Seriphium plumosum	1	+	+	+	+	.	.	.
Species group D								
Loudetia simplex	.	.	+	1	1	a	1	.
Pseudognaphalium luteo-album	+	.	+	+	+	+	+	.
Polygala uncinata	+	.	+	+	.	+	+	.
Pentanisia angustifolia	.	+	+	.	.	+	+	.
Species group E								
Sphenostylis angustifolia	.	.	.	+	+	+	+	.
Senecio lydenburgensis	.	+	.	+	+	+	+	.
Species group F								
Eulalia villosa	+	+	a	+	1	+	+	.
Indigofera hedyantha	+	.	+	+	.	+	+	.
Thesium utile	+	+	+	.	.	+	+	.
Hemizygia pretoriae	+	.	.	+	.	.	+	.
Andropogon chinensis	+	1	.	.	.	1	1	.
Species group G								
Themeda triandra	1	b	5	a	4	1	a	a
Eragrostis racemosa	1	+	1	a	a	1	+	3
Protea caffra	1	r	+	b	+	a	1	r.
Cyperus rupestris	.	+	+	+	b	1	+	+
Diheteropogon amplectens	.	1	a	+	a	a	.	+
Panicum natalense	+	.	+	1	a	1	a	+
Brachiaria serrata	+	.	a	+	a	1	+	1
Melinis repens	+	.	+	+	+	+	.	+
Trachypogon spicatus	.	.	+	.	+	.	+	+
Tristachya leucothrix	.	a	+	.	.	+	.	+
Vernonia natalensis	.	.	+	.	.	+	.	+

4.1.2 Discussion of plant communities

Transects 1 & 2

The phytosociological data from these transects indicate that there are two subcommunities within the larger community all associated in respect of distance from development. The plots of subcommunity 1.1 (*Acacia melanoxylon-Themeda triandra* Open Woodland) are the closest to the development (15m) comprising mostly invasive, weedy and pioneer species such as *Acacia melanoxylon, Bidens pilosa* and *Pennisetum clandestinum* (species group A – Table 3). Sub community 1.2 (*Themeda triandra-Panicum natalense* Open Woodland) represents the sampling plots within the 25-75 m zone from the edge of development. This subcommunity comprises a mixture of sub-climax and climax species such as *Eragrostis racemosa, Panicum natalense, Themeda triandra* and *Sphenostylis angustifolia* with only a few pioneer and weedy species such as *Nidorella hottentotica* (species group B), *Tagetes minuta* (species group F – Table 1) and *Conyza podocephala* (species group F – Table 3) present. The three variants within this subcommunity are very similar with only slight differences in species composition (species group B – Table3). Relevés 2 & 5 are located within the 25-35 m zone from development while relevés 3 & 6 are located within the 45-55 m zone from development.

However, no clear distinction could be made between these four relevés in the phytosociological table with relevé 2 differing slightly from relevé 5 in species composition. Relevé 7 (Variant 1.2.3) is located in the 65-75 m zone from development and consists mainly of climax woody, grass and forb species. This variant (1.2.3) differs from variants 1.2.1 and 1.2.2 due to the absence of species from species groups C and

D only. The three variants identified within subcommunity 1.2 thus have large numbers of species overlapping with only cover abundance differences of the different species distinguishing them from each other.

Thus based on the phytosociological data of transects 1 & 2 only, the most distinct difference in terms of plant communities lies at a distance of 15 m from development where the pioneer plant species almost disappear from the other sampling plots (species group A – Table 3), with the next most distinct difference at 55 m from development.

Transects 3 & 4

There are three clear distinctions in these transects as their phytosociological data indicate that there are three subcommunities within the larger community also associated in respect of distance from development. The plots of subcommunity 1.1 (*Bidens pilosa-Themeda triandra* Open Woodland) are the closest to the development (15m) comprising mostly invasive, weedy and pioneer species such as *Acacia melanoxylon, Bidens pilosa* and *Tagetes minuta* (species group A – Table 4).

Sub community 1.2 (*Panicum natalense-Themeda triandra* Open Woodland) represents the sampling plots within the 25-75 m zone from the edge of development. This subcommunity comprises a mixture of sub-climax and climax species such as *Loudetia simplex, Polygala uncinata,* and *Pentanisia angustifolia* with only a few pioneer and weedy species such as *Pseudognaphalium luteo-album* (species group B), *Nidorella hottentotica* (species group C – Table 4) present. From the phytosociological discussions it is evident that the three variants within this subcommunity are very similar with only slight differences in species composition. The species composition of these three variants does not differ in terms of the dominant and prominent species. The three variants identified within subcommunity 1.2 thus have large numbers of species overlapping with only cover differences of the different species distinguishing them from each other. That, together with the fact that the different variants comprise plots of different distances within the 25-65m zone indicates that there is no clear distinction in species composition between the 25m and 75m zones. Relevé 13 is located within the 25-35 m zone from development while relevés 10 & 14 are located within the 45-55 m zone from development.

However, no clear distinction could be made between these four relevés in the phytosociological table with relevé 13 (variant 1.2.1) differing slightly from relevé 14 (variant 1.2.3) in species composition. All three variants are located broadly across the 25-75m zones from the development edge and consist mainly of climax grass and forb species. Although sub-community 1.3 differs from sub-community 1.2 in that species groups B, C, D, E &F are not present the broad species composition thereof is still similar to that of the total area. Interestingly this sample plot is located within the 25-35m zone and cannot be mapped out as a separate unit. This sample plot although not differing noticeably from sub-communities 1.1 and 1.2 could possibly be regarded as an outlier not fully representative of the study site. This could explain why all the dominant species of sub-community 1.2 are not present.

Thus based on the phytosociological data of transects 3 & 4 only, the most distinct difference in terms of plant communities again lies at a distance of 15 m from development where the pioneer plant species almost disappear from the other sampling plots (species group A – Table 4), with the next most distinct difference at 25 m from development.

4.1.3 Plant Density

The density data for the Kloofendal site was analyzed using the Chi-squared test for independence to determine whether the number of individual plants per successional group was independent from the position of the plot (with plot 1 being closest to the development and plot 4 furthest). Under the null hypothesis of independence of number of species and position the Kloofendal site rendered no significant result ($p>0.05$) i.e. the number of individual plants per successional group were independent from the position of the plot. This means that the density of species per successional group does not show a statistically significant pattern that any successional group of species increase or decrease closer or further away from development.

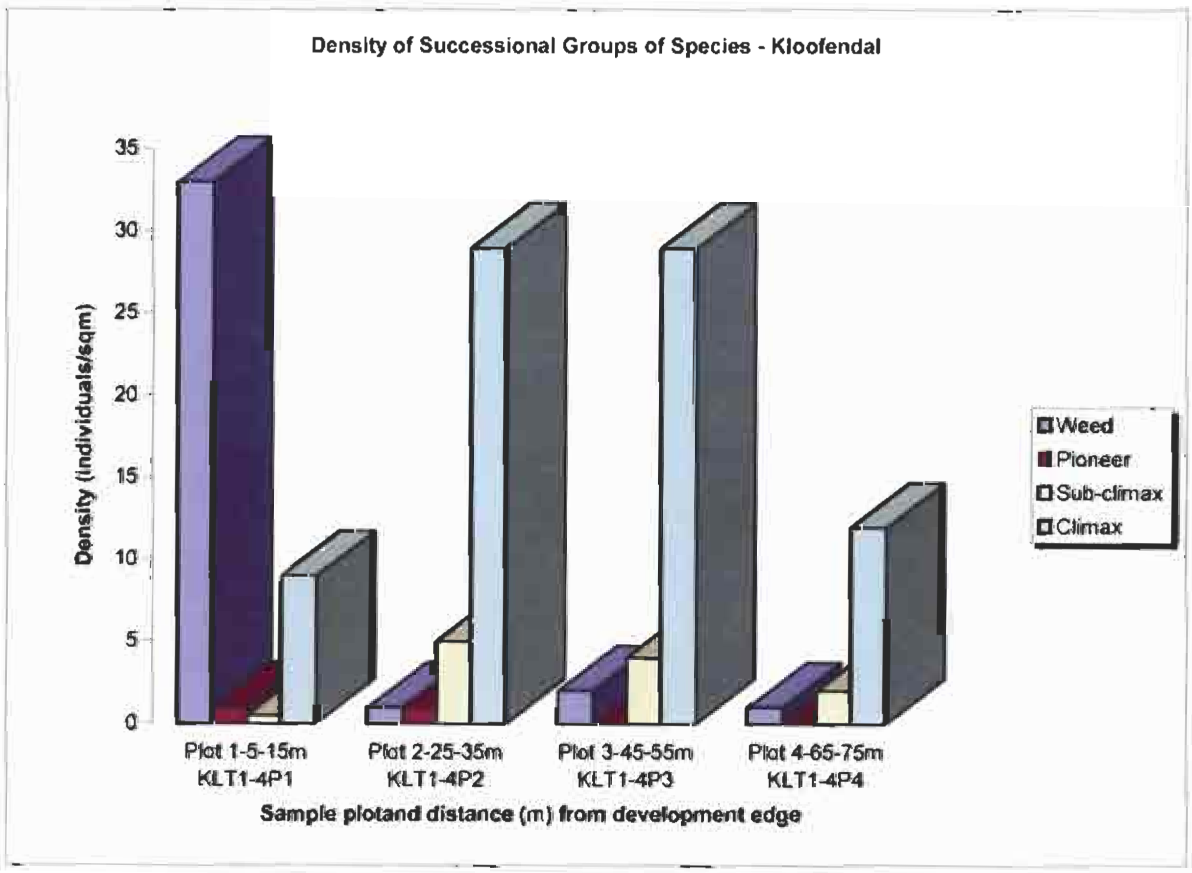

Figure 11. Density of successional groups of species relative to distance from the development edge - Kloofendal

Although not significantly different the density data for the Kloofendal site indicates that the highest density of weedy species are present in the 5-15m zone with 33 individuals/ m^2 (Figure 11) but that climax species have a density of 9 individuals/ m^2.

However, the number of weedy species/m^2 declines drastically from 33 individuals/ m^2 in the 5-15m zone to 1 individual / m^2 in the 25-35m zone and then remains fairly constant along the gradient.

Interestingly the highest density of climax species (29 individuals/ m^2) is found within the 25-55m zone where thereafter they decrease to 12 individuals / m^2 in the 65-75m zone. The highest density of sub-climax species (5 individuals/ m^2) are also present in the 25-35m distance though not in as high density as the climax species. Pioneer species are present with the same density of 1individual / m^2 within the 5-15m zone as well as the 25-35m zone where after the pioneer species decrease all together. The density data indicates that the only clear distinction in the successional groups of species occurs at 15m from the development edge. Thus from figure 11 the density of different successional groups supports the phytosociological data as discussed above.

In the triplot of a CCA-ordination for the Kloofendal (K-L) study area (Figure 12) the distance from the development edge is closely associated with both the first and second axes, and the CANOCO results confirm this correlation as 0.51 and 0.21 respectively. The eigenvalue for the first axis is 0.4 and the second ordination axis is 0.37, representing 14.3 per cent and 27.3 per cent of the total variance respectively. Thus the first two axes account for 41.6 per cent of the variance in the successional groups of species/environment data.

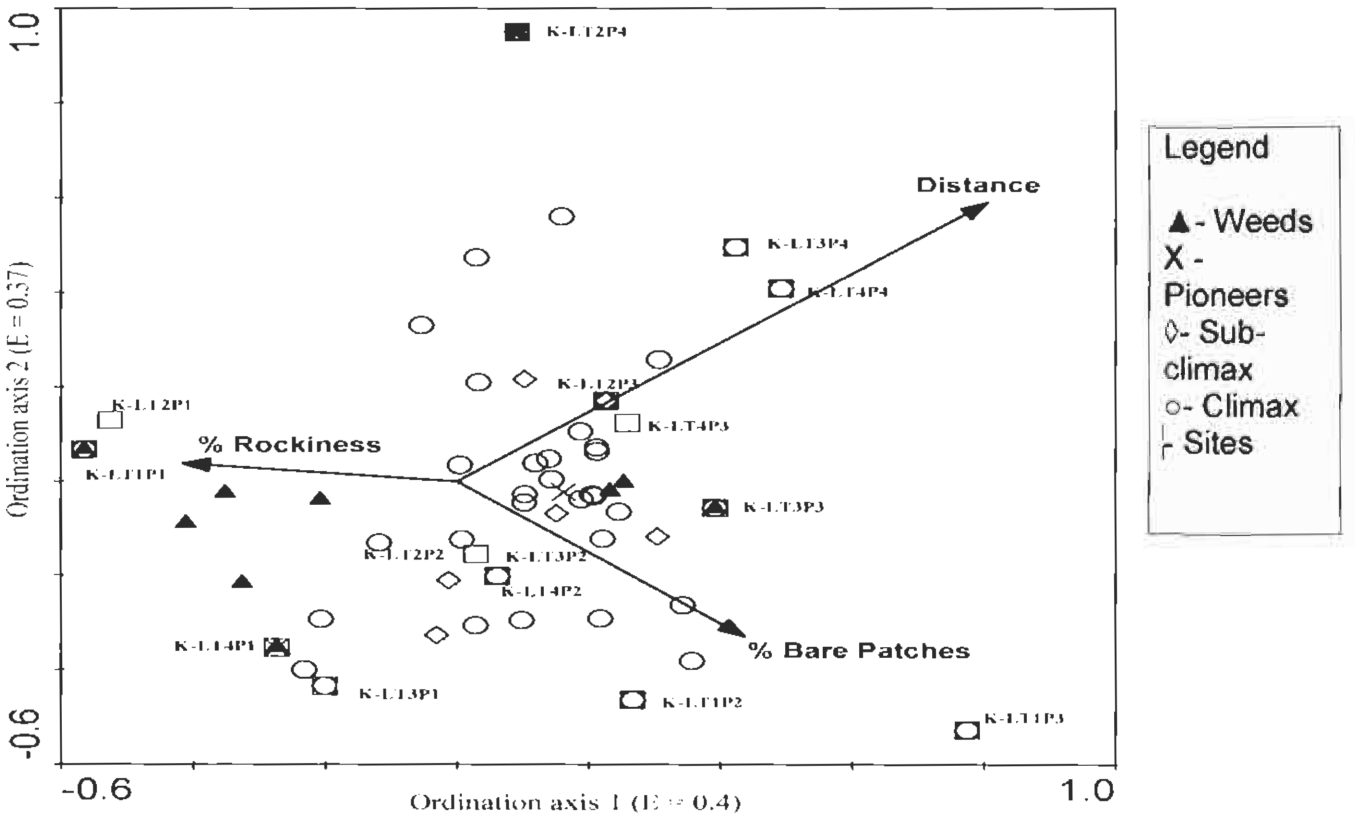

Figure 12. Triplot of a CCA ordination for density of successional groups of species - Kloofendal site.

The triplot (Figure 12) shows the successional group of species from the development edge very clearly, with various groupings of successional stages emerging.

Highest densities of weedy species are shown to the lower left of the graph indicating a positive association with the rocky areas and a negative association with distance i.e. closest to the development edge. The plots are clearly situated along this gradient in distance from the development edge (bottom left) to the areas furthest away (top right). Most of the weedy species are situated on or close to rocky areas and this is indicated by the close association between weedy species and rockiness with ordination axis 1. Bare patches were found in some of the plots and are associated mainly with climax species.

It therefore appears that distance is the most important variable responsible for successional species grouping. Figure 11 indicates that the distance from the development edge where the most distinct change in the successional species grouping density occurs is 15m for this study site. Beyond 15m (plots 2-4) there are no significant changes in the species density. Therefore, for this specific site the recommended minimum buffer zone would be 15m. This 15m (plot 1) zone is also supported by the phytosociological descriptions. There is no difference in density of climax and sub-climax species after 15m.

4.2 Morning Hill Study Area

This study site chosen is representative of the *Protea caffra, Eragrostis chloromelas* Open Woodland as described by Bredenkamp & Brown (2003).

4.2.1 Description of plant communities

4.2.1.1 Transects 1&2

The phytosociological descriptions below for transects 1 & 2 are all relevant to Table 5. Reference to Table 5 will therefore not necessarily be made when referring to the different species groups.

1. *Protea caffra- Eragrostis chloromelas* Open Woodland

The majority of the study area comprises grassland vegetation on bottom slopes, mid-slopes as well as the crest areas while the woody species were only found on the mid-slopes and crest. The vegetation of the total area within which these transects were laid is classified as *Protea caffra- Eragrostis chloromelas* Open Woodland and is characterized by the prominence of the tree *Protea caffra* and the grass *Eragrostis chloromelas* (species groups B & E respectively). Species from species group E are characteristic for the study site. These include the sub-climax grasses *Eragrostis chloromelas* and *Eragrostis racemosa* and the climax forbs, *Pellaea calomelanos, Cyanotis speciosa* and *Wahlenbergia undulata* and the weed forb *Pseudognaphalium luteo-album.*

This community can be divided into three subcommunities namely (Table 5):

1.1 *Eragrostis chloromelas- Eragrostis curvula* Open Woodland;
1.2 *Eragrostis chloromelas- Panicum natalense* Open Woodland;
1.3 *Eragrostis chloromelas- Cymbopogon plurinodis* Open Woodland.

1.1 *Eragrostis chloromelas- Eragrostis curvula* Open Woodland

This subcommunity (relevés 16 & 20) is characterized by the presence of species from species group A and includes the climax grass *Panicum maximum*, the sub-climax grass *Eragrostis curvula,* the pioneer grass *Cynodon dactylon,* and the climax forb *Helichrysum cephaloideum* the weedy forbs *Bidens pilosa, Tagetes minuta, Ipomoea purpurea* and the weed grass *Pennisetum clandestinum* (species group A).

There was no woody layer present in this sample site while the herbaceous layer dominated with a 75-85% cover. The vegetation is dominated by the sub-climax grass *Eragrostis curvula* (species group A) while the weed *Pennisetum clandestinum* (species group A), the pioneer grass *Cynodon dactylon* (species group A), and the pioneer forbs *Bidens pilosa* and *Tagetes minuta* (species group A) are prominent throughout this community.

This subcommunity is representative of the vegetation of the plots MT1P1 (transect 1, plot 1) and MT2P1 (transect 2, plot 1) within the 5-15 m zone from development and comprises a collection of climax, sub-climax, pioneer and weedy species. The area has a slope of 4-6° shallow soils and a rocky cover of 5-30%. There are small piles of domestic garden refuse and building rubble throughout this site.

1.2 *Eragrostis chloromelas- Panicum natalense* open woodland

This sub-community (Relevés 17, 18, 21 & 22) is characterized by the species belonging to species group B and includes the climax forbs *Helichrysum setosum, Helichrysum callicomum, Ledebouria ovatifolia, Dianthus mooiensis, Dovyalis caffra,* the sub-climax forb *Sphenostylis angustifolia,* the weed forb *Cleome rubella* and the climax woody species *Protea caffra.*

The woody layer with a 1-2% cover is dominated by the tree *Protea caffra* (species group B) while the grass layer with a cover of 90-95% is dominated by the sub-climax grasses *Eragrostis chloromelas, Eragrostis racemosa* (species group E), the climax grass *Panicum natalense,* the sub-climax grasses *Heteropogon contortus, Digitaria monodactyla* and the pioneer grass *Melinis repens* (species group C). The climax forb *Commelina africana var. barberae* (species group C), the sub-climax forb *Sphenostylis angustifolia*, and the weedy species *Nidorella hottentotica* (species group B) are also present.

This subcommunity is representative of the vegetation plots between 25-55 m (MT1P2 - P3 (transect 1, plots 2-3) and MT2P2-P3 (transect 2, plots 2-3)) from development and consists mainly of sub-climax and climax species though some pioneer and weedy species are also present. The area has a slope of 4-6° shallow soils and a rocky cover of 15-35%.

There is a well-worn footpath bisecting the site but no erosion or building rubble or garden refuse were identified in these sample sites.

1.3 *Eragrostis chloromelas- Cymbopogon plurinodis* open woodland.

This subcommunity (Relevés 19 & 23) is characterized by the presence of species from species group D and includes the climax forbs *Albuca species, Aloe greatheadii, Hemizygia pretoriae, Plectranthus verticillatum, Pelargonium luridum*, *Scabiosa columbaria,* the sub-climax forb *Oxalis depressa,* and the climax grass *Tristachya leucothrix* (species group D).

The woody layer was absent while the grass layer with a cover of 90-95% is dominated by the sub-climax grasses *Eragrostis chloromelas, Eragrostis racemosa* (species group E), the climax grasses *Cymbopogon plurinodis, Panicum natalense* and the climax forbs *Cyperus rupestris* (species group C), the climax forbs *Oxalis depressa, Hemizygia pretoriae, Plectranthus verticill, Aloe greatheadii, Albuca species* (species group D) and the climax forb *Cyanotis speciosa, Pellaea calomelanos* (species group E), the climax forb *Cheilanthes hirta* and the weedy forb *Nidorella hottentotica* (species group C).

This subcommunity is representative of the vegetation plots between 65-75 m (MT1P4 (transect 1, plot 4) and MT2P4 (transect 2, plot 4)) from development and mainly consists of sub-climax and climax species though some pioneer and weedy species are also present. This community was found at the highest altitude on the ridge with a slope of 5-7° on the south facing aspect. The soil is shallow and well-worn footpaths bisect this study area. The estimated rock cover is 10-15%.

Table 5. Phytosociological table for Morning Hill transect 1&2

	1							
	1.1		1.2				1.3	
Relevé	16	20	22	18	17	21	19	23
Species group A								
Eragrostis curvula	3	4	.	.	.	.	.	.
Bidens pilosa	a	a	.	.	.	.	.	.
Tagetes minuta	a	a	.	.	.	.	.	.
Ipomoea species	a	.	.	.	.	.	.	.
Pennisetum clandestinum	b	.	.	.	.	.	.	.
Panicum maximum	.	b	+	.	.	.	.	.
Cynodon dactylon	.	3	.	.	.	.	.	.
Ipomoea purpurea	.	1	.	.	.	.	.	.
Helichrysum cephaloideum	+	+	.	.	.	.	.	.
Species group B								
Helichrysum setosum	.	.	.	+	.	+	.	.
Ledebouria ovalifolia	.	.	.	+	.	+	+	.
Dianthus mooiensis	.	.	.	.	+	+	.	.
Dovyalis caffra	.	.	.	+	.	.	.	.
Sphenostylis angustifolia	.	.	.	+	.	.	.	.
Helichrysum callicomum	+	.	.	+	+	.	.	.
Cleome rubella	.	a	+	+	.	.	.	.
Protea caffra	.	.	.	+	.	1	.	.
Species group C								
Heteropogon contortus	.	.	+	+	3	.	a	1
Digitaria monodactyla	.	.	.	a	+	+	a	+
Melinis repens	.	.	.	+	1	1	a	+
Eulalia villosa	.	.	.	.	+	+	a	+
Commel africana v. barberae	.	.	+	+	+	.	+	+
Elionurus muticus	.	.	.	+	+	.	1	+
Panicum natalense	.	.	1	.	a	1	1	b

Clematopsis scabiosifolia	.	.	.	+	+	+	+	.
Harpochloa falx	.	.	.	+	1	1	+	+
Cymbopogon plurinodis	.	.	.	+	1	.	1	b
Cheilanthes hirta	+	.	.	+	+	+	+	+
Enneapogon scoparius	.	.	1	.	+	+	+	+
Cyperus rupestris	.	.	+	a	1	.	3	+
Nidorella hottentotica	.	.	+	1	+	+	+	+
Brachiaria serrata	.	.	.	1	.	+	.	+
Themeda triandra	.	.	+	1	.	+	1	+
Species group D								
Albuca species	.	.	.	+	.	.	+	+
Aloe greatheadii	.	.	.	+	.	.	+	+
Hemizygia pretoriae	.	.	.	.	.	.	+	1
Plectranthus verticillatus	.	.	.	.	+	.	+	+
Pelargonium caledonicum	.	.	+	.	.	.	1	.
Oxalis depressa	.	.	.	.	.	a	a	+
Scabiosa columbaria	.	.	.	+	.	.	.	+
Tristachya leucothrix	.	.	.	.	1	.	.	+
Species group E								
Cyanotis speciosa	+	.	+	+	.	.	+	+
Pellaea calomelanos	+	.	.	1	3	3	.	1
Pseudognapha luteo-album	+	.	+	.	+	.	+	.
Wahlenbergia undulata	+	.	+	+	1	a	+	+
Eragrostis chloromelas	a	b	3	3	.	3	3	+
Eragrostis racemosa	a	.	.	+	3	b	a	a

4.2.1.2 Transects 3&4

The vegetation of the total area within which these transects were laid is classified as *Protea caffra- Themeda triandra* Open Woodland as described by Bredenkamp & Brown (2003). Transects 3 & 4 study area were separated from transect 1 & 2 study area by a depression which appeared to have been created whilst construction of the residential area was in progress. The depression appears to have been a minor borrow pit, which was most likely used for excavating soil during construction of the road or residences.

The phytosociological descriptions below for transects 3 & 4 are all relevant to Table 6. Reference to Table 6 will therefore not necessarily be made when referring to the different species groups.

1. ***Protea caffra- Themeda triandra* Open Woodland**

The vegetation of the total area within which these transects were laid is classified as *Protea caffra- Themeda triandra* Open Woodland Species and species from species group F are characteristic for the study site. This study areas is characterized by the prominence of the grasses *Themeda triandra, Eragrostis chloromelas, Eragrostis curvula* and *Trachypogon spicatus* (species group F), *Eragrostis racemosa*, and *Brachiaria serrata* (species group E), the forb *Nidorella hottentotica* (species group E).

Although the study area is part of one main community, the following two sub-communities can be distinguished namely:

1.1 *Themeda triandra - Hyparrhenia hirta* Open Woodland;

1.2 *Diheteropogon amplectens – Eragrostis racemosa* Open Woodland

12.1 *Themeda triandra* Variant

1.2.2 *Eragrostis racemosa* Variant

The woody species were again found on the mid-slopes and crest. Species characteristic for this study site are the climax grasses *Themeda triandra* and *Trachypogon spicatus*, the sub-climax grasses *Eragrostis chloromelas* and *Eragrostis curvula* (species group F).

1.1 *Themeda triandra - Hyparrhenia hirta* Open Woodland

This subcommunity (relevés 24,25,28 & 29) is characterised by the sub-climax grasses *Hyparrhenia hirta, Setaria sphacelata* and the climax forb *Senecio venosus* and the weed forb *Tagetes minuta* and the forb *Indogofera species* (species group A). The dominant species for this community are the climax grasses *Themeda triandra* and *Trachypogon spicatus* (species group F) the sub-climax grasses *Eragrostis curvula, Eragrostis chloromelas* (species group F), *Hyparrhenia hirta* and *Setaria sphacelata* (species group A) and the climax forb *Senecio venosus,* the weed forb *Tagetes minuta* and the forb *Indigofera species* (species group A).

There was no woody layer present in this sample site while the herbaceous layer dominated with a 100% cover. This community is representative of the vegetation of the plots (MT3P1-P2 (transect 3, plots 1-2) and MT4P1-P2 (transect 4, plots 1-2)) within the 5-35 m zone from development and comprises a collection of climax, sub-climax, pioneer and weedy species. The area has a slope of 5-6^{o} shallow soils and a rocky cover of 2%. There are small piles of domestic garden refuse and building rubble within this site.

1.2 *Diheteropogon amplectens – Eragrostis racemosa* Open Woodland

This community is characterised by the prominence of the climax grasses *Themeda triandra* and *Trachypogon spicatus,* the sub-climax grasses *Eragrostis chloromelas, Eragrostis curvula* (species group F), the climax grass *Brachiaria serrata,* the sub-climax grass *Eragrostis racemosa* and the pioneer grass *Melinis repens* (species group E), the climax grass *Diheteropogon amplectens* and the sub-climax grass *Digitaria monodactyla* (species group B), and the weedy forb *Nidorella hottentotica*, the climax forb *Vernonia natalensis* (species group E), the climax forbs *Clematopsis scabiosifolia, Cheilanthes hirta, Cyanotis speciosa* (species group B) and *Cyperus rupestris* (species group D).

Species from species groups B are the diagnostic species of this subcommunity. These include the climax forbs *Clematopsis scabiosifolia Cheilanthes hirta, Cyanotis speciosa* (species group B), the sub-climax grass *Digitaria monodactyla* (species group B).

Other grasses that are also present include the climax grass *Panicum natalense,* the climax forb *Eulalia villosa* (species group B) and the climax grass *Elionurus muticus* (species group E) and the climax forbs *Pearsonia sessilifolia, Pellaea calomelanos* and the weed forb *Pseudognapha luteo-album* (species group B).

There was a very low representation of the woody layer with an approximate cover of 1%, which is dominated by the shrub *Rhus rigida* (species group D) while the grass layer with a cover of 90-95% is dominated by the grasses, *Eragrostis racemosa, Themeda triandra, Eragrostis chloromelas, Trachypogon spicatus* (species group F), *Melinis repens* (species group E).

1.2.1 *Themeda triandra* Variant

This variant is characterized by the presence of species from species groups C and the absence of species group D. This variant represents the sampling plot (relevés 26 &30) that is located in the 45-55 m buffer zone from the development.

The vegetation is dominated by the woody species *Rhus rigida* and the climax forbs *Crassula setulosa* and *Senecio species* (species group C).

1.2.2 *Eragrostis racemosa* Variant

This variant is characterized by the presence of species from species groups D and the absence of species group C. This variant represents the sampling plot (relevés 27 &31) that is located in the 65-75 m buffer zone from the development.

The vegetation is dominated by the climax grass *Tristachya leucothrix* and the climax forb *Cyperus rupestris* (species group D).

Table 6. Phytosociological Table Morning Hill transect 3&4

	1							
	1.1				1.2			
					1.2.1		1.2.2	
Relevé	28	29	24	25	26	30	31	27
Species group A								
Setaria sphacelata	1	+	a	.	.	.	.	.
Hyparrhenia hirta	3	+	.	+	a	.	.	.
Senecio venosus	3	+	.	.	.	.	.	.
Tagetes minuta	b	.	.	b	.	.	.	.
Indigofera species	b	.	.	+	.	.	.	.
Cymbopogon plurinodis		.	+	+	.	.	.	.
Species group B								
Panicum natalense	.	+	.	+	1	+	+	+
Clematopsis scabiosifolia	.	.	.	.	+	+	+	+
Cheilanthes hirta	.	.	.	.	+	+	+	+
Digitaria monodactyla	.	.	.	.	a	+	+	+
Eulalia villosa	.	.	+	.	+	+	+	+
Pearsonia sessilifolia	.	.	.	.	.	+	+	+
Cyanotis speciosa	.	.	.	.	+	+	+	+
Pellaea calomelanos	.	.	.	.	+	+	.	+
Pseudognapha luteo-album	.	.	.	.	+	+	.	+
Diheteropogon amplectens	.	.	.	+	.	1	+	4
Species group C								
Rhus rigida		.	.	.	+	+	.	.
Crassula setulosa		.	.	.	+	+	.	.
Senecio species		.	a	.	+	+	.	.
Species group D								
Cyperus rupestris	.	.	.	+	.	.	1	b
Tristachya leucothrix	.	+	.	+	.	.	+	+
Species group E								
Eragrostis racemosa	.	b	+	3	b	b	3	3
Nidorella hottentotica	.	+	+	.	.	a	r	a
Melinis repens	.	+	.	+	1	a	+	+
Brachiaria serrata	.	1	.	+	.	.	3	b
Elionurus muticus	.	.	+	+	+	.	.	+
Helichrysum rugulosum		.	.	1	.	.	.	+
Vernonia natalensis		.	.	+	+	.	+	.
Species group F								
Themeda triandra	4	5	4	a	.	3	a	1
Eragrostis chloromelas	b	+	b	a	b	1	1	1
Eragrostis curvula	3	r	a	.	1	.	1	.
Trachypogon spicatus	1	.	+	+	.	1	4	+

4.2.2 Discussion of plant communities

Transects 1&2

The phytosociological data from these transects indicated that there is one prominent plant community with three sub-communities all associated in respect of distance from development. Subcommunity 1 (*Eragrostis chloromelas- Eragrostis curvula* Open Woodland) is the closest to the development (15m) comprising mostly weedy and pioneer species such as *Bidens pilosa, Pennisetum clandestinum, Ipomoea purpurea* and *Cynodon dactylon* (species group A – Table 5). Sub community 2 (*Eragrostis chloromelas- Panicum natalense* open woodland) represents the sampling plots between 25-55m zone from the edge of development. This subcommunity comprises a mixture of sub-climax and climax species such as climax forbs *Helichrysum setosum, Helichrysum callicomum, Ledebouria ovatifolia, Dianthus mooiensis, Dovyalis caffra,* the sub-climax forb *Sphenostylis angustifolia,* the weed forb *Cleome rubella* and the climax woody species *Protea caffra* (species group B – Table 5). Community 3 (*Eragrostis chloromelas- Cymbopogon plurinodis* open woodland) represents the sampling plots between 65-75m zone from the edge of development. This subcommunity comprises a mixture of sub-climax and climax species such as the climax forbs *Albuca species, Aloe greatheadii, Hemizygia pretoriae, Plectranthus verticill, Pelargonium luridum*, *Scabiosa columbaria,* the sub-climax forb *Oxalis depressa,* and the climax grass *Tristachya leucothrix* (species group D – Table 5).

Relevés 16 & 20 are located within the 5-15 m zone from development while relevés 17,18,19,21,22 & 23 are located within the 25-75 m zone from development. No clear distinction could however be made between the first two (16 & 20) and the six remaining relevés in the phytosociological table as they differ only slightly in species composition. Thus, these relevés have large numbers of species overlapping with only cover differences of the different species distinguishing them from each other. The most noticeable difference between these three subcommunities is the presence of weedy species (species groups A) being present in subcommunity 1, which was anticipated as this community is found between 5-15m from the development edge.

Whilst in subcommunity 3, which is between 65-75m from the development edge, there is only one pioneer species (*Aloe greatheadii*) and one sub-climax (*Oxalis depressa*), and the remaining species are all climax species (species group E). Therefore, based on the phytosociological data of transects 1 & 2 only, the most distinct difference in terms of plant communities lies at a distance of 15 m from development where the pioneer plant species almost disappear from the other sampling plots (species group A - Table 5), with the next most distinct difference at 55 m from development.

<u>Transects 3 & 4</u>

The phytosociological data from these transects indicated that there are two subcommunities within the larger community also associated in respect of distance from development.

The plots of subcommunity 1.1 (*Themeda triandra - Hyparrhenia hirta*) are the closest to the development (15m) and is characterised by the sub-climax grasses *Hyparrhenia hirta, Setaria sphacelata* and the climax forb *Senecio venosus* and the weed forb *Tagetes minuta* and the forb *Indogofera* species (species group A). Subcommunity 1.2 (*Diheteropogon amplectens – Eragrostis racemosa* Open Woodland) represents the sampling plots within the 45-75 m zone from the edge of development. This subcommunity comprises a mixture of sub-climax and climax species such as climax grasses *Themeda triandra* and *Trachypogon spicatus,* the sub-climax grasses *Eragrostis chloromelas, Eragrostis curvula* (species group F), the climax grass *Brachiaria serrata,* the sub-climax grass *Eragrostis racemosa* with only a few pioneer and weedy species such as *Melinis repens* (species group E), *Nidorella hottentotica* (species group E – Table 6) present. From the phytosociological discussions it is evident that the two variants within this subcommunity are very similar with only slight differences in species composition. The species composition of these three variants does not differ in terms of the dominant and prominent species. The three variants identified within subcommunity 2.2 thus have large numbers of species overlapping with only cover differences of the different species distinguishing them from each other. That, together with the fact that the different variants comprise plots of different distances within the 25-65m zone indicates that there is no distinction between the 25m and 75m zones.

Relevé 26 is located within the 45-55 m zone from development while relevés 27 & 31 are located within the 65-75 m zone from development. However no clear distinction could be made between these four relevés in the phytosociological table with relevé 26 (variant 2.2.1) differing slightly from relevé 27 (variant 2.2.2) in species composition. Both variants are located broadly across the 45-75m zones from the development edge and consist mainly of climax grass and forb species. Although sub-community 2.2.1 differs from sub-community 2.2.2 in that species group D is not present the broad species composition thereof is still similar to that of the total area.

Thus based on the phytosociological data of transects 3 & 4 only, the most distinct difference in terms of plant communities again lies at a distance of 15 m from development where the pioneer plant species almost disappear from the other sampling plots (species group A - Table 6), with the next most distinct difference at 25 m from development.

4.2.3 Plant density

The density data for the Morning Hill site was analyzed using the Chi-squared test for independence to determine whether the number of individual plants per successional group was independent from the position of the plot (with plot 1 being closest to the development and plot 4 furthest).

Under the null hypothesis of independence of number of species and position the Morning Hill site also rendered no significant result ($p>0.05$) i.e. the number of individual plants per successional group was independent from the position of the plot.

This means that the density of species per successional group does not show a statistically significant pattern that any successional groups of species increase or decrease from plot 2 onwards from development edge.

Although not significantly different the density data for the Morning Hill site indicates that the highest number of weedy species are clearly present in the 5-15m zone with 25 individuals/ m^2 (Figure 13), and climax species are poorly represented with a density of 2 individuals/ m^2. As with the previous study site, the number of weedy species/m^2 declines drastically from 25 individuals/ m^2 in the 5-15m zone to 0.5 individuals / m^2 in the 25-35m zone where after there were no weed species detected within the 45-55m zone and only 1 individuals/ m² in the final plot (65-75m. Interestingly the highest density of climax species (18 individuals/ m²) is found within the 65-75m zone. The highest density of sub-climax species (5 individuals/ m²) are also present in the 45-75m distance, coupled with the climax species density this study site is more indicative of the successional sequence model. Pioneer species are present in the highest density (3 individuals / m²) within the 5-15m zone and then decrease gradually through each successive plot until there is only a density of 1 individual/ m² in the 65-75m zone. The density data indicates that the only clear distinction in the successional groups of species occurs at 15m from the development edge. Thus from Figure 13 the density of different successional groups supports the phytosociological data as discussed above.

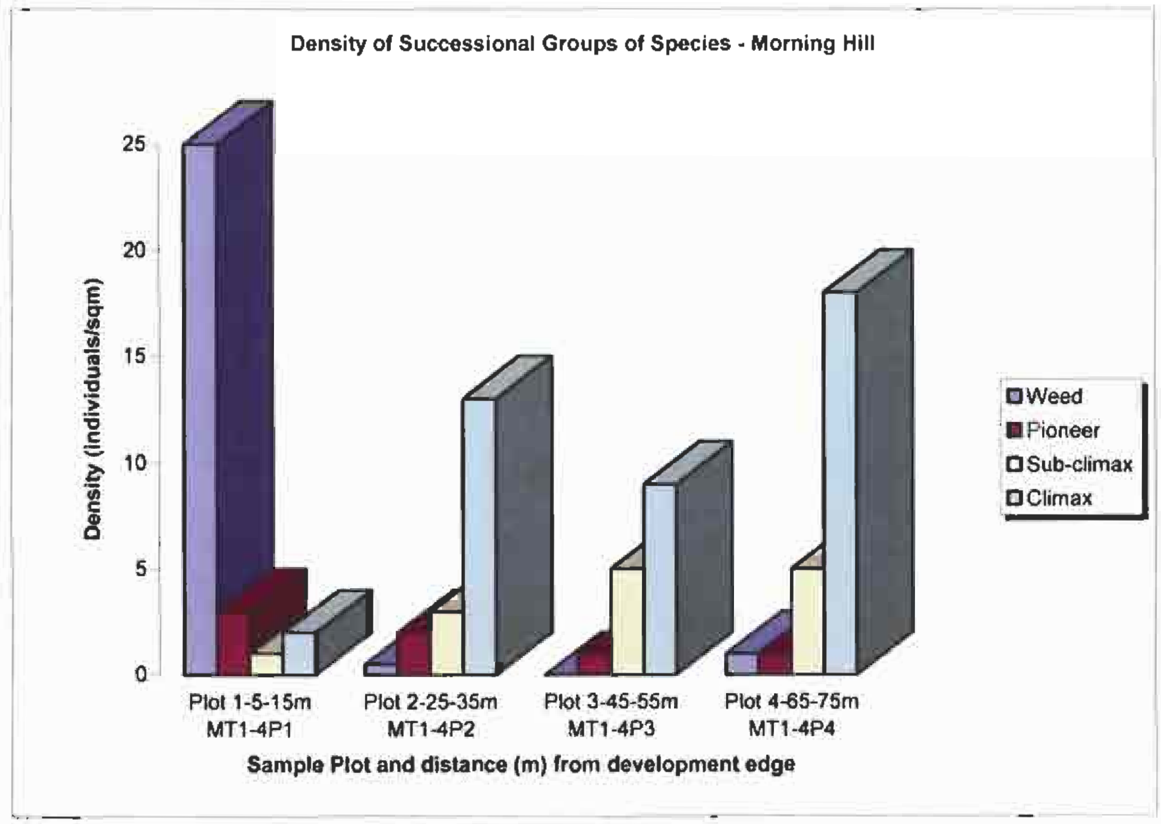

Figure 13. Graph indicating density of successional groups of species relative to. distance from the development edge – Morning Hill

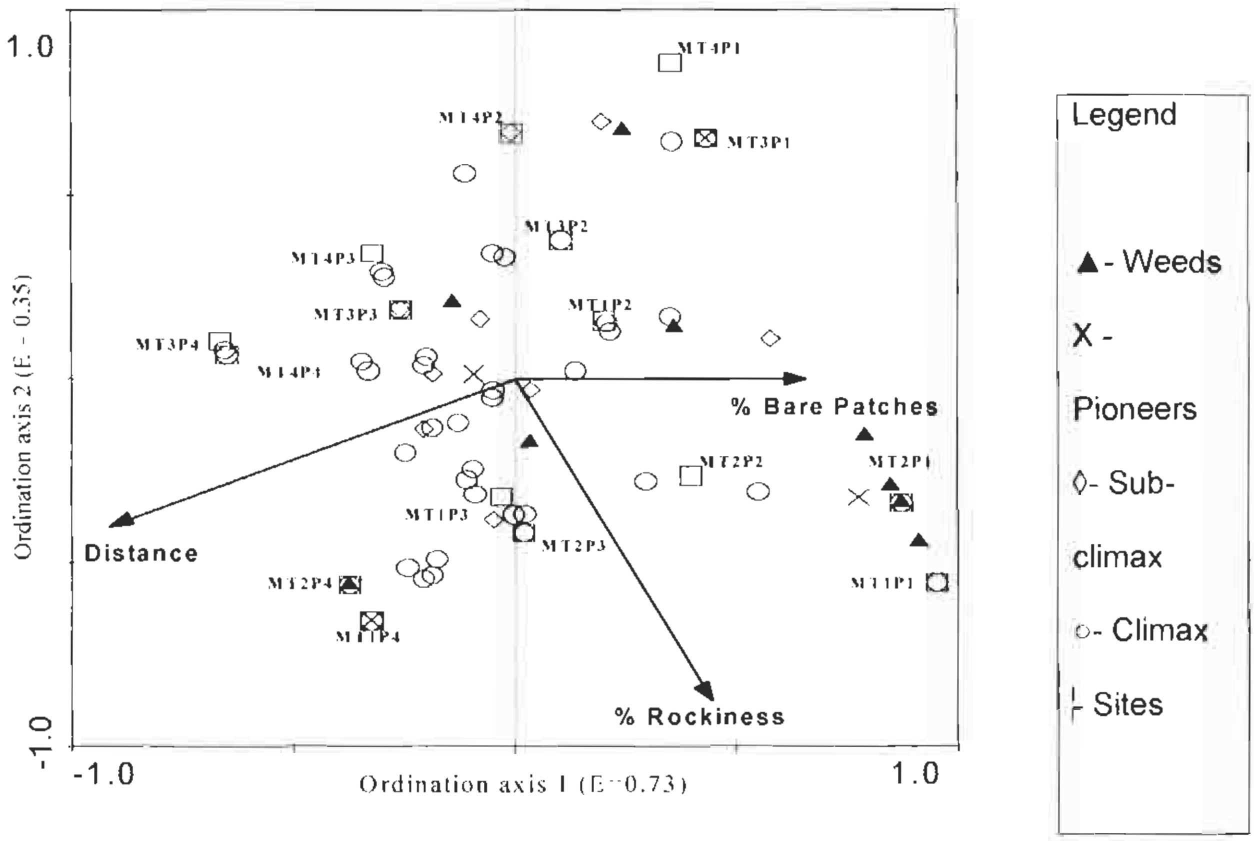

Figure 14. Triplot of CCA ordination for density of successional groups of species – Morning Hill.

In the triplot of a CCA ordination for Morning Hill (MH) study area the bare patches are most highly associated with the first axis and the CANOCO results confirm this correlation as 0.74 but does not indicate an influence on the density of sub-climax and climax species. The eigenvalue for the first axis of the successional groups of species/environment triplot is 0.73 and the second ordination is 0.35, representing 20.4 per cent and 30.4 per cent of the total variance respectively. Thus the first two axes account for 50.8 per cent of the variance in the successional species groups/environment data.

The indication that distance from the development edge is the most influential variable is well illustrated with pioneer, sub-climax and climax species occurring along this vector.

The observed pattern in this study site is that the further along the gradient one moves from the development edge, the higher the density of sub-climax and climax species (lower left quadrant).

Conversely, closer to the development edge a higher abundance of weeds and pioneer species is present (upper right quadrant), which also indicates a closer association with the presence of Bare Patches. The areas dominated by rock did not support much vegetation; hence the further away you move from rocky areas the higher the abundance of plant species. Pioneer species are represented in low densities in the same area as the weedy species, which is expected, but are represented in higher densities to the left of the diagram, which also represents the highest density of sub-climax and climax species. The overall relative abundance of weeds is low though.

This community is largely comprised of sub-climax and climax species, with weeds and pioneer species also present. These groupings are clearly shown in relation to the arrows representing the environmental factors and gradients. Again, the weedy species are shown to have a higher density in close proximity to the development edge, closest to the area of impact. However, this study area does not indicate a correlation between weedy species and rocky areas but does indicate a relationship between weedy species and bare patches. The diagram indicates that the sub-climax and climax species occur in highest densities where the bare patch and rock environmental factors (axis) are insignificant (not present) but occur in high densities throughout the transect.

However, the data dispersion indicates that climax species occur throughout the sample transect but with noticeably higher densities from the 15m zone (plots 2-4) i.e. there is no distinct zone of no-climax species where impact of development reduced the communities climax potential. However, the drastic decrease in weedy and pioneer species from the 15m zone would indicate that this would serve as a minimum buffer zone.

4.3 Kliprivier Study area

4.3.1 Description of plant communities

As previously stated the study site chosen is representative of the *Themeda triandra-Acacia karoo* Microphyllous Woodland as described by Bredenkamp & Brown (2003). This is indicated by the presence and abundance of *Acacia caffra* (species group I) on the lower mountain slopes, the herbaceous layer being dominated by grasses *Themeda triandra* (species group I), the sub-climax grass *Setaria sphacelata* (species group E) while the sub-climax grasses *Eragrostis curvula, Heteropogon contortus,* the climax grass *Digitaria eriantha* (species group I) and the climax grass *Elionurus muticus* (species group C) are also locally abundant.

The phytosociological descriptions below for this study area are all relevant to Table 7. Reference to Table 7 will therefore not necessarily be made when referring to the different species groups.

The vegetation of this study site is classified as *Themeda triandra-Acacia karoo* Microphyllous Woodland and is characterized by species group I which includes the climax tree *Acacia caffra,* the climax grass *Themeda triandra,* the sub-climax grass *Heteropogon contortus* and the sub-climax forb *Vernonia oligocephala* (species group I – Table 7).

The data analysis indicates that this larger community can be divided into four different sub-communities namely:

1.1 Acacia caffra-Aristida congesta Woodland

1.2 Senecio spp-Hyparrhenia hirta Woodland

1.3 Eragrostis curvula-Hyparrhenia hirta Woodland

1.4 Acacia caffra-Setaria lindenbergiana Woodland

1.1 *Acacia caffra-Aristida congesta* Woodland

This sub-community (relevés 32, 38, 42 & 46) is characterized by the presence of the pioneer grass *Aristida congesta* subsp. *congesta*, the climax grass *Harpochloa falx*, and the climax forbs *Scabiosa columbaria* and *Pentanisia angustifolia* (species group B – Table 7).

The presence of species groups B, C, D, E & I and the absence of species groups F, G & I, characterize this vegetation. This community can be further sub-divided into two variants based on presence or absence of species group A, though for the purpose of this study it will not be discussed.

The vegetation is dominated by the sub-climax grass *Hyparrhenia hirta,* the pioneer grass *Melinis repens*, (species group D), *Heteropogon contortus* and the sub-climax forb *Vernonia oligocephala*. Both grasses *Hyparrhenia hirta* and *Aristida congesta* subsp *congesta* are indicative of disturbed areas (Van Oudtshoorn 1999) and all relevés are located in the 10m-55m zones from the development edge.

There was a very low representation of the woody layer with an approximate cover of 5%, which is dominated by the tree *Acacia caffra* (species group I) while the grass layer with a cover of 95-98% is dominated by the pioneer grass, *Melinis repens* and the sub-climax *Hyparrhenia hirta* (Species group D), and the sub-climax grass species *Heteropogon contortus* and the sub-climax forb species *Vernonia oligocephala* (Species group I)

This subcommunity is representative of the vegetation plots between 5-15m (KT1P1 (transect 1, plot1), KT3P1 (transect 3, plot1), KT4P1 (transect 4, plot1)) but also includes a sample plot within 65-75m (KT1P4 (transect 1, plot4)) from the development edge. This community is composed of all the ecological successional species with climax species and weedy species occurring with high abundance values within 15m from the development edge. The area has a slope of 4-6^{o} shallow soils and a rocky cover of 5-15%. There is minor sheet erosion; building rubble and garden refuse in these sample sites.

1.2 *Senecio spp-Hyparrhenia hirta* Woodland

Although there are no diagnostic species for this community (*Senecio spp-Hyparrhenia hirta* Woodland) it is characterised by the absence of species group B.

The vegetation is dominated by the sub-climax grass *Hyparrhenia hirta* (species group D) and the climax grass *Themeda triandra* (species group I). The woody layer is characterised by the prominence of the climax tree *Acacia caffra* (species group I) locally while the sub-climax grass *Heteropogon contortus* (species group I), pioneer grass *Melinis repens* (species group D), the weed forb *Tagetes minuta* (species group I) and the geophyte *Aloe greatheadii* (species group E) are locally prominent.

This community (relevés 33, 34, 40, 47 & 48) is representative of the vegetation plots between 25-55m (KT1P2 (transect 1, plot2), KT1P3 (transect 1, plot3), KT2P3 (transect 2, plot3), KT4P2 (transect 4, plot2), KT4P3 (transect 4, plot3)) from the development edge. The vegetation is characterized by the presence of species groups C, D, E & I and the absence of species groups A, B, F, G & H. This community is also composed of all the ecological successional species with climax species and weedy species occurring with high abundance values throughout the study site. The area has a slope of 4-6^{o} shallow soils and a rocky cover of 2-10%. There was no sheet erosion; building rubble or garden refuse in these sample sites.

1.3 *Eragrostis curvula-Hyparrhenia hirta* Woodland

This subcommunity does not have characteristic species but is rather characterised by the exclusion of species groups A, B and C.

The vegetation is dominated by the grasses *Hyparrhenia hirta* and *Melinis repens* (species group D). This community is representative of the vegetation plots between 25-55m (KT3P2, KT3P3) from development edge. The vegetation is characterized by the presence of species groups D, E & I and the absence of species groups A, B, C, F, G & H.

1.4 *Acacia caffra-Setaria lindenbergiana* Woodland

This subcommunity is characterized by the presence of the woody shrub *Rhus leptodictya, Euclea crispa* (species group F), the grass *Setaria lindenbergiana* and the forb *Solanum species.*

The vegetation is dominated by the woody shrub *Rhus leptodictya (species group F),* the grasses *Setaria lindenbergiana* (species group F), *Setaria sphacelata* (species group E), *Hyparrhenia hirta, Melinis repens* (species group D).

With the exception of one plot (KT2P2 (transect 2, plot 2), which is 25-35m from the development edge, this community is representative of the vegetation plots between 65-75m (KT1P4 (transect 1, plot 4), KT2P4 (transect 2, plot 4), KT3P4 (transect 3, plot 4), KT4P4 (transect 4, plot 4)) from development edge. The vegetation is characterized by the presence of species groups D, E, F, G, H & I and the absence of species groups A, B, & C.

Table 7. Phytosociological table Kliprivier
Transects 1-4

	1															
	1.1				1.2					1.3		1.4				
Relevés	32	42	46	38	33	47	40	34	48	43	44	39	41	45	35	49
Species group A																
Eragrostis superba	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pelargonium luridum	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Andropogon chinensis	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helichrysum harveyanum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species group B																
Scabiosa columbaria	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Pentanisia angustifolia	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Aristida congesta subsp *barbicollis*	.	1	1	1	.	r	.	.	.	.	.	+	.	.	.	.
Harpochloa falx	.	+	.	+	.	.	.	+	+	.	.	.	.	.	.	.
Species group C																
Elionurus muticus	+	+	+	+	+	+	.	1	1	.	.	.	+	.	.	.
Brachiaria serrata	1	+	+	+	r	1	+	.	+	.	.	.	.	.	.	.
Senecio species	1	.	a	a	+	.	1	.	1	.	+	.	.	.	.	.
Corchorus asplenifolius	+	.	.	+	+	+	+	+	+	.	.	.	.	.	.	.
Vahlia capensis	+	.	.	.	+	+	.	+	a	.	.	.	.	+	.	.
Acalypha angustata	+	.	+	+	+	.	+	.	.	.	.	.	.	.	.	.
Anthospermum hispidulum	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.
Felicia muricata	+	+	.	.	+	.	+	+	.	.	.	.	.	.	.	.
Eragrostis racemosa	.	.	1	.	+	+	.	.	a	.	+	.	.	.	.	.
Chenopodium album	+	+	.	+	+	+	.	+	+	+	.	.	.	.	.	.
Nidorella hottentotica	.	+	+	.	.	+	a	.	.	+	.	.	.	+	.	.
Eragrostis chloromelas	.	.	.	1	+	.	+	1	3	b	.	.	.	.	r	.
Species group D																
Hyparrhenia hirta	1	4	3	1	a	+	3	.	a	4	b	b	r	a	.	.
Melinis repens	3	1	a	1	r	+	b	b	a	.	1	+	1	+	.	.
Species group E																
Aloe greatheadii	+	.	1	.	+	+	+	b	1	.	.	+	+	+	+	r
Setaria sphacelata	1	.	+	.	+	+	+	1	+	.	.	1	1	+	+	+
Hypoxis rigidula	.	.	+	+	+	.	+	+	+	.	.	+	+	+	.	+
Aristida transvaalens	.	.	.	.	.	r	.	4	a	.	.	r	1	.	+	r
Species group F																
Setaria lindenbergiana	.	.	.	.	.	.	1	a	.	.	+	+	3	3	4	4
Rhus leptodictya	.	.	.	.	.	.	.	+	.	.	.	.	+	+	+	+
Solanum species	.	.	.	.	.	.	.	1	.	.	.	+	.	.	+	.
Euclea crispa	.	r	.	r	.	.	1	.	.	.	.	+	+	.	+	.
Species group G																
Cynodon dactylon	.	.	.	.	.	.	.	.	.	.	.	+	r	b	.	.
Diospyros lycioides subsp *guerkei*	+	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.
Lantana camara	.	.	.	+	.	.	.	.	.	.	.	+	.	+	.	.
Ipomoea purpurea	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Urochloa panicoides	.	.	.	.	.	.	.	.	.	.	.	.	+	r	.	.

Species group H																
Bidens pilosa	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Hibiscus trionum	.	.	.	.	.	.	.	.	.	.	.	.	.	r	+	+
Pavonia burchellii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Ziziphus mucronata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Protasparagus species	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	+
Species group I																
Acacia caffra	+	.	+	+	+	r	+	3	a	.	+	r	a	r	3	a
Heteropogon contortus	b	+	1	3	+	r	1	b	3	+	r	.	+	.	+	.
Themeda triandra	.	1	1	+	1	r	a	1	a	a	.	.	+	+	.	+
Tagetes minuta	.	1	+	1	.	+	.	1	1	.	+	+	+	r	+	a
Pentarrhinum insipidum	.	b	.	b	.	.	.	a	1	.	+	r	a	+	+	b
Vernonia oligocephala	3	1	a	b	+	+	.	a	a	+	.	.	+	+	+	+
Eragrostis curvula	.	+	.	.	+	+	b	.	.	b	a	+	+	b	.	.
Digitaria eriantha	.	.	+	.	.	.	+	1	.	1	.	.	+	+	r	+
Schkuhria pinnata	.	+	+	.	.	.	+	+	+	+	.	+	+	r	.	a

4.3.2 Discussion of plant communities

The phytosociological data from these transects indicate that there are four subcommunities within the larger community which show no association in respect of distance from development. The plots of subcommunity 1.1 (*Acacia caffra-Aristida congesta* Woodland) lie throughout the 5m –55m distance from the development edge and include weedy species, pioneer, sub-climax and climax. It is interesting to note that the highest cover abundance within this subcommunity is by the sub-climax grass *Hyparrhenia hirta* and the pioneer grass *Melinis repens* (species group D – Table 7) with both species being known to occur in disturbed places (Van Oudtshoorn 1999). Subcommunity 1.2 (*Senecio spp-Hyparrhenia hirta* Woodland) is represented by plots which lie within the 5-75m zone, along the entire transect. This subcommunity comprises a mixture of weeds, sub-climax and climax species such as *Hyparrhenia hirta* (species group D) and the climax grass *Themeda triandra* (species group I) sub-climax grass *Heteropogon contortus* (species group I), pioneer grass *Melinis repens* (species group D), the weed forb *Tagetes minuta* (species group I – Table 7). Both sub communities 1.3 (*Eragrostis curvula-Hyparrhenia hirta* Woodland) and 1.4 (*Acacia caffra-Setaria lindenbergiana* Woodland) show the same relationship with plots 5m and 75m from the development edge. However no clear distinction could be made between these four subcommunities in the phytosociological table. The four subcommunities thus have large numbers of species overlapping with only cover differences of the different species distinguishing them from each other.

Thus based on the phytosociological data of this study site there is no association in respect of distance from development.

4.3.3 Plant density

The density data for the Kliprivier site was also analyzed using the Chi-squared test for independence to determine whether the number of individual plants per successional group was independent from the position of the plot (with plot 1 being closest to the development and plot 4 furthest). Under the null hypothesis of independence of number of species and position the Kliprivier site rendered no significant result ($p>0.05$) i.e. the number of individual plants per successional group was independent from the position of the plot. This means that the density of species per successional group does not show a statistically significant pattern that any successional group of species increase or decrease closer or further away from development.

Although not significantly different the density data for the Kloofendal site indicates that the highest number of weedy species are present in the 65-75m zone with 6 individuals/ m^2 (Figure 15) although the climax species have a higher cover abundance and are represented in the same sample plot with a density of 15 individuals/ m^2. One of the factors that may have contributed to the highest density of weedy species being present in the 65-75m zone is that the weedy species were located under the canopy of the climax tree *Acacia caffra* which was identified in highest cover abundance within the 65-75m zone (species group I- Table 7). Conversely, the density of weedy species is lowest in the 25-35m zone where the climax species have the highest density (15 individuals/ m^2) which is consistent with the findings in the other study sites.

This again indicates the dominance of the climax successional sequence within the 25-35m zone from a development edge. Interestingly the density of climax species closest to the development edge (5-15m) is 10-individuals/ m^2 and dominates the 5-15m zone in this study site. The highest density of sub-climax species (3 individuals/ m^2) is also present in the 5-15m zone. Pioneer species are present with the same density of 2 individuals/ m^2 within the 5-15m zone as well as the 25-35m zone where after the pioneer species increase to 3 individuals/ m^2 in the 45-55m zone and then decrease to 1 individual/ m^2 in the 65-75m zone. Thus from Figure 15 the density of different successional groups supports the phytosociological data as discussed above. However, this study site does not display the anticipated effects of the development on the immediate (5-15m) surrounds, which is represented in the other study sites by the high densities of weedy and pioneer species within the same zone. This study site tends to indicate that in this community no proposal could be made regarding the width of a buffer zone.

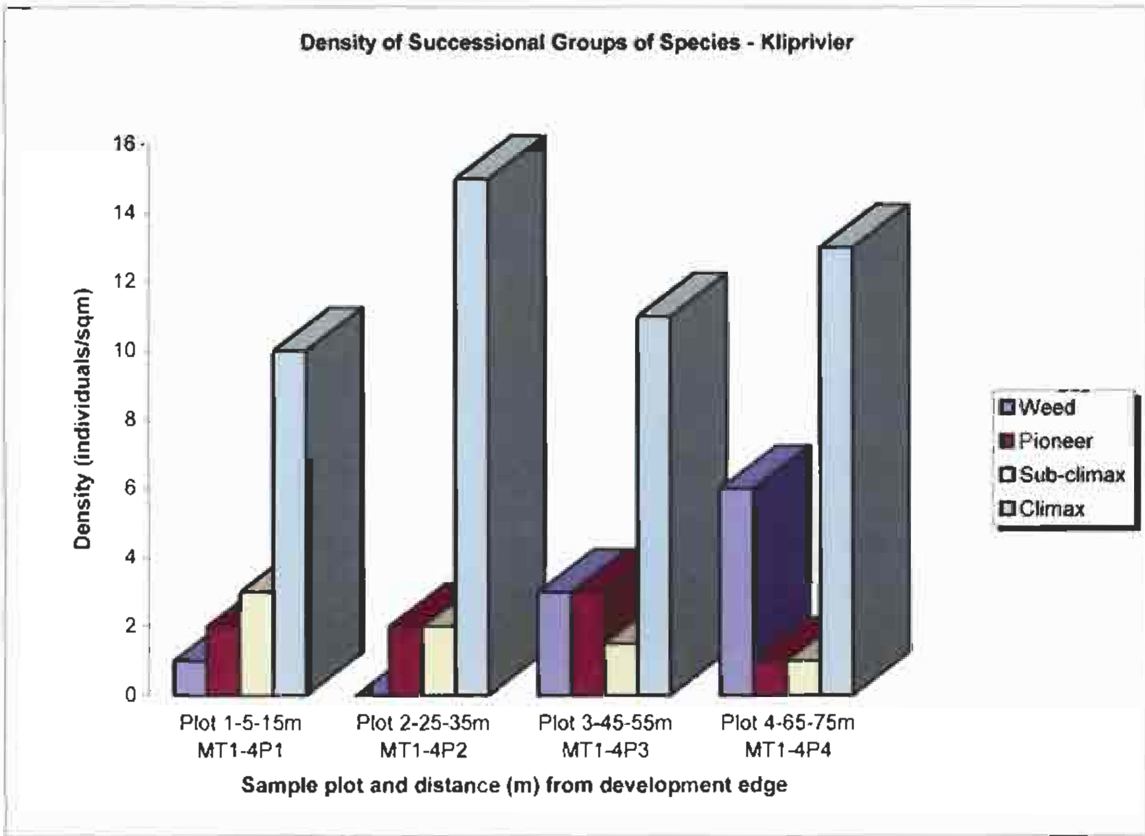

Figure 15. Graph indicating density of successional groups of species relative to distance from the development edge – Kliprivier.

The density data reveals an anomaly in that the highest density of weedy species is found in plot 4, furthest away from the development edge and closest to the protected reserve.

Moreover, the density of climax species is consistently high throughout the length of the transect. This anomaly is difficult to explain without further investigation. On the basis of these results there is no apparent impact beyond 5m from the development edge. However, due to the anomalous nature of the results in the Kliprivier study site, no definitive conclusions can be made.

The triplot of a CCA ordination for the Klipriver (K) study area (Figure 16) shows the successional groups of species from the development edge less effected by distance from the development edge. The CANOCO result of 0.51 confirms this low correlation with both the first and second axis. The eigenvalue for the first axis is 0.33 and the second correlation is 0.18, representing 11.4 per cent and 17.9 per cent of the total variance respectively. Thus the first two axes account for 29.3 per cent of the variance in the successional groups of species and the environment data.

The right hand two quadrants, dominated by bare patches and rocky areas have the highest number of successional species groupings surveyed close to the impacted area. Conversely, the left hand quadrants, where the distance vector is located has a higher number of sites far away from the impact edge. The bare patch axis is influencing the pioneer and sub-climax species but what is most noticeable in this study area is that distance does not effect climax species density.

Weedy species are shown in each plot with a low correlation to the distance from development edge but with a higher correlation to bare patches. Climax species are located along the entire gradient and Figure (15) indicates this very clearly. There is however a stronger correlation between the climax successional group and the rock vector.

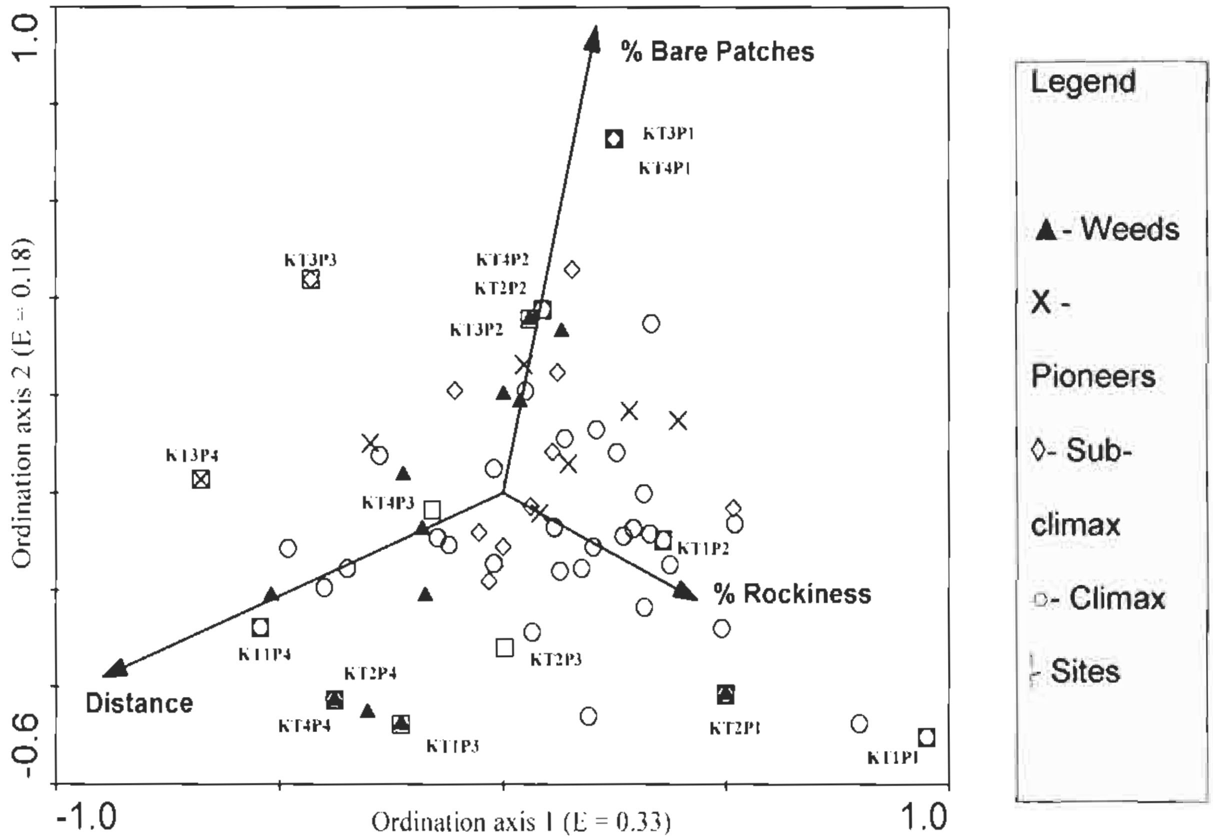

Figure 16. Triplot for CCA ordination for density of successional groups of species - Kliprivier site

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This study focused on determining and evaluating the distance at which the climax successional stage of specific plant communities on rocky ridges, in Johannesburg, develops from a point of disturbance (development edge) as a measure of the distance required for these plant communities to re-establish their equilibrium (climax community) post impact phase.

The present 'blanket' application of a standard 200m buffer zone to every development proposal on rocky ridges is not scientifically justifiable. This study found no statistical difference ($p>0.05$) in the density of successional groups within the plots surveyed beyond Plot 2 (i.e. 15-25m from the development edge) i.e. the species density per successional category beyond Plot 2 was independent from the position of the plot. Therefore, the density of species beyond Plot 2 is random.

These results provide a basis for using the Braun-Blanquet method to define a buffer zone of 15-25m for the two *Protea* ridge study sites, confirming the importance of phytosociological studies as tools in evaluating and describing different plant communities in relation to current and future development proposals (Bredenkamp & Brown 2001).

The density data in the two *Protea* ridge study sites (Kloofendal and Morning Hill) indicates that the climax and sub-climax species dominate in plots 2-4 which are 15-

25m from the development edge. Therefore based on the equilibrium theory of successional sequence, both communities associated with these sites (the *Protea caffra-Themeda triandra* Open Woodland and the *Protea caffra, Eragrostis chloromelas* Open Woodland) developed a climax successional community between 15-25m from the development edge. According to GDACEL this area would presently require a buffer zone of 200m instead of the 15-25m as indicated in this study. This implies that if a development were proposed within these plant communities, a 25m buffer zone could be adequate to filter out the exogenous disturbances sufficiently to allow a climax community to re-establish. These findings are essentially corroborated by the CCA ordination triplots of plant density data for the Kloofendal (KL) and the Morning Hill (M) study sites. On the basis of these results it is possible to infer that the sub-climax and climax successional sequence is established in plot 2, 25-35m from the development edge. These findings are also further corroborated by the graphs of the plant density data.

However, the data results from the *Themeda triandra-Acacia karoo* Microphyllous Woodland study site (Kliprivier) shows that the entire 75m-sample area has been encroached by weedy species, with highest densities in the 65-75m zone (furthest from the development edge). Nevertheless, the climax species persist at high densities along the entire gradient. This type of disturbance has been documented by the Conservation Biology Institute (2000), which found that alien plant species can extend up to about 99m into natural habitat from disturbed edges, including roads. Due to the anomalous nature of the results in the Kliprivier study site, no definitive conclusions can be made without more data repetitions within this plant community. In retrospect, this specific site was not a good choice and this may have been affected by the time constraints imposed on locating the final study site within the optimal summer flowering period of December to February.

The suggestion of buffer zones of 25m for these specific ridges partially tested the hypothesis that it is possible to develop scientifically based guidelines in establishing ecologically acceptable buffer zones on rocky ridges and hills. By using the scientific Braun-Blanquet method to ecologically classify the vegetation type and then analyze the quantitative data in order to determine possible significant statistical differences within the investigation area, the study offers a scientifically based method to assist environmental assessors when establishing ecologically acceptable buffer zones for *Protea* (Kloofendal & Morning Hill) ridges in Johannesburg, Gauteng. While the results for the *Acacia* (Kliprivier) ridge do not support the hypothesis, the Kliprivier site may yield more conclusive results should more data repetitions be performed.

This study advocates the consideration of determining buffer zones, specifically formulated via assessment of the plant community of concern, on an individual proposal basis and not on a non-discriminatory rule of one fixed buffer zone for all proposals basis. Policy makers and environmental consultants see buffer zones as a powerful approach of simultaneously conserving areas of ecological importance and attaining economic development objectives. This in turn will contribute to the implementation of environmentally responsible development by creating buffer zones that overlay both the urban fringe and any adjacent natural areas thus facilitating co-operative management whilst absorbing adverse effects from either area.

The data indicates that although it is important to follow a cautious approach when setting buffer zones, different plant communities will require different buffer zones, as hypothesised. Therefore, proposing a buffer zone, which has been formulated by using a vegetation-based model (at the population and community level), may present developers with a more rational procedure, which will be more readily supported and used. This is corroborated by Stephens (1998) who stated that a variable buffer zone model offers an effective means of co-managing the relationship between urban and natural areas.

However, one of the shortcomings of this study is that it did not investigate whether the community differences identified along transects were sufficiently related to abiotic variation. It is therefore strongly recommended that further studies be carried out, as the scope of this mini-dissertation did not allow for investigations into ecological and ecosystem processes such as gene transfer and nutrient cycling between patches in landscape mosaics. However, Wood *et al.* (1994) advise that with intensive management, ecological processes necessary for species survival can be maintained in natural areas as small as 6ha (edge 125m).

Pickett *et al.* (1992) stated that the new contemporary paradigm of ecosystems recognized that episodic events, openness of ecological systems, and multiplicity of locus and kind of regulation, are more realistic bases for conservation planning and management. We do, therefore, acknowledge that the classical equilibrium theory of successional sequence could be limited in its capacity to evaluate and describe the state of a plant community's response to development impacts.

CHAPTER 6

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