

# **A vegetation study on the area leased for mining purposes by Impala Platinum, Rustenburg South Africa**

**Adriaan Johannes Hendrikus Lamprecht**  
**20330782**

**Dissertation submitted in partial fulfillment of the degree *Magister Scientiae in Environmental Sciences* at the Potchefstroom campus of the North-West University**

**Supervisor: Prof S.S. Cilliers**  
**Co-supervisor: Prof K. Kellner**

**November 2010**

## **Abstract**

Conservation and management of the ecology of natural areas has become a prerequisite for mining companies in South Africa. Systematic conservation planning provides a useful tool for land-use planning and impact assessment, particularly in the mining industry. A study was therefore undertaken to provide sufficient, spatially explicit biodiversity and veld condition information to aid in the development and establishment of an official conservation plan for the leased mining area of Impala Platinum. By identifying areas with high plant diversity or endemism and by assessing veld conditions as well as grazing and browsing capacities, recommendations could be made towards management strategies and potential future land-use practices.

The licensed mining area, north of Rustenburg, covers 29334 ha and includes 14 operational shafts. The area was stratified into three main categories based on landscape types namely: norite koppies; thornveld and rehabilitated areas. The Braun Blanquet approach was followed to sample 139 stratified random relevés. Additional computer software packages were used for capturing, processing and presentation of the phytosociological data (TURBOVEG) as well as a visual editor for phytosociological tables (MEGATAB). Ordinations were subsequently performed to confirm the plant communities and illustrate possible environmental gradients, using multivariate statistic analyses (CANOCO). Four plant communities with two sub-communities were identified and described in both the norite koppies and thornveld respectively while three plant communities with three sub-communities were identified in the rehabilitated areas. Specific environmental factors that influence plant community structure and composition in the norite koppies were the aspect and percentage of soil surface rockiness while soil types proved to be the distinguishing factor in the thornveld. The distribution of plant communities in the rehabilitated areas is mainly due to anthropogenic influences rather than any environmental factors.

The Fixed Point Monitoring of Vegetation Methodology- FIXMOVE was then used to sample 32 stratified random survey plots in four selected plant communities in order to quantify and compare veld conditions as well as grazing and browsing capacities. The determination of landscape functionality served to support these quantitative results. The Landscape Function Analysis (LFA) method was used for this purpose. Multivariate statistic analyses (CANOCO) were used to indicate possible degradation gradients between the plant communities. Conclusions regarding conservation and management units were reached by interpreting the quantitative data in accordance with the phytosociological results and recommendations could then be made. All the norite koppies plant communities were recommended as areas for

conservation because of unique and high biodiversity and anthropogenic threats. The *Eragrostis rigidior-Ziziphus mucronata* and *Acacia caffra-Bothriochloa insculpta* Communities in the thornveld showed the best potential for browsing and grazing practices but were also recommended for conservation because of their high species diversity and anthropogenic threats. The high landscape functionality, veld condition and grazing capacity of the *Aristida bipartita-Bothriochloa insculpta* Community indicated that the rehabilitation of the opencast mining areas had been relatively successful at the time of the surveys. Selected parts of the *Indigofera heterotricha-Aristida bipartita* Community were also recommended for conservation and management in the form of controlled and more effective grazing strategies were recommended for the rest of the thornveld.

**Key words:** Systematic conservation; phytosociology; biodiversity; FIXMOVE; veld condition; grazing and browsing capacity; landscape functionality.

## Opsomming

Bewaring en bestuur van die ekologie van natuurlike areas het 'n vereiste geword vir mynmaatskappye in Suid Afrika. Sistematiese bewaringsbeplanning bied 'n waardevolle instrument vir beplanning van toekomstige grondgebruik en impak bepaling veral in die mynbou industrie. 'n Studie is daarom onderneem om voldoende, ruimtelik eksplisiete biodiversiteits- en veldtoestandsinligting te verskaf om die ontwikkeling en daarstelling van 'n amptelike bewaringsplan vir die gehuurde myngebied van Impala Platinum te ondersteun. Deur gebiede met hoë plantdiversiteit en endemisme te identifiseer en deur veldtoestand sowel as wei- en blaarvreetkapasiteit te evalueer, kon aanbevelings gemaak word ten opsigte van bestuurspraktyke en potensiële grondgebruikspraktyke.

Die gelisensieerde myngebied, noord van Rustenburg beslaan 29334 ha en sluit 14 operasionele skagte in. Die gebied is in drie hoof kategorieë, wat op landskaptipes gebaseer is, gestratifiseer. Die kategorieë is norietkoppies; doringveld en gerehabiliteerde gebiede. Die Braun Blanquet benadering is gevolg om 139 gestratifiseerde ewekansige persele te monster. Addisionele rekenaar sagteware pakette is gebruik vir die vaslê, verwerking en aanbieding van die fitososiologiese data (TURBOVEG) sowel as 'n visuele verwerker vir fitososiologiese tabelle (MEGATAB). Ordenings is vervolgens uitgevoer, om die plantgemeenskappe te bevestig sowel as om moontlike omgewingsgradiënte te illustreer, deur gebruik te maak van meerveranderlike statistiese analyses (CANOCO). Vier plantgemeenskappe met twee sub-gemeenskappe is geïdentifiseer en beskryf in beide die norietkoppies en doringveld onderskeidelik terwyl drie plantgemeenskappe met drie sub-gemeenskappe in die gerehabiliteerde gebiede geïdentifiseer is. Daar is bevind dat aspek en persentasie oppervlak-klipperigheid die spesifieke omgewingsfaktore is wat plantgemeenskapstruktuur en -samestelling beïnvloed in die norietkoppies terwyl grondtipe die onderskeidende faktor in die doringveld was. Die verspreiding van plantgemeenskappe in die gerehabiliteerde gebiede is meestal as gevolg van antropogeniese invloede eerder as omgewingsfaktore.

Die "Fixed Point Monitoring of Vegetation Methodology- FIXMOVE" is daarna gebruik om 32 gestratifiseerde ewekansige persele in vier geselekteerde plantgemeenskappe te monster met die doel om veldtoestand sowel as wei- en blaarvreetkapasiteit te kwantifiseer en te vergelyk. Die bepaling van landskapsfunksionaliteit het gedien ter ondersteuning van hierdie kwantitatiewe resultate wat verkry is. Die "Landscape Function Analysis" (LFA) metode is vir hierdie doel gebruik. Meerveranderlike statistiese analyses (CANOCO) is gebruik om moontlike degradasie-gradiënte tussen die plantgemeenskappe aan te toon. Gevolgtrekkings aangaande bestuurs- en bewaringseenhede is bereik deur die interpretering van die kwantitatiewe data in

samehang met die fitososiologiese resultate en aanbevelings kon daarna gemaak word. Al die plantgemeenskappe van die norietkoppies is aanbeveel as bewaringsgebiede op grond van unieke en hoë biodiversiteit en antropogeniese bedreiging. Die *Eragrostis rigidior-Ziziphus mucronata* en *Acacia caffra-Bothriochloa insculpta* Gemeenskappe in die doringveld het die beste potensiaal vir weiding en blaarvreetkapasiteit getoon maar is ook vir bewaring aanbeveel weens hulle hoë spesiediversiteit en antropogeniese bedreigings. Die hoë landskapsfunksionaliteit, veldtoestand en weikapasiteit van die *Aristida bipartita-Bothriochloa insculpta* Gemeenskap het aangedui dat die rehabilitasie van die oopgroef myngebiede relatief suksesvol was tydens die opnames. Geselekteerde dele van die *Indigofera heterotricha-Aristida bipartita* Gemeenskap is ook vir bewaring aanbeveel en bestuur in die vorm van gekontroleerde en meer effektiewe weidingsstrategieë is aanbeveel vir die res van die doringveld.

**Sleutel-woorde:** Sistematiese bewaring; fitososiologie; biodiversiteit; FIXMOVE; veldtoestand; wei- en blaarvreetkapasiteit; landskapsfunksionaliteit.

## **Acknowledgements**

I would like to offer my sincerest gratitude to the following people for their contributions.

**Encouragement and support:** My parents Mr. A. Lamprecht & Mrs. M. Lamprecht as well as my friends Miss N. Botha & Miss M. Westcott.

**Guidance and advice:** My supervisors Prof. S.S. Cilliers & Prof K.K. Kellner.

**Fieldwork:** Mr. A.R. Götze; Prof. S.S. Cilliers; Prof. S. Siebert; Mrs. S. Kürzweg; Miss L van der Walt & Mr. P. Ayres.

**Species identification:** Mr. A.R. Götze; Prof. S. Siebert & Mrs. S. Kürzweg

**Soil classification:** Mr. P. van Deventer.

**Photography:** Mrs. S. Kürzweg.

**Aid in GIS mapping, multivariate statistic analyses and general technical aspects:** Miss M.J. du Toit, Miss M. la Grange, Mrs. F Jordaan, Miss Y. Els & Mrs. D. Oberholzer.

**Logistic arrangements:** Mr. J. Fick.

## Table of contents

Abstract.....	i
Opsomming.....	iii
Acknowledgements.....	v
List of Tables.....	ix
List of Figures.....	xi
<b>CHAPTER 1: Introduction.....</b>	<b>1</b>
1.1. Introduction.....	1
1.1.1. What is Conservation Biology?.....	1
1.1.2. Conservation Biology and its importance.....	3
1.1.3. Biodiversity conservation in the North West Province.....	4
1.1.4. The role of systematic conservation planning.....	6
1.1.5. Systematic conservation planning in the mining sector.....	7
1.1.6. The systematic approach in practice.....	8
1.1.7. Motivation behind the study of the Impala Platinum mining area.....	10
1.1.8. The importance of vegetation classification as a foundation for conservation and management planning.....	10
1.2. Study objectives.....	12
1.2.1. Main objective.....	12
1.2.2. Specific objectives.....	12
1.2.3. Hypotheses.....	12
1.3. Dissertation structure and content.....	12
1.4. References.....	13
<b>CHAPTER 2: Study area.....</b>	<b>15</b>
2.1. Location and use.....	15
2.2. Physical environment.....	17
2.2.1. Climate.....	17
2.2.2. Geology, Soil, Topography and Land types.....	19
2.3. Vegetation description.....	20
2.4. References.....	25

<b>CHAPTER 3: Vegetation Classification and Description.....</b>	<b>26</b>
3.1. Introduction.....	26
3.2. Materials and Methods.....	27
3.3. Results and Discussion.....	30
3.3.1. Norite koppies.....	30
3.3.1.1. Description of plant communities.....	38
3.3.1.2. Ordinations.....	44
3.3.2. Thornveld.....	49
3.3.2.1. Description of plant communities.....	55
3.3.2.2. Ordinations.....	62
3.3.3. Rehabilitated areas.....	64
3.3.3.1. Description of plant communities.....	67
3.3.3.2. Ordinations.....	73
3.3.4. Vegetation map of the Impala Platinum mining area.....	76
3.3.5. Comparison of the three landscape categories.....	78
3.4. Conclusions.....	79
3.5. References.....	82
<b>CHAPTER 4: Veld condition assessment, grazing and browsing capacity</b>	<b>84</b>
4.1. Introduction.....	84
4.2. Materials and Methods.....	85
4.3. Results and Discussion.....	88
4.3.1. Discussion of veld conditions as well as grazing and browsing capacities of the four plant communities.....	88
4.3.1.1. <i>Indigofera heterotricha-Aristida bipartita</i> Community.....	88
4.3.1.2. <i>Aristida bipartita-Bothriochloa insculpta</i> Community.....	93
4.3.1.3. <i>Eragrostis rigidior-Ziziphus mucronata</i> Community.....	96
4.3.1.4. <i>Acacia caffra-Bothriochloa insculpta</i> Community.....	100
4.3.2. Comparison of veld conditions as well as grazing and browsing capacities of the four plant communities.....	102
4.4. Conclusions.....	123
4.5. References.....	123
<b>CHAPTER 5: Recommendations and Conclusions.....</b>	<b>126</b>
5.1. Recommendations.....	126

5.1.1. Norite koppies.....	126
5.1.2. Thornveld.....	127
5.1.2.1. <i>Eragrostis rigidior-Ziziphus mucronata</i> Community.....	127
5.1.2.2. <i>Acacia caffra-Bothriochloa insculpta</i> Community.....	128
5.1.2.3. <i>Indigofera heterotricha-Aristida bipartita</i> Community.....	129
5.1.2.4. <i>Cyperus sexangularis-Cynodon dactylon</i> Riparian community.....	130
5.1.3. Rehabilitated areas.....	130
5.2. Conclusions.....	131
5.3. References.....	134
<b>APPENDIX.....</b>	<b>136</b>

## List of Tables

<b>Table 3.1</b> Phytosociological table of the Norite koppies.....	31
<b>Table 3.2</b> Phytosociological table of the Thornveld.....	50
<b>Table 3.3</b> Phytosociological table of the Rehabilitated areas.....	65
<b>Table 3.4</b> Red Data List-, Protected- as well as Declared weeds and invader species of the three landscape categories.....	79
<b>Table 4.1</b> Frequencies of the herbaceous species of the four plant communities.....	106
<b>Table 4.2</b> Comparison of the herbaceous layers of the four plant communities.....	111
<b>Table 4.3</b> Comparison of the woody layers of the four plant communities.....	115
<b>Table 4.4</b> Frequencies of the woody species of the four plant communities.....	119
<b>Table A1</b> Species with low constancy and cover for the Norite koppies.....	137
<b>Table A2</b> Species with low constancy and cover for the Thornveld.....	142
<b>Table A3</b> Species with low constancy and cover for the Rehabilitated areas.....	147
<b>Table A4</b> Quantitative species data of the herbaceous layer of the <i>Indigofera heterotricha-Aristida bipartita</i> Community.....	149
<b>Table A5</b> Quantitative ecological data of the herbaceous layer of the <i>Indigofera heterotricha-Aristida bipartita</i> Community.....	151
<b>Table A6</b> Quantitative species data of the woody layer of the <i>Indigofera heterotricha-Aristida bipartita</i> Community.....	152
<b>Table A7</b> Quantitative ecological data of the woody layer of the <i>Indigofera heterotricha-Aristida bipartita</i> Community.....	153
<b>Table A8</b> Quantitative species data of the herbaceous layer of the <i>Aristida bipartita-Bothriochloa insculpta</i> Community.....	154
<b>Table A9</b> Quantitative ecological data of the herbaceous layer of the <i>Aristida bipartita-Bothriochloa insculpta</i> Community.....	155
<b>Table A10</b> Quantitative species data of the woody layer of the <i>Aristida bipartita-Bothriochloa insculpta</i> Community.....	155
<b>Table A11</b> Quantitative ecological data of the woody layer of the <i>Aristida bipartita-Bothriochloa insculpta</i> Community.....	156
<b>Table A12</b> Quantitative species data of the herbaceous layer of the <i>Eragrostis rigidior-Ziziphus mucronata</i> Community.....	157

<b>Table A13</b> Quantitative ecological data of the herbaceous layer of the <i>Eragrostis rigidior-Ziziphus mucronata</i> Community.....	159
<b>Table A14</b> Quantitative species data of the woody layer of the <i>Eragrostis rigidior-Ziziphus mucronata</i> Community.....	159
<b>Table A15</b> Quantitative ecological data of the woody layer of the <i>Eragrostis rigidior-Ziziphus mucronata</i> Community.....	160
<b>Table A16</b> Quantitative species data of the herbaceous layer of the <i>Acacia caffra-Bothriochloa insculpta</i> Community.....	161
<b>Table A17</b> Quantitative ecological data of the herbaceous layer of the <i>Acacia caffra-Bothriochloa insculpta</i> Community.....	162
<b>Table A18</b> Quantitative species data of the woody layer of the <i>Acacia caffra-Bothriochloa insculpta</i> Community.....	162
<b>Table A19</b> Quantitative ecological data of the woody layer of the <i>Acacia caffra-Bothriochloa insculpta</i> Community.....	163
<b>Table A20</b> Statistically significant differences between the grazing capacity and grass biomass of the four plant communities.....	164
<b>Table A21</b> Statistically significant differences between the woody density of the four plant communities.....	164
<b>Table A22</b> Statistically significant differences between the leaf biomass of the woody component of the four plant communities.....	165
<b>Table A23</b> Statistically significant differences between the canopy spread of the woody component of the four plant communities.....	165
<b>Table A24</b> Statistically significant differences between the average height of the woody component of the four plant communities.....	166

## List of Figures

<b>Figure 2.1</b> The location of the Impala Platinum mining area in the North-West Province and Savanna biome of South Africa.....	16
<b>Figure 2.2</b> Average minimum and maximum daily temperatures of the Impala Platinum mining area of each month for the years 2003-2009.....	18
<b>Figure 2.3</b> Average monthly precipitation as well as minimum and maximum relative daily humidity of the Impala Platinum mining area of each month for the years 2003-2009.....	18
<b>Figure 2.4</b> The vegetation types (Mucina & Rutherford, 2006) and topography of the Impala Platinum mining area.....	22
<b>Figure 3.1</b> Map showing the vegetation types (Mucina & Rutherford, 2006) and Braun Blanquet sampling points of the three identified categories inside the Impala Platinum mining area.....	29
<b>Figure 3.2</b> The <i>Microchloa caffra-Sporobolus stapfianus</i> Community. GPS: lat 25°35'30.0"S, long 26°19'16.7"E. Notice the dome shaped outcrops of sheetrock and the little amount of soil present. This community is dominated by low growing grass - and forbs species.....	38
<b>Figure 3.3</b> An illustration of highly fragmented outcrop areas in this community. GPS: lat 25°32'44.5"S, long 27°18'27.0"E. Notice the high degree of rock fragmentation on the surface and grass species such as <i>Hyperthelia dissoluta</i> and <i>Schizachyrium sanguineum</i> exclusively utilizing such micro-habitats.....	39
<b>Figure 3.4</b> The <i>Pappea capensis-Heteropogon contortus</i> Community. GPS: lat 25°35'56.2"S, long 27°19'07.7"E. The community does not have differential species but is rather characterised by the absence of certain species found on the south facing slopes. Notice the low percentage soil surface rockiness of most of the slope compared to the high rockiness of the <i>Ficus abutilifolia-Croton gratissimus</i> Community which is encircled in the photograph.....	40
<b>Figure 3.5</b> The <i>Themeda triandra-Acacia caffra</i> Sub-community. GPS: lat 25°33'02.4"S, long 27°18'58.4"E. Notice the low percentage rock cover and the dense woody layer. The dominant species <i>Acacia caffra</i> can be seen in the photograph.....	42

<b>Figure 3.6</b> The <i>Ficus burkeii</i> - <i>Dombeya rotundifolia</i> Sub-community. GPS: lat 25°32'15.8"S, long 27°17'38.7"E. Notice the very high percentage rock cover which is mostly in the form of large boulders. The differential species <i>Ficus burkeii</i> as well as the dominant species <i>Dombeya rotundifolia</i> are present in the photograph.....	43
<b>Figure 3.7</b> The <i>Ficus abutilifolia</i> - <i>Croton gratissimus</i> Community. GPS: lat 25°34'13.5"S, long 27°18'08.5"E. Notice the steep rocky cliffs mainly consisting of large boulders. <i>Ficus abutilifolia</i> , which is a differential species, is present in this photograph.....	44
<b>Figure 3.8</b> Correspondence Analysis (CA) ordination bi-plot showing the correlations in species composition between the plant communities of the norite koppies and indicating the aspect as the environmental variable influencing plant community structure and composition.....	45
<b>Figure 3.9</b> Correspondence Analysis (CA) ordination bi-plot showing the correlations in species composition between the two sub-communities found on south facing slopes and indicating the percentage soil surface rockiness as the environmental variable influencing plant community structure and composition.....	47
<b>Figure 3.10</b> Correspondence Analysis (CA) ordination bi-plot showing the correlations in species composition between the two plant communities found on north facing slopes and indicating the percentage soil surface rockiness as the environmental variable influencing plant community structure and composition.....	48
<b>Figure 3.11</b> The <i>Indigofera heterotricha</i> - <i>Aristida bipartita</i> Community. GPS: lat 25°25'48.5"S, long 27°10'07.9"E. Notice the typical savanna physiognomy. The area is dominated by <i>Acacia</i> species and the soil is classified as Arcadia. The dominant grass and woody species, <i>Aristida bipartita</i> and <i>Acacia tortilis</i> can be seen in the photograph...	56
<b>Figure 3.12</b> The <i>Acacia caffra</i> - <i>Bothriochloa insculpta</i> Community. GPS: lat 25°32'55.4"S, long 27°18'44.5"E. Notice the dominance of the woody species <i>Acacia caffra</i> . The grass species, <i>Bothriochloa insculpta</i> can also be seen dominating the herbaceous layer in the photograph.....	57
<b>Figure 3.13</b> The <i>Eragrostis rigidior</i> - <i>Ziziphus mucronata</i> Community. GPS: lat 25°33'57.6"S, long 27°12'31.0"E. Notice the dense woody layer that includes broad - and fine leaved species. The red-brown Shortlands and Oakleaf soils on which this community is found is also seen in the photograph.....	58
<b>Figure 3.14</b> The <i>Searsia lancea</i> - <i>Cyperus sexangularis</i> Riparian sub-community. GPS: lat 25°31'52.0"S, long 27°10'30.4"E. Notice the well developed woody stratum consisting of tall trees on the banks of the river as well as the very tall grass species present. The differential species <i>Searsia lancea</i> is also present in the photograph.....	60

<b>Figure 3.15</b> The <i>Paspalum distichum-Cyperus sexangularis</i> Riparian sub-community. GPS: lat 25°26'19.1"S, 27°10'45.6"E. Notice the absence of a woody layer which distinguishes it from sub-community 4.1. Also notice the dominance of the forb <i>Cyperus sexangularis</i> along the banks.....	61
<b>Figure 3.16</b> Detrended Correspondence Analysis (DCA) ordination bi-plot showing the correlations in species composition between the plant communities of the thornveld and indicating the soil type as the environmental variable influencing plant community structure and composition.....	62
<b>Figure 3.17</b> The <i>Acacia galpinii-Chloris gayana</i> Community. GPS: lat 25°31'31.1"S, long 27°11'49.2"E. Notice the dominant grass layer with a well developed woody component consisting mainly of the differential species <i>Acacia galpinii</i> and <i>Faidherbia albida</i> which do not occur in the surrounding natural areas.....	67
<b>Figure 3.18</b> The <i>Pseudognaphalium luteo-album-Arundo donax</i> Sub-community. GPS: lat 25°30'41.2"S, long 27°13'23.4"E. Notice the total dominance of the grass species, <i>Arundo donax</i> which is listed as a category 1 declared weed and invader. This species reaches up to 5m in height in many parts of the sub-community.....	69
<b>Figure 3.19</b> The <i>Dodonaea angustifolia-Cenchrus ciliaris</i> Sub-community. GPS: lat 25°31'49.0"S, long 27°14'47.5"E. Notice the significantly lower growing grass species than in sub-community 2.1. The dominant species, the grass <i>Cenchrus ciliaris</i> can be seen in the photograph.....	70
<b>Figure 3.20</b> The <i>Imperata cylindrica-Tamarix ramosissima</i> Sub-community. GPS: lat 25°31'00.2"S, long 27°11'48.6"E. Notice the large areas of bare soil on the surface. The differential grass species, <i>Imperata cylindrica</i> can be seen in the photograph and the dominant species, the shrub <i>Tamarix ramosissima</i> is also present in the background. Also notice the presence of the problematic encroachment species, <i>Seriphium plumosum</i> .....	71
<b>Figure 3.21</b> The <i>Aristida bipartita-Bothriochloa insculpta</i> Community. GPS: lat 25°31'12.4"S, long 27°10'11.3"E. Notice the lack of a well established woody component although bush encroachment is taking place mostly in the form of <i>Acacia</i> species.....	72
<b>Figure 3.22</b> Detrended Correspondence Analysis (DCA) ordination bi-plot showing the correlations in species composition between the communities of the rehabilitated areas.....	74
<b>Figure 3.23</b> Correspondence Analysis (CA) ordination bi-plot showing the correlation in species composition between the sub-communities of Community 2.....	75

<b>Figure 3.24</b> Vegetation map of the Impala Platinum mining area.....	76
<b>Figure 3.25</b> A comparison of plant community characteristics of the three landscape categories.....	78
<b>Figure 4.1</b> Vegetation map (from Chapter 3) and FIXMOVE sampling points inside the Impala Platinum mining area.....	87
<b>Figure 4.2</b> Plot number 21. GPS: lat 25°35'08.6"S, long 27°19'32.4"E. This plot is located in the south of the Impala Platinum mining area and serves as an example of areas close to residential settlements which are intensely exploited for grazing. Notice the low herbaceous biomass and bush encroachment mostly by <i>Acacia karroo</i> .....	90
<b>Figure 4.3</b> Plot number 22. GPS: lat 25°32'37.0"S, long 27°14'28.7"E. This plot has the highest grazing capacity in the <i>Indigofera heterotricha-Aristida bipartita</i> Community. Notice the high herbaceous biomass and the lower density of the woody component compared to Figure 4.2.....	91
<b>Figure 4.4</b> Plot number 23. GPS: lat 25°33'57.8"S, long 27°12'49.5"E. Notice the dominance of the annual grass species <i>Panicum volutans</i> as well as the forbs <i>Cirsium vulgare</i> and <i>Tagetes minuta</i> . All these species are mostly found on newly disturbed areas.....	94
<b>Figure 4.5</b> Plot number 15. GPS: lat 25°29'14.3"S, long 27°09'20.3"E. Notice the high herbaceous biomass and the presence of the dominant perennial grass species <i>Bothriochloa insculpta</i> . Species present are mostly sub-climax species which indicate that ecological succession has progressed more in this plot than in plot number 23.....	94
<b>Figure 4.6</b> Plot number 9. GPS: lat 25°28'55.1"S, long 27°11'41.6"E. Notice the low herbaceous basal cover as well as the large sizes and high frequency of bare patches...	99
<b>Figure 4.7</b> Principle Component Analysis (PCA) ordination bi-plot indicating the correlation between the herbaceous species composition of the sampling plots in terms of ecological status of the species for the four plant communities. Certain plots are numbered in the ordination and will be referred to in the text.....	104
<b>Figure 4.8</b> Species frequencies for the different ecological status categories of the (a) <i>Indigofera heterotricha-Aristida bipartita</i> Community (3.1.1); (b) <i>Aristida bipartita-Bothriochloa insculpta</i> Community (3.1.2); (c) <i>Eragrostis rigidior-Ziziphus mucronata</i> Community (3.1.3) and (d) <i>Acacia caffra-Bothriochloa insculpta</i> Community (3.1.4).....	105
<b>Figure 4.9</b> Grazing capacities (ha/LSU) of the four plant communities.....	110
<b>Figure 4.10</b> Herbaceous biomass (kg/ha) and grazing value of the four plant communities.....	110

<b>Figure 4.11</b> Average stability, infiltration and nutrient cycling indices of the four plant communities.....	113
<b>Figure 4.12</b> Woody density (plants/ha) of the four plant communities in the strata under and above 2m.....	115
<b>Figure 4.13</b> Leaf biomass (kg/ha) of the woody component of the four plant communities in the strata under and above 2m.....	117
<b>Figure 4.14</b> Canopy spread (m <sup>2</sup> /ha) of the woody component of the four plant communities in the strata under and above 2m.....	117
<b>Figure 4.15</b> Average height of the woody component of the four plant communities in the strata under and above 2m.....	118
<b>Figure 4.16</b> Correspondence Analysis (CA) ordination bi-plot indicating correlations in species composition, veld condition, grazing capacities and woody densities between the four plant communities. Certain plots are numbered in the ordination and will be referred to in the text.....	121

# CHAPTER 1

## Introduction

### 1.1. Introduction

*“The successful survival of the human race depends on the planet’s sufficient biodiversity as a major resource.” (Driver et. al., 2003)*

Earth is currently in a period of experiencing unprecedented loss in biodiversity at the hand of humanity. Fragmentation, transformation and loss of natural habitat due to anthropogenic influences are immense and ever increasing. Ecosystems such as rainforests, coral reefs and coastal wetlands and their species that have taken millions of years to develop are being destroyed and physically decreased in size at rapid rates as a result of human activities (Primack, 2008). The fact is thus that every natural ecosystem on the planet has been altered by humanity, some even to the point of collapse (Meffe & Carroll, 1997).

Threats to natural biodiversity are accelerating due to ever increasing human populations and our demands for space and resources (Primack, 2008). If these needs are simply blindly fulfilled, without considering the impact it has on the environment and on the sustainability of resources, we may very well permanently exhaust them. This could ultimately even lead to the extinction of the human race. The question that arises now is: How do we protect and maintain biodiversity while simultaneously managing to provide in the demands of current and future human populations? The answer to this question lies in the discipline of Conservation Biology.

#### 1.1.1. What is Conservation Biology?

Conservation Biology is the integrated, multidisciplinary, applied scientific field which is occupied with maintaining and preserving the world’s biological diversity to ensure its continued existence (Primack, 2008; Hunter, 2002; Spellerberg, 2000). According to Primack (2008), Conservation Biology has three main goals namely to document the full range of biological diversity on earth; to investigate human impact on species, communities and ecosystems and to develop practical approaches to prevent the extinction of species, maintain genetic diversity within species as well as protect and restore biological communities and their associated ecosystem function.

A common realization arose in the 1980's that isolated, traditionally applied disciplines of resource management such as forestry, agriculture and wildlife management were not comprehensive enough to effectively aid in the prevention of increased biodiversity loss (Primack, 2008; Meffe & Carroll, 1997). The idealistic view of unconditional biodiversity protection was unrealistic and more reasonable and practically applicable solutions for balancing biodiversity conservation and human requirements of resources needed to be found. A scientific discipline had to be developed which not only focused on theoretical aspects from certain fields but incorporated all sectors of society into conservation processes. This would provide holistic views of situations and more efficient solutions could be achieved. The modern discipline of Conservation Biology was therefore born.

Conservation Biology focuses on uniting traditionally academic disciplines with applied fields in order to achieve efficient, practical solutions (Meffe & Carroll, 1997). It represents a synthesis of many basic sciences that provide principles and new approaches for applied fields of resource management. It also recognizes the contributions that need to be made from non-biological sectors such as social sciences, economics and political sciences (Hunter, 2002; Meffe & Carroll, 1997) and takes them into account because ultimately the solutions achieved for biodiversity related problems will not be feasible if negative effects are offered to human society. Environmental law provides foundations on which governmental protection of endangered and critical species and habitats are based; economists analyze economic values of biodiversity in order to support conservation arguments and decisions; social sciences monitor impacts of conservation on local communities and provide methods to attempt to include them in protecting the environment; even by incorporating Conservation Biology ideals into educational programs, it can shape the way future conservation is implemented (Primack, 2008; Hunter, 2002). Although the science of Ecology still provides the most essential information of all these disciplines (Spellerberg, 2000), Conservation Biology is truly a multidisciplinary science.

Ecosystems and species do not function in isolation, in stead they form integrated and interdependent units and every individual component plays an integral part in order to ensure the continuous successful survival of such a biological system (Begon *et. al.*, 2006). Because of the integrated dependencies between ecological communities and species, the protection and preservation of only certain species is inadequate. Ecological systems need to be protected holistically in order to ensure ongoing functionality and by doing so, species or ecological communities of interest will be indirectly preserved. Conservation Biology acknowledges this fact and differs from other applied disciplines in its emphasis on long term

preservation of entire biological systems rather than simply focusing on species of interest or value (Primack, 2008).

### **1.1.2. Conservation Biology and its importance**

The importance of conserving our natural resources and biodiversity is undeniable. The value of biodiversity and therefore the importance of Conservation Biology can be categorized into two groups according to Primack (2008):

- Direct economic values are considered as the most important benefit provided to societies by their natural resources. Great economic gain is achieved from identifying the value and usability of natural resources and then harvesting and trading with these products. Direct economic values are further divided into two categories namely consumptive- and productive use values. Consumptive use values are assigned to resources and products harvested from the natural environment which are mainly consumed locally by communities. These products therefore do not provide commercial gain and are not traded within the national or international marketplace but rather provide to the basic needs of local people. Productive use values are assigned to products harvested from the environment and sold commercially on national and international markets for financial gain. Much of the modern global capital and economic profit is gained from the market which has developed for trading with such resources. In fact, trading with natural resources and their by-products has become the backbone of global business. Therefore, by conserving natural biodiversity in the form of ecosystems, the continuous functioning of global economics as we know it today can be guaranteed.
- Indirect or non-consumptive use values are assigned to aspects of biodiversity that can provide both present and future economic benefits without being harvested or destroyed during use. These include ecosystem services and environmental processes such as the maintenance of good natural water and soil quality and regulation of regional and global climates. The plant and animal communities, on which we are dependant for many of our natural resources, depend on services such as high soil and water quality in order to stay healthy and functional. They also play important roles in moderating climatic conditions. We are therefore indirectly dependant on such ecosystem processes and services to keep our resources sustainable. If natural ecosystems are not available to provide such benefits, substitute sources need to be found, often at great expense, in order to keep economies from collapsing. Ecosystems also provide recreational services such as camping, hiking, wild game watching and other ecotourism activities. Such non-consumptive activities provide people with important aesthetic services and engagement into these activities also produce indirect economic benefits without degrading the resources.

It is therefore evident from this discussion that the main objective of Conservation Biology is to encourage sustainable development through which present and future global human demands/needs are satisfactorily met while not discrediting the viability of natural resources or decreasing biodiversity (Primack, 2008; Meffe & Carroll, 1997).

### **1.1.3. Biodiversity conservation in the North West Province**

The North West Province has no official Conservation Plan but biodiversity assessments which will form the basis for the development of a Conservation Plan for the province are currently being conducted (North West Department of Agriculture, Conservation and Environment, 2010). This collaborative project between the North West Department of Agriculture, Conservation and Environment (NWDACE) and the South African National Biodiversity Institute (SANBI) is intended to be completed within the next two years and implemented soon thereafter. It is envisaged that the Conservation Plan will form an essential part of governing and steering development in the province towards a position where no more loss of or damage to intact and conservation worthy habitats will take place.

According to the Environmental Outlook report of the North West Province (North West Department of Agriculture, Conservation and Environment, 2010), approximately 283 308 ha is currently being formally protected within the province which constitutes only 2.4% of the surface area of the province. This is significantly less than the 10% for each vegetation type recommended by the 1992 UNCED Convention (North West Department of Agriculture, Conservation and Environment, 2010). Formal conservation in the province is not restricted to national parks and provincial nature reserves but also includes private game reserves and protected natural environments. The Pilanesberg and Borakalalo National Parks are the only two National Parks in the North West Province and they contain important areas of biodiversity. They do however not contain all forms of vegetation types present in the province and according to Mucina & Rutherford (2006), most vegetation types in the North West Province are inadequately conserved. Other important nature reserves within the province linked to conservation include the Madikwe Game Reserve; Baberspan Bird Sanctuary; Bloemhof Dam Nature Reserve; Botsalano Game Reserve; Molopo Game Reserve; Mafikeng Game Reserve; SA Lombard Nature Reserve; Vaalkop Dam Nature Reserve; Boskop Dam Nature Reserve; Wolwespruit Dam Nature Reserve; Molemane Eye Nature Reserve (North West Department of Agriculture, Conservation and Environment, 2010). The importance of conservation outside officially designated areas must, however, be realized if the intention of adequately and sustainably conserving our biodiversity in the province is to be reached. Areas currently under non-state conservation, in South Africa,

cover more than twice the area of conservation areas that are state-controlled (Scholes, 2010). Such unofficial areas may include privately-owned as well as communally-owned areas. The degree of protection in such unofficial areas, however, varies considerably depending on their primary land-use. Conservation, for example, tends to be a major priority in private nature reserves whereas land fragments set aside by other types of landowners for protection of certain ecological aspects tends to deliver a more partial level of conservation (Scholes, 2010). Whatever the case, informal conservation in such areas forms a critical component of successfully managing biodiversity on a local, national and global scale in a sustainable way.

Scholes (2010) lists three main reasons for conserving biodiversity outside the official state-owned system:

- By conserving biodiversity outside officially designated areas, a significantly larger fraction of land surface can be managed sustainably than would be possible if conservation was exclusively state-run. The possibility of increasing the size of official conservation areas in South Africa is low because of more than 85% of land being privately or communally-owned. Acquiring more land for conservation purposes is, therefore, an expensive process for the state. Although most state-run conservation areas exhibit economic productiveness in terms of tourism, the productiveness of private land in terms of job creation and food production also decreases once it is converted to formal conservation areas because of the restrictions regarding land-use. If we, therefore, purely rely on official conservation of areas owned by the state, the amount of biodiversity conservation will be inadequate and the distribution will be limited to isolated and far spread fragments of land.
- In many instances, the agricultural potential of privately owned land is low for climatic, edaphic or economic reasons. The economic potential of informally conserving land for ecotourism or recreational activities such as hunting, which could be managed to have virtually no negative impacts on ecosystems, needs to be realized in such cases. By incorporating such land-uses, economic gain can be stimulated while at the same time informally contributing to protection of biodiversity. Areas where agriculture such as grazing is the primary land-use, can also still be compatible with biodiversity protection. Many forms of biota such as birds, reptiles, small mammals and plants may be virtually unaffected in such areas if key habitats are protected and adequate grazing strategies are followed. Informal nature conservation can, therefore, often provide potential financial advantages.
- By increasing the amount of informally protected land, more conserved landscapes can be connected. This is a vital necessity for the successful survival of all forms of biodiversity in an ever changing environment. For plants and animals to adapt to changing climates, they need

to be able to migrate through the landscape. The development of formal migrating corridors for biota is not feasible but the connection of large formal areas by informal conservation corridors provides a more effective option.

#### **1.1.4. The role of systematic conservation planning**

*“There is a need for a clear and practical strategy for biodiversity conservation which can guide decision-makers on national and international levels.”* (Venevsky & Venevskaia, 2005)

The importance of biodiversity conservation and the inadequacy thereof in the North West Province is realized after the former discussion but how exactly to proceed in attempting this challenge is another problem on its own. Conservation can not take place indefinitely because of limited resources such as finances, time and available land. The most effective strategies, therefore, need to be followed in order to focus conservation on areas that are of greatest importance for total biodiversity maintenance.

The systematic approach to conservation provides a useful tool for identifying priority biodiversity areas and for planning future land-use (Driver *et. al.*, 2003). It is a practically orientated approach which aims at identifying and setting quantitative and spatially explicit conservation targets and strategies which can be implemented in practice (Driver *et. al.*, 2003). It involves objective determination of sufficient sizes and locations for conservation sites based on quantitatively gathered biodiversity data and scientific knowledge. The focus is not just on the theoretical assessment of the ecology of areas but rather on developing realistically feasible solutions for biodiversity issues which will satisfy all the major sectors of society. The ecology of natural areas and its requirements can therefore not be the only aspect considered. The impacts of conservation strategies on the local economic and social spheres also need to be taken into account. Negative impacts on these sectors need to be prevented as far as possible because local communities and companies form part of conservation strategies as stakeholders and if they are disadvantaged during conservation processes, the project will lose their cooperation. This will pose major problems for the potential success of conservation strategies. Therefore, because of its practical but still objective and data-driven nature, the systematic approach to conservation and recommendations made from it are implementable in practice while also being scientifically defensible (Driver *et. al.*, 2003; Margules & Pressey, 2000).

According to Pierce *et. al.* (2005); Driver *et. al.* (2003) and Margules & Pressey (2000), the systematic approach to biodiversity conservation is initially based on two important principles: At least one representative sample of all habitats and species present in an area

needs to be conserved. This is referred to as the *principle of representation*. It is however often not enough to simply conserve habitats. If we wish for biodiversity and ecosystems to persist, the ecological and evolutionary processes that drive their functionality also need to be protected and this is termed the *principle of persistence*. The question that inevitably arises is: How much needs to be conserved in order to ensure the continued successful existence and functionality of an ecosystem? According to Driver *et. al.* (2003), the answer lies in the maintenance of living landscapes (a living landscape is defined as a landscape which sustainably supports life of all forms over time). Conservation should therefore focus on identifying areas of land that are crucial for ensuring living landscapes and aim at protecting such priority areas.

Conservation is, however, often associated with formal reserves and places that are fenced off where the locations of such reserves have been driven by factors that have little to do with optimal biodiversity conservation of important areas. Protected areas are often located in areas where land is cheap or where scenery is spectacular or in areas to conserve a single species (Maze *et. al.*, 2004). Although such areas are important, conservation in modern times can not merely be restricted to formal procedures. Modern conservation is becoming increasingly relevant to multiple sectors of the landscape, from urban development to agriculture and mining to pristine wilderness (Maze *et. al.*, 2004). It is therefore vital to incorporate these sectors into conservation actions rather than attempting biodiversity conservation only in a formal manner distinct from other parts of society.

#### **1.1.5. Systematic conservation planning in the mining sector**

*“Loss of natural habitats is the single biggest cause of biodiversity loss in South Africa and the rest of the world... Certain types of mining result in irreversible loss of natural habitat across large areas.”* (Maze *et. al.*, 2004)

The applicability of biodiversity conservation to the mining sector and, more importantly, to the current study is of importance. South Africa has the third highest biodiversity in the world (Germishuizen *et. al.*, 2006) and this presents great challenges for land-use planning and development. Frequent clashes between the mining and biodiversity sectors occur and regulation strategies need to be created to find midways between the importance of development and economic advancement of the mining sector and biodiversity conservation. Systematic conservation planning is important to the mining sector for a number of reasons. Firstly, the mining sector is governed by legislation which obligates it to take biodiversity and its conservation into account during operations. Key legislation includes the Mineral and

Petroleum Resources Development Act 28 of 2002 (South Africa, 2002) and the National Environmental Management Act 107 of 1998 (South Africa, 1998). The former importantly states that environmental impact assessments (EIA's) are mandatory when applying for mining rights to ensure that operations will not result in unacceptable pollution, ecological degradation or damage to the environment. Management plans are also compulsory to rehabilitate and manage the impacts on mining areas. It also states that environmental management principles as stated in the National Environmental Management Act 107 of 1998 (South Africa, 1998) apply to all mining operations. This includes avoiding, or if not possible, minimizing disturbance to ecosystems and loss of biodiversity due to mining operations. Sensitive and vulnerable ecosystems also require specific attention during planning and management procedures, according to this act, especially where they are pressured by development. The systematic approach is therefore relevant in adhering to these legislations as it provides clear and reliable information on the location of biodiversity priority areas which can help mining companies in their decision-making to avoid or reduce negative impacts (Maze *et. al.*, 2004). By developing practically implementable strategies and action plans for their mining areas based on the systematic approach, these companies are also given the opportunity to become actively involved in conservation processes together with other land-use sectors such as the conservation sector (Maze *et. al.*, 2004). Such participation can encourage other sectors to also accept their responsibilities towards the conservation of biodiversity in their specific areas.

#### **1.1.6. The systematic approach in practice**

A good example of how the systematic approach to conservation planning has been used in South Africa is the Succulent Karroo Ecosystem Program (SKEP) ([www.skep.org.za](http://www.skep.org.za)). The Succulent Karroo biome contains more than 6300 plant species and many other forms of biota of which over 40% is endemic to South Africa (Mucina & Rutherford, 2006). The Succulent Karroo is therefore recognized as one of only 25 international biodiversity hotspots. Only 3.5% of this biome's total area is, however, protected (Mucina & Rutherford, 2006), which is inadequate for such an ecologically important region. Small and large scale mining as well as irrigated agriculture and over-grazing have transformed significant amounts of this landscape and because of these impacts the need for the establishment of a regional conservation plan was identified. SKEP followed a local consultative and inclusive approach together with intense scientific research. More than 60 scientific experts and 400 stakeholders took part in this project ([www.skep.org.za](http://www.skep.org.za)). Priority biodiversity areas were quantitatively and explicitly identified and actions were recommended to focus conservation and sustainable development on those areas. Local stakeholders were included in the

developmental stages of the project in order to acknowledge and consider their requirements and objectives. By involving stakeholders from different sectors of society, consensus could be reached and a holistic approach towards conservation and sustainable land-use could be created. The stakeholders would not only play passive roles by reducing their own impacts but would actively contribute to conservation and sustainable land-use in various ways. These recommendations surrounding the conservation plan were readily accepted by the stakeholders because of the defensible and considerate nature of the systematic approach.

The role of the systematic approach to conservation was successfully applied to its full potential in the case of SKEP and produced the desired positive results. This proves the value of a practically orientated approach in being much more realistic and comprehensive.

Margules and Pressey (2000) list six important stages of developing a systematic conservation action plan which correspond well with the framework of the SKEP project. The process is not unidirectional and many feedbacks and altering of decisions will take place as the process develops and new obstacles are reached. The six stages are:

- The data compilation and mapping of biodiversity of a planning region.
- The identification of conservation goals for the planning region.
- The review of the potential existence of similar conservation areas.
- The selection of additional conservation areas to fill the possible gaps.
- The implementation of conservation actions.
- The maintenance of the predetermined standards set for the conservation areas.

A conservation plan is worth little if it doesn't provide a basis for implementation strategies. Driver *et. al.* (2003) also lists six aspects to consider when developing an operational framework for a conservation plan:

- Take into account for whom the project is being conducted and exactly what objectives/ goals they intend to achieve with the project.
- Pay attention to the design of the project. The design is unique for every project and is determined by various factors such as the aims of the conservation plan as well as the budget available for the project. Time must be invested into the planning of all major aspects surrounding the project.
- Implementing agencies must form part of the conservation assessment team. Conservation agencies from the public sector are usually good implementation agencies to consider. Such agencies can, however, also include municipalities, community based organizations, NGO's or even private companies. This all depends on the nature and end goals of the project.

These agencies are an extremely important component during the conservation assessment processes and they should either lead or form part of the conservation teams.

- Stakeholders need to be involved in the planning processes. When this is achieved, their requirements and interests in a project can be addressed and considered.
- Conservation assessment should be conducted according to the principles of systematic conservation planning. This will provide explicit, scientifically defensible data on priority biodiversity areas which will make projects more efficient than attempting to focus the conservation on entire landscapes (which is not necessary or possible in most cases).
- The results obtained from the conservation assessment need to be interpreted for a wide audience which will include implementing agencies and stakeholders in order for them to understand what exactly the results imply. The planned outcomes then need to be mainstreamed into the company's and other stakeholders' daily policies and activities to actively include them in the conservation processes.

#### **1.1.7. Motivation behind the study of the Impala Platinum mining area**

The Implats Group, of which the Impala Platinum operation outside Rustenburg forms a part, adopted a revised environmental policy in November 2008 which showed an increased focus on environmental matters from the previous integrated Health, Safety and Environment Policy ([www.implats.co.za](http://www.implats.co.za)). This new policy included the development of a Biodiversity Action Plan for the leased mining area of Impala Platinum, which was to commence in the beginning of 2009 and be completed and fully implemented by 2011 ([www.implats.co.za](http://www.implats.co.za)). The program was intended to identify any threatened species and habitats and was designated to protect and restore any important biological systems within the mining area as well as aid in determining land-use potential ([www.implats.co.za](http://www.implats.co.za)). A biodiversity study, therefore, needed to be conducted in the mining area in order to provide sufficient data for the establishment of the Action Plan. A study of the vegetation diversity in the Impala Platinum mining area, which would provide important initial information for further biodiversity and potential land-use studies, was therefore launched in 2009.

#### **1.1.8. The importance of vegetation classification as a foundation for conservation and management planning**

Vegetation and its functionality form the basis of all ecological systems on the planet. It provides the habitat and the basic resources on which life-forms of all trophic levels directly or indirectly depend (Kent & Coker, 2000). The flow of energy through systems is governed by the type and abundance of the vegetation and this flow is the characteristic that influences a system's whole biodiversity composition and abundances. Dengler *et. al.* (2008) stated that

the conservation of species depends on the maintenance of their habitats. Knowledge of the vegetation in an area provides baseline information about the habitat types which is mostly needed to conduct studies on the fauna and other life-forms (Kent & Coker, 2000). Kent & Coker (2000) further describe a large variety of applied and academic uses for vegetation studies from which it is, therefore, reasonable to deduce that vegetation studies should form the basis of any ecological biodiversity study.

Phytosociology provides the most comprehensive and consistent methodology for vegetation classification (Dengler *et. al.*, 2008). The principle goal of phytosociology is to classify and functionally characterize vegetation types/plant communities based on total floristic composition. The influences of environmental factors on distributions of such vegetation types can also be determined and by linking environmental variables to species composition data, predictive vegetation distribution patterns or models can be developed. This acknowledges an important attribute of phytosociology, especially for the current study namely, that for conservation and management to be successfully implemented in practice, we cannot simply rely on isolated biodiversity information. By combining phytosociological studies with geographic information systems (GIS's), spatially explicit data, which is pivotal for environmental management and conservation decision making processes, can be provided (Dengler *et. al.*, 2008). Phytosociology can therefore provide a spatial dimension without which the implementation of environmental conservation strategies cannot take place.

As has been discussed the systematic approach to conservation is practically orientated and focuses on the application of management and conservation strategies in an area (Driver *et. al.*, 2003). By collecting and illustrating spatially explicit vegetation data of areas, the backbone on which implementation actions are based, is provided. This explicit plant community data can be used to describe habitat types which can, in turn, be used as a reference for the conduction of further studies on other forms of biota. In the current study, the spatially explicit phytosociological information, conveyed in a vegetation map, could be used for further biodiversity and land-use potential studies in the Impala Platinum mining area. A collaboration of biodiversity data based on the spatially explicit vegetation data can provide useful conclusions from which management and conservation recommendations can be made.

## **1.2. Study objectives**

### **1.2.1. Main objective**

- Provide spatially explicit plant diversity information as well as potential land-use and management recommendations which will aid in the establishment of an official conservation plan for the Impala Platinum mining area.

### **1.2.2. Specific objectives**

- Identify, describe and spatially illustrate all the plant communities present in the Impala Platinum mining area.
- Determine possible environmental variables influencing plant community structure and species composition.
- Determine veld condition, grazing and browsing capacities and landscape functionality of selected plant communities in the Impala Platinum mining area.

### **1.2.3. Hypotheses**

- Environmental factors such as topography, aspect, rockiness and soil type will play possible roles in regulating the distribution of plant communities in the Impala Platinum mining area.
- The veld conditions will be better and grazing and browsing capacities and landscape functionality will be higher in natural areas than in rehabilitated areas.

## **1.3. Dissertation structure and content**

Chapter 1 gives an introduction into the world of biodiversity conservation and an overview of the importance of conservation and obstacles to be overcome, especially in the mining sector. It provides the rationale behind the study at Impala Platinum as well as the objectives and hypotheses.

Chapter 2 provides a description of the study area in terms of its location and use; its physical environment and previous vegetation classification done in the area.

Chapter 3 conveys the results of the phytosociological study conducted in the Impala Platinum mining area. It provides an in depth classification and description of the plant communities present in the study area as well as environmental variables influencing them.

Chapter 4 conveys the results of the quantitative study conducted in the Impala Platinum mining area. It provides discussions and comparisons of the herbaceous and woody layers of

selected plant communities in terms of their veld conditions, ecological status of species, grazing and browsing capacities and landscape functionality.

Chapter 5 concludes the study and provides recommendations towards future land-use potential, management and conservation of the Impala Platinum mining area.

The Appendix includes additional data tables mentioned and discussed in the text as well as examples of the data sheets used during the study.

## 1.4. References

- Begon, M., Townsend, C.R., Harper, J.L. 2006.** Ecology: From Individuals to Ecosystems. 4<sup>th</sup> Ed. Blackwell Publishing.
- Dengler, J., Chytry, M. & Ewald, J. 2008.** Phytosociology. (*In* Encyclopedia of Ecology, 4. p. 2767-2779.)
- Driver, A., Cowling, R.M. & Maze, K. 2003.** Planning for living landscapes: Perspectives and lessons from South Africa. Botanical Society of South Africa, Cape Town.
- Germishuizen, G., Meyer, N.L., Steenkamp, Y. & Keith, M. (eds.) 2006.** A checklist of South African plants. Southern African Botanical Diversity Network Report No. 41. SABONET, Pretoria.
- Hunter, M.L.JR. 2002.** Fundamentals of Conservation Biology. 2<sup>nd</sup> Ed. Blackwell Science Inc.
- Kent, M. & Coker, P. 2000.** Vegetation description and analysis: A practical approach. John Wiley & Sons, New York.
- Margules, C.R. & Pressey, R.L. 2000.** Systematic conservation planning. *Nature*, 405: 243-253.
- Maze, K., Driver, A. & Brownlie, S. 2004.** Mining and Biodiversity in South Africa: A discussion paper. [Web:] <http://www.foresttrends.org/biodiversityoffsetprogram>. [Date of use: 17 November 2008]
- Meffe, G.K. & Carroll, C.R. 1997.** Principles of Conservation Biology. 2<sup>nd</sup> Ed. Sinauer Associates Inc. Publishers.
- Mucina, L. & Rutherford, M.C. (eds.) 2006.** The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.
- North West Department of Agriculture, Conservation and Environment. 2010.** North West Province, Environmental Outlook: A report on the state of the environment 2008.

[Web:] [http://www.nwpg.gov.za/Agriculture/NW\\_ENVIRONMENTAL\\_OUTLOOK/index.asp](http://www.nwpg.gov.za/Agriculture/NW_ENVIRONMENTAL_OUTLOOK/index.asp).

[Date of use: 11 February 2010.]

**Pierce, S.M., Cowling, R.M., Knight, A.T., Lombard, A.T., Rouget, M. & Wolf, T. 2005.** Systematic conservation planning products for land-use planning: Interpretation for implementation. *Journal of Biological Conservation*, 125: 441-458.

**Primack, R.B. 2008.** A Primer of Conservation Biology. 4<sup>th</sup> Ed. Sinauer Associates Inc. Publishers.

**Scholes, B. 2010.** Biodiversity conservation outside state protected areas. [Web:] <http://www.nacsa.org.za/GCApdfBobScholesPaper.pdf>. [Date of use: 24 November 2010.]

**South Africa, 1998.** National Environmental Management Act. 1540:401, 27 November. Pretoria: Government Printer.

**South Africa, 2002.** Mineral and Petroleum Resources Development Act. No 700:467, 7 June. Pretoria: Government Printer.

**Spellerberg, I.F. 2000.** Conservation Biology. Longman Group Limited.

**Venevsky, S. & Venevskiaia, I. 2005.** Hierarchical systematic conservation planning at the national level: Identifying national biodiversity hotspots using abiotic factors in Russia. *Journal of Biological Conservation*, 124: 235-251.

## CHAPTER 2

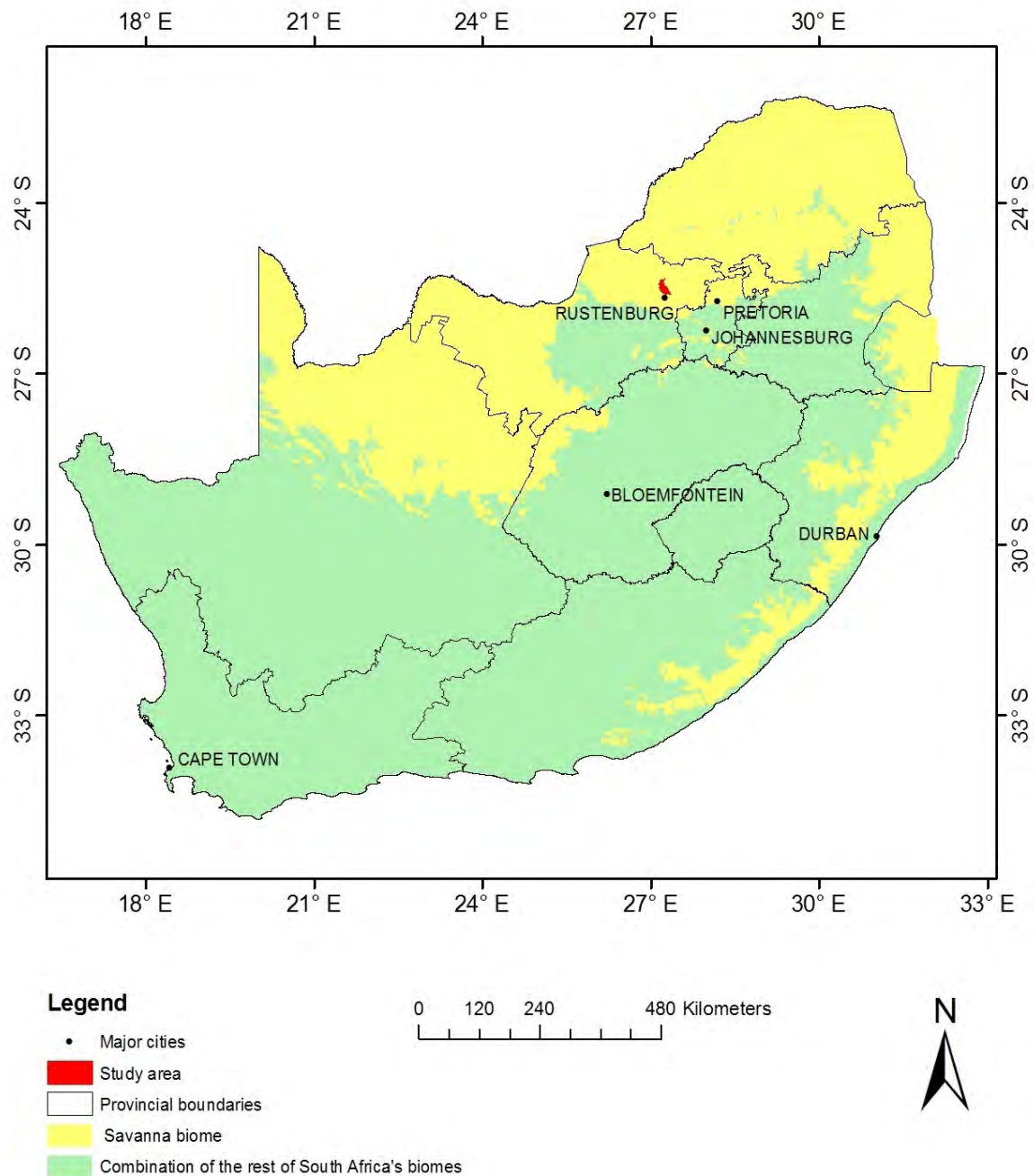
### Study area

#### 2.1. Location and land-use

The licensed operating mining area of the Impala Platinum Company, which forms part of the Implats Group, is situated approximately 5 km north of Rustenburg in the North-West Province of South Africa (Figure 2.1). The study area will henceforth be referred to as the Impala Platinum mining area. It covers 29 334 ha (GIS calculated) and there are currently fourteen operational shafts on the property ([www.implats.co.za](http://www.implats.co.za)). A lease for the area (predominantly owned by the Bafokeng Tribe, now known as the Royal Bafokeng Nation) was granted in November 1967 to the Implats Group ([www.implats.co.za](http://www.implats.co.za)). Only the Merensky reef was mined for platinum initially but in the 1980's the company also started mining the UG2 reef ([www.implats.co.za](http://www.implats.co.za)). By the early 1990's Impala Platinum had become the second largest platinum producer in the world, with an annual output of one million ounces ([www.implats.co.za](http://www.implats.co.za)). The bulk of the mining at Impala Platinum is conventional underground mining while limited opencast mining takes place at the reef outcrop ([www.implats.co.za](http://www.implats.co.za)). In 1999 an agreement was reached with the Royal Bafokeng Nation regarding mineral rights and royalties over the major portion of the area over which Impala Platinum had mining rights ([www.implats.co.za](http://www.implats.co.za)). The Royal Bafokeng Nation currently holds 13.4% of Impala Platinum's shares ([www.implats.co.za](http://www.implats.co.za)). The group recorded production of 1.7 million ounces of platinum in 2009 and have set a target of producing 2.1 million ounces annually by 2014 ([www.implats.co.za](http://www.implats.co.za)). Local residential settlements of the Royal Bafokeng Nation as well as informal settlements are also present in certain parts of the Impala Platinum mining area and most of the natural areas, especially surrounding settlements, are used for grazing by livestock. No official farming properties are however owned by individuals and fenced boundaries are absent. All farming activities taking place are therefore in the form of uncontrolled continuous grazing.

The Rustenburg area falls into the Central Bushveld Bioregion of the Savanna biome (Mucina & Rutherford, 2006), the largest biome in South Africa (Figure 2.1) which covers more than 32% of the country's surface area (Mucina & Rutherford, 2006; Low & Rebelo, 1998; Acocks, 1988). According to Mucina & Rutherford (2006) as well as Low & Rebelo (1998) most savannas are described as having an herbaceous layer dominated by grasses and a discontinuous to sparse open woody layer. The savannas of southern Africa occur where there is high summer rainfall and winter drought and altitudes that vary from sea level

to 2000 m (Mucina & Rutherford, 2006; Low & Rebelo, 1998). The mean daily maximum temperature for February is rarely under 26°C and often exceeds 32°C. The temperature stays above 10°C in most of the biome during July but on the highveld (southern edge) temperatures can drop below 0°C (Mucina & Rutherford, 2006). Frost is uncommon in winter, but does occur between June and August. Outside the Kalahari areas, most of the Savanna has an annual rainfall of 500-750mm (Mucina & Rutherford, 2006).



**Figure 2.1 The location of the Impala Platinum mining area in the North-West Province and Savanna biome of South Africa.**

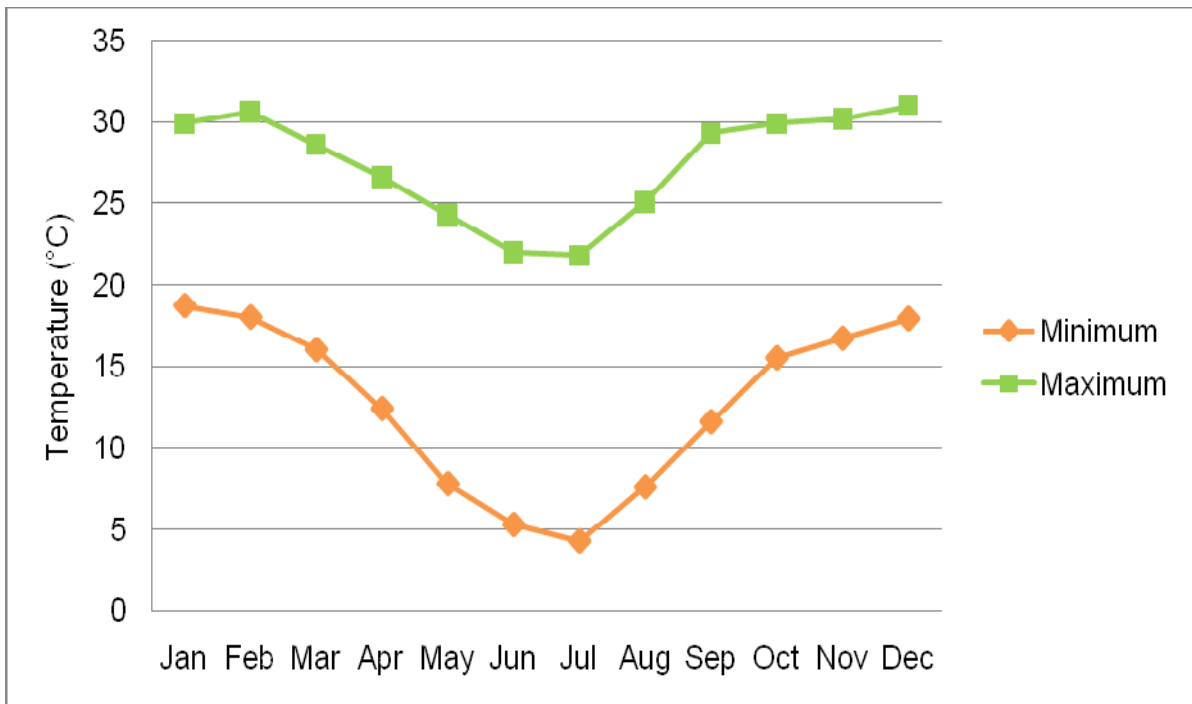
Profound losses of Savanna areas took place before the 1960's mostly due to cultivation and other agricultural transformation activities (Mucina & Rutherford, 2006) but substantial progress has been made in conservation of the Savanna biome since then. According to Mucina & Rutherford (2006), 8.75% of the Savanna biome is currently protected in South Africa and this includes formal conservation areas such as national parks. Target percentages for protected Savanna areas are however still far from being reached. A more biologically relevant way of approaching systematic conservation is increasingly being adopted which focuses conservation efforts specifically on vegetation types rather than on broader biomes (Mucina & Rutherford, 2006). The relevance of biodiversity conservation in the Impala Platinum mining area will, therefore, become evident during the discussion of the vegetation types present in the leased mining area.

## **2.2. Physical environment**

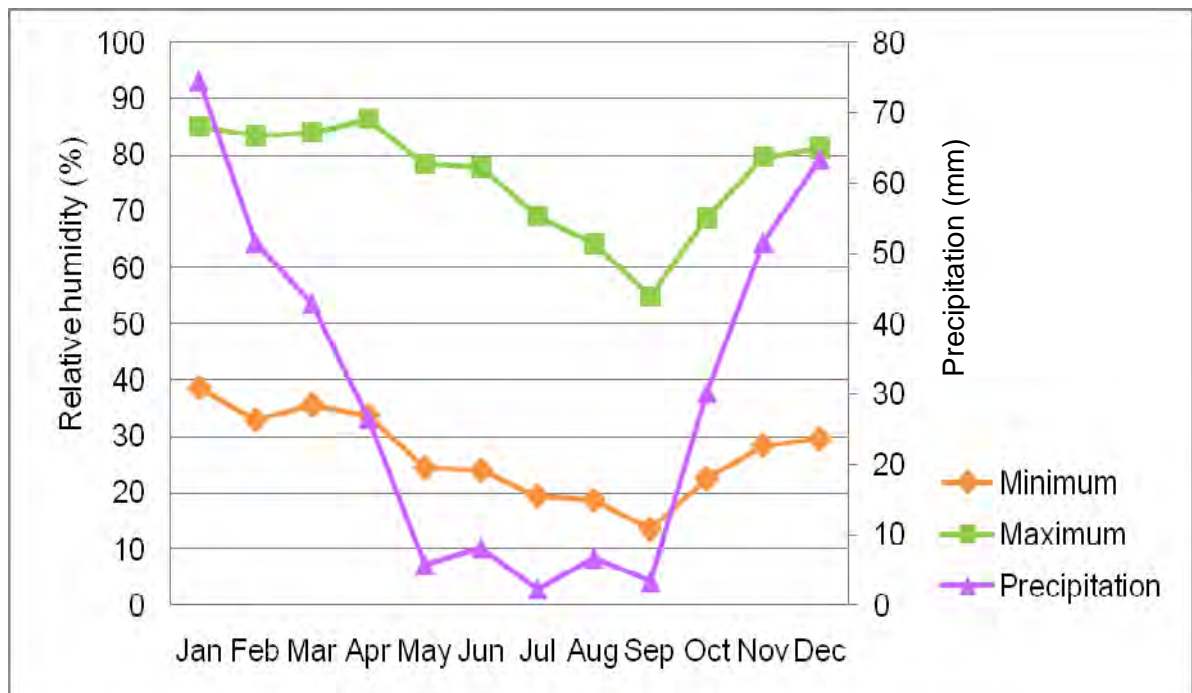
### **2.2.1. Climate**

The Impala Platinum mining area is located in the summer rainfall zone of South Africa according to Mucina & Rutherford (2006). Data from the Rustenburg Shaft 10 weather station was used for the description of the climate of the study area because the station is located inside the Impala Platinum Mining area. The climatic data was obtained from the South African Weather Services (2010). Average minimum and maximum daily temperatures for each month for the years 2003-2009 are the highest from October-February and the lowest from May-August (Figure 2.2). The area experiences less than one frost day per annum on average.

Average monthly precipitation as well as minimum and maximum relative daily humidity for each month for the years 2003-2009 are illustrated in Figure 2.3. The total annual precipitation varied between 280 mm and 420 mm with an average of 338.7 mm over the past seven years (2003-2009). Precipitation decreases profoundly during the autumn and winter months and the humidity is correlated with this decrease.



**Figure 2.2** Average minimum and maximum daily temperatures of the Impala Platinum mining area of each month for the years 2003-2009.



**Figure 2.3** Average monthly precipitations as well as minimum and maximum relative daily humidity of the Impala Platinum mining area of each month for the years 2003-2009.

### 2.2.2. Geology, Soil, Topography and Land types

The Impala Platinum mining area is situated in a rock formation unit of the larger Vaalian Eratheem known as the Bushveld Complex (Johnson *et. al.*, 2006). The majority of the Impala Platinum mining area more accurately falls into the Rustenburg Layered Suite which consists of alternating layers of especially peridotite and pyroxenite at the base and gabbro, norite anorthosite, troctolite and diorite closer to the surface (Johnson *et. al.*, 2006). The total diameter of the Rustenburg Layered Suite is approximately 8700 m in the eastern and 8200m in the western lobe (Coetzee, 2004). The suite is divided into four depth zones starting from the top-zone at the surface through the main and critical zones down to the bottom-zone (Coetzee, 2004). The top-zone, known as the Bierkraal Magnetite Gabbro, is characterized by the absence of magnetite (Johnson *et. al.*, 2006). It, however, only constitutes a small area in the north-eastern part of the Impala Platinum mining area. More than 70% of the Impala Platinum mining area consists of the main-zone (Pyramid Gabbro-Norite) which is about 3500m in diameter (Coetzee, 2004). It consists mostly of gabbro and norite while chromite is absent (Johnson *et. al.*, 2006). There is also a belt running down the western side of the Impala Platinum mining area which is classified as the Schilpadnest Sb. suite of the Rustenburg Layered Suite (Johnson *et. al.*, 2006). The most north-easterly corner of the Impala Platinum mining area is categorized under the Rashoop Granophyre Suite (a mixture of quartz and feldspar) (Johnson *et. al.*, 2006), but it only covers a small area.

According to the Map of Soil Classes created by the land type survey staff of the Agricultural Geo-Referenced Information System (AGIS, 2010), swelling clay soils completely dominate the Impala Platinum mining area (more than 80% cover). Although having the restriction of being very plastic and sticky and having high swell-shrink potential, these soils are highly fertile (AGIS, 2010). Certain areas in the south-east of the Impala Platinum mining area are described as non soil land classes (AGIS, 2010). These are mainly the areas where the Norite Koppies Bushveld vegetation type is present (Figure 2.4) and they therefore have high percentage rockiness and little soil cover.

The topography of the Impala Platinum mining area varies between 1000 m and 1180 m above sea level (Figure 2.4). The areas with higher altitudes located in the south-eastern part, constitute rocky hills which form part of the Norite Koppies Bushveld vegetation type (Figure 2.4). The only two permanent rivers in the Impala Platinum mining area are the Leragane river (which branches from the Elands river) running through the central parts and the Hex river in the south.

Three land types are present in the Impala Platinum mining area namely the Ea land type (which is dominant); Ib land type (only present in the south-eastern part) and Fb land type (only in the top north-eastern part) (Land Type Survey Staff, 1987). The terrain, geological, soil and climatic characteristics of these land types narrowly correspond with the discussion above.

### 2.3. Vegetation description

Three veld types are present in the Impala Platinum mining area based on the work of Acocks (1988), the dominant one being the Sourish Mixed Bushveld. This is a more clearly defined veld type than the Mixed Bushveld which is also present in the Impala Platinum mining area (Acocks, 1988). It consists mostly of open Savanna areas dominated by *Acacia caffra* and a dense grass layer which includes species like *Cymbopogon pospischilii*, *Themeda triandra*, *Elionurus muticus* and *Hyparrhenia* species. The Mixed Bushveld, which is only present in the north of the Impala Platinum mining area, consists of multiple variations of which the *Combretum apiculatum* Veld and the Mixed *Terminalia-Dichapetalum* Veld are the two mainly recognized ones (Acocks, 1988). The third veld type, which is present in the south of the Impala Platinum mining area, is categorized as Other Turf Thornveld which has four variations namely on Limestone, Norite Black Turfveld, *Acacia* Veld and Knoppiesdoring Veld (Acocks, 1988).

According to Low & Rebelo (1998) the Impala Platinum mining area is categorized by two vegetation types namely the Clay Thorn Bushveld (dominant) and the Mixed Bushveld (only present in the north of the Impala Platinum mining area). The former is dominated by *Acacia* species such as *Acacia tortilis*, *A. nilotica* and *A. karroo* whilst other broad leaved woody species like *Ziziphus mucronata* and *Grewia flava* are also present (Low & Rebelo, 1998). A dense grass layer also covers this vegetation type and characteristic soils include black or red vertic clays derived from basalt (Low & Rebelo, 1996). The Mixed Bushveld varies from a dense, short bushveld to an open tree Savanna with soils being coarse, sandy and shallow, overlaying granite, quartzite, sandstone or shale (Low & Rebelo, 1998).

According to Mucina & Rutherford (2006) the Impala Platinum mining area includes four vegetation types (Figure 2.4) with the largest part of the area being covered by the Zeerust- and Marikana Thornveld. A small part in the north-eastern corner of the study area falls inside the Central Sandy Bushveld vegetation type and a number of norite koppies are present in the lower south-east corner which constitutes the Norite Koppies Bushveld vegetation type.

## **Zeerust Thornveld**

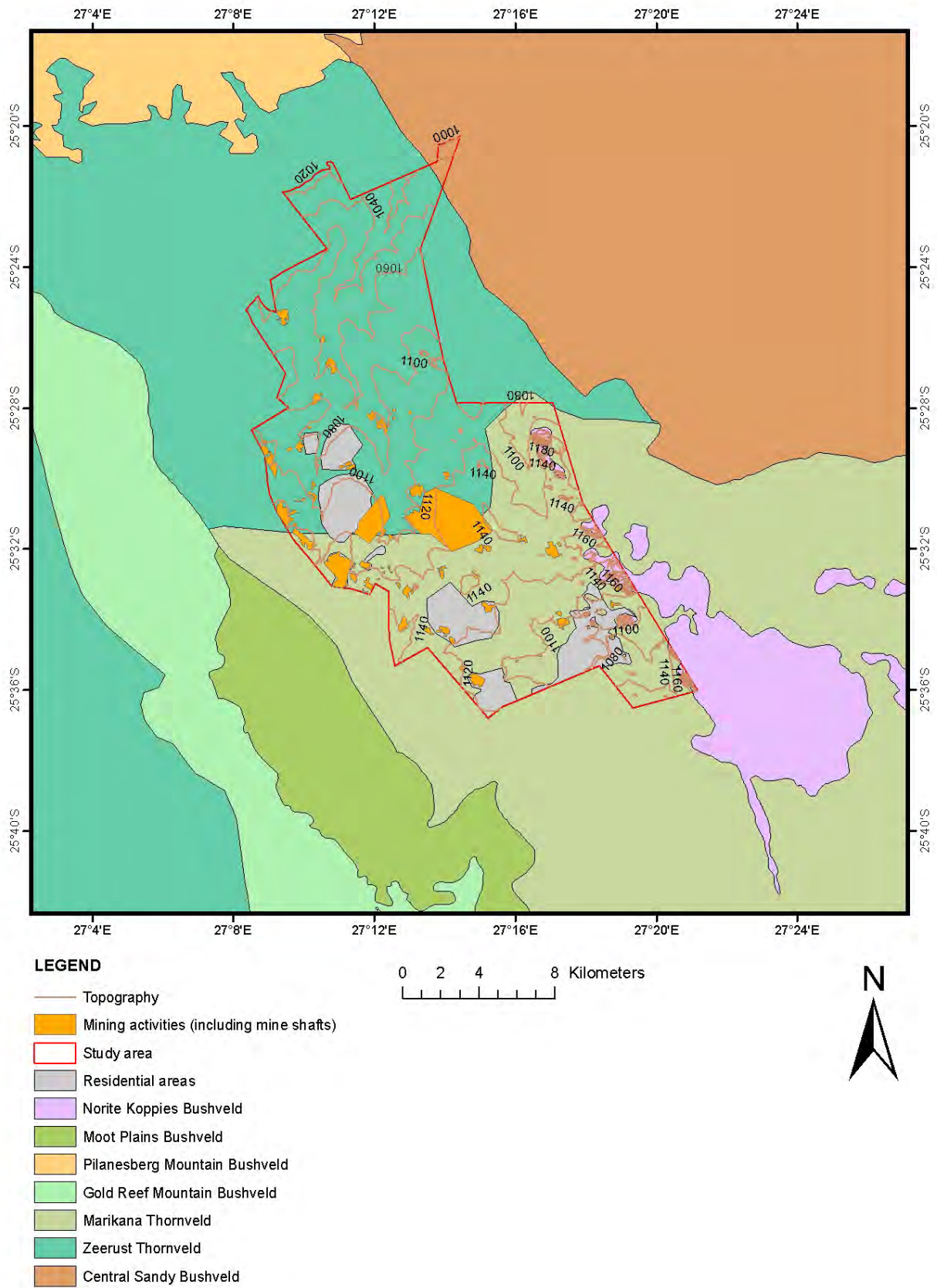
The distribution of this vegetation types extends along the plains of the North-West Province from the Lobatsi River in the west *via* Zeerust, Groot Marico and Mabaalstad to the flats between the Pilanesberg and the western end of the Magaliesberg in the east. The area is a deciduous region. It consists of open to dense short thorny woodlands dominated by *Acacia* species with a grassy herbaceous layer.

The geology of the landscape lies within the Rustenburg Layered Suite (Bushveld Igneous Complex) with bronzite, harzburgite, gabbro and norite. Soils are mostly deep, red-yellow, apedal, freely drained with high base status and also with some vertic or melanic clay. The land types are mainly Ae and Ea.

The area receives summer rainfall with very dry winters (annual rainfall varies between 550-600 mm). Frost is fairly frequent during winter mornings and in the late evenings. The mean monthly maximum and minimum temperatures for the area for January and June are 36.7°C and -0.4°C respectively.

Important species include tall trees like *Acacia burkei* and *A. erioloba* while smaller trees include *A. mellifera* subsp. *detinens*, *A. nilotica*, *A. tortilis* subsp. *heteracantha*, *Searsia lancea* and others. Tall shrubs found in this vegetation type include *Diospyros lycioides* subsp. *lycioides*, *Grewia flava* and *Mystroxydon aethiopicum* subsp. *burkeanum*. Lower shrubs include *Searsia grandidens*, *Sida chrysantha*, *Clerodendrum ternatum* and the grasses include *Eragrostis lehmanniana*, *Panicum maximum*, *Aristida congesta* and *Cymbopogon pospischilii*. Herbs present in this vegetation type include *Blepharis integrifolia*, *Chamaecrista absus*, *C. mimosoides* and others. An endemic taxon found in this region is *Searsia maricoana* which is a low growing shrub.

The Zeerust Thornveld vegetation type is categorized as least threatened for conservation. Less than 4% of the targeted 19% of this vegetation type is however currently being statutorily conserved and this is spread between four reserves.



**Figure 2.4** The vegetation types (Mucina & Rutherford, 2006) and topography of the Impala Platinum mining area.

### **Marikana Thornveld**

This vegetation type is present on plains from Rustenburg through Marikana and Brits to Pretoria that lay east of Rustenburg. It consists of more open *Acacia karroo* woodland and occurs in valleys, undulating plains and lowland hills.

The vegetation type is situated on the Rustenburg Layered Suite of the Bushveld Igneous Complex. The main rock types include gabbro, norite, pyroxenite and anorthosite. The land types are mainly Ea, Ba and Ae.

It is a summer rainfall area with annual rainfall of 600-700 mm. The mean maximum and minimum temperatures are 35.3°C and -1.4°C (November and July) and frost occurs during winter months.

The important tree species that occur in this vegetation type include *Acacia nilotica*, *Acacia tortilis* subsp. *heteracantha*, *Ziziphus mucronata* and *Celtis africana*. Tall shrubs found include *Searsia pyroides* var. *pyroides*, *Grewia flava*, *Diospyros lycioides* subsp. *guerkei* and the grasses include *Elionurus muticus*, *Fingerhutia africana*, *Heteropogon contortus* and *Melinis nerviglumis*. Some of the herb species found here are *Hermannia depressa*, *Ledebouria revoluta* and *Ipomoea obscura*.

The Marikana Thornveld vegetation type is categorized as an endangered vegetation type for conservation. Nineteen percent (19%) is targeted for conservation purposes but less than 1% is being statutorily conserved.

### **Norite Koppies Bushveld**

Norite koppies consist of rocky hills embedded in the Marikana Thornveld mostly between Rustenburg and Pretoria. The vegetation type can be identified as noritic outcrops with low, semi-open to closed woodlands that consist of dense deciduous shrubs and trees in shallow soil with sparse undergrowth.

The geology of this vegetation type usually consists of gabbro and norite with interlayered anorthosite of the Pyramid Gabbro-Norite, Rustenburg Layered Suite which is part of the Bushveld Complex. The land types include mostly Ib and some of Ea.

It is a summer rainfall area with frequent frost occurring mostly around the base of the hills and less on the hills during winters which are drier.

Some of the important tree species of this vegetation type are *Sclerocarya birrea* subsp. *caffra*, *Ficus abutilifolia*, *Pappea capensis*, *Obetia tenax* and *Euphorbia cooperi*. Shrubs include *Pouzolzia mixta*, *Grewia flavescens* and *Vitex zeyheri* while important grass species on these outcrops are *Eustachys paspaloides*, *Panicum maximum* and *Heteropogon contortus*. The herbs include *Pellaea calomelanos*, and *Scadoxus puniceus*.

These norite koppies have varying vegetation patterns which are primarily determined by the amount of rockiness and the aspect. The north facing slopes will consist of distinct and different species and plant communities from those on the colder south facing slopes.

The conservation status of the Norite Koppies Bushveld vegetation type is least threatened according to remote sensing but ground truthing indicates that it is rather susceptible to transformation. This vegetation type is not conserved in any statutory reserves although having a conservation target of 24%. Only 4% is conserved in the Onderstepoort Nature Reserve.

### **Central Sandy Bushveld**

This vegetation type occurs mainly in a broad arch south of the Springbokvlakte from the Pilanesberg in the west through Groblersdal to GaMasemola in the east. It is characterised by low undulating areas and at some points extend into valleys. In some cases it is also present between mountains and on isolated sandy rises. Species of *Acacia*, *Euclea* and *Ziziphus* are found in the flatter areas and less sandy soils which are normally grass dominated areas with relatively low basal cover while *Combretum* woodlands are often present on shallow rocky or gravelly soils.

The southern and eastern parts of this vegetation type are underlain by granite of the Lebowa Granite Suite and some granophyre of the Rashoop Granophyre Suite (both part of the Bushveld Complex). The relevant land types are Bb, Fa, Ba, Bd and Ac.

It is a summer rainfall area with the wet season usually extending from November to April. Annual rainfall is between 500-700 mm and the area doesn't receive frequent frost.

Important trees species include *Acacia robusta*, *Combretum zeyheri* and *Searsia leptodictya*. Shrubs include *Grewia bicolor*, *Grewia monticola* and *Combretum hereroense*. Many grass species are found in this vegetation type, some of which are *Eragrostis rigidior*, *Panicum maximum* and *Themeda triandra* while important herbs include *Crabbea angustifolia*, *Geigeria burkei*, *Indigofera daleoides* and *Waltheria indica*.

The conservation status of the Central Sandy Bushveld vegetation type is vulnerable and only 3% of the targeted 19% is statutorily conserved while an additional 2% is conserved in other reserves.

## 2.4. References

**Acocks, J.P.H. 1988.** Veld Types of South Africa. Memoirs of the Botanical Survey of South Africa. No. 57. Botanical Research Institute, Department of Agriculture and Water Supply, South Africa.

**AGIS (Agricultural Geo-Referenced Information System). 2010.** Map of Soil Classes compiled by the Land type Survey Staff. [Web:] <http://www.agis.agric.za>. [Date of use: 12 August 2010.]

**Coetzee, M.S. 2004.** Suid Afrikaanse Geologie: Studiegids vir GLGN 121 Fakulteit Natuurwetenskappe. North West University, Potchefstroom. p. 458–462.

**Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. 2006.** The Geology of South Africa. Johannesburg: The Geology Society of South Africa and Pretoria: Council of Geosciences.

**Land Type Survey Staff, 1987.** Land types of the maps 2526 Rustenburg, 2528 Pretoria. Memoirs on the Agricultural Natural Resources of South Africa, 8. ARC-Institute for Soil, Climate and Water, Pretoria.

**Low, A.B. & Rebelo, A.G. (eds.) 1998.** Vegetation of South Africa, Lesotho and Swaziland: A companion to the vegetation map of South Africa, Lesotho and Swaziland. 2<sup>nd</sup> Ed. Department of Environmental Affairs & Tourism, Pretoria.

**Mucina, L. & Rutherford, M.C. (eds.) 2006.** The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.

**South African Weather Services. 2010.** De Villiers, C. ([Coleen.deVilliers@weathersa.co.za](mailto:Coleen.deVilliers@weathersa.co.za)) 10 Mrt. 2010. Weather data for the Rustenburg Shaft 10 Weather Station. E-mail to: Lamprecht, A.J.H. (20330782@student.nwu.ac.za).

## CHAPTER 3

### Vegetation Classification and Description

#### 3.1. Introduction

Vegetation forms an integral part of any ecosystem and can therefore only be fully understood by studying its functionalities and interactions in such a system rather than in isolation (Warning as quoted by Kent & Coker 2000). There are two main reasons for the importance of vegetation in understanding ecosystems. Firstly most ecologists identify ecosystems on the grounds of similar vegetation types. Vegetation is therefore the most obvious physical representation of an ecosystem (Kent & Coker, 2000). Secondly, solar energy is converted into green plant tissue during the process of photosynthesis. This is the most primary energy production and conversion process on the planet and serves as the base of all energy on earth. Any form of trophic energy flow through an ecosystem is therefore linked to the initial production by vegetation (Kent & Coker, 2000) and for this reason different vegetation types are directly and indirectly responsible for the biotic structure and functionality of any ecological system.

It is believed, according to Morgenthal *et. al.* (2001), that a phytosociological and biodiversity approach should be a prerequisite for any descriptive or experimental ecological study. Phytosociology is currently the mainstream vegetation classification scheme in Europe and its popularity worldwide has increased since the 1990's (Dengler *et. al.*, 2008). For effective international communication, it is therefore in the best interest to follow such approaches. Phytosociological information forms a foundation which can be used as a suitable reference entity for virtually any ecological research, bio-indication and nature conservation practices (Dengler *et. al.*, 2008). The conservation of species depends on the maintenance of habitats which are generally classified based on floristic attributes and it is thought that, by preserving extant plant communities, the continuous survival of other biotic components can be assured (Dengler *et. al.*, 2008). The discipline of phytosociology can also be used to monitor spatial and temporal vegetation dynamics and its underlying causes such as change in environmental conditions because of it being explicit in both those dimensions (Dengler *et. al.*, 2008). According to Kent & Coker (2000), changes in vegetation cover due to anthropogenic activities mostly take place at the plant community scale and phytosociology is therefore best suited for efficient monitoring. This use is very relevant for providing answers about vegetation dynamics of rehabilitated areas (Morgenthal, *et. al.*, 2001) as in the case of Impala Platinum. Phytosociology also forms a crucial component of applied ecological studies such as veld condition assessments, environmental impact

assessments and environmental management. The importance of phytosociological data is undeniable and recent examples of the role of phytosociology in ecological management and conservation of both natural and urban areas are abundant in the literature (Swanepoel & Bredenkamp, 2007; Grobler *et al.*, 2006; Zietsman & Bredenkamp, 2006; Cleaver *et al.*, 2005; Van Staden & Bredenkamp, 2005; Götze *et al.*, 2003). However, when deciding on which methods to employ for vegetation descriptions it is important to understand the exact purpose and scale of the study at hand as well as knowing about the resources available.

In the case of Impala Platinum, a conservation plan needs to be developed for the company's leased mining area. The systematic approach to conservation is a practically oriented field which aims to provide a basis from which realistic, implementable strategies can be developed for the identifying and setting of explicit, quantitative targets for management and conservation purposes (Driver *et al.*, 2003; Pierce *et al.*, 2005). For this reason spatially explicit biodiversity information forms an important part of systematic conservation.

The first objectives of the study were to identify, describe and spatially illustrate the plant communities present in the mining area as well as to determine possible environmental variables that influence community structure and species composition. An initial phytosociological study of the mining area was, therefore, conducted during 2009. It provided a habitat platform for further diversity surveys of the fauna as well as to assist in ecological interpretation and hypothesis generation for further quantitative vegetation studies during 2010 which included veld condition assessments, landscape function analyses as well as determining grazing and browsing capacities. The compilation of all this data will ultimately aid in the establishment of the official conservation plan.

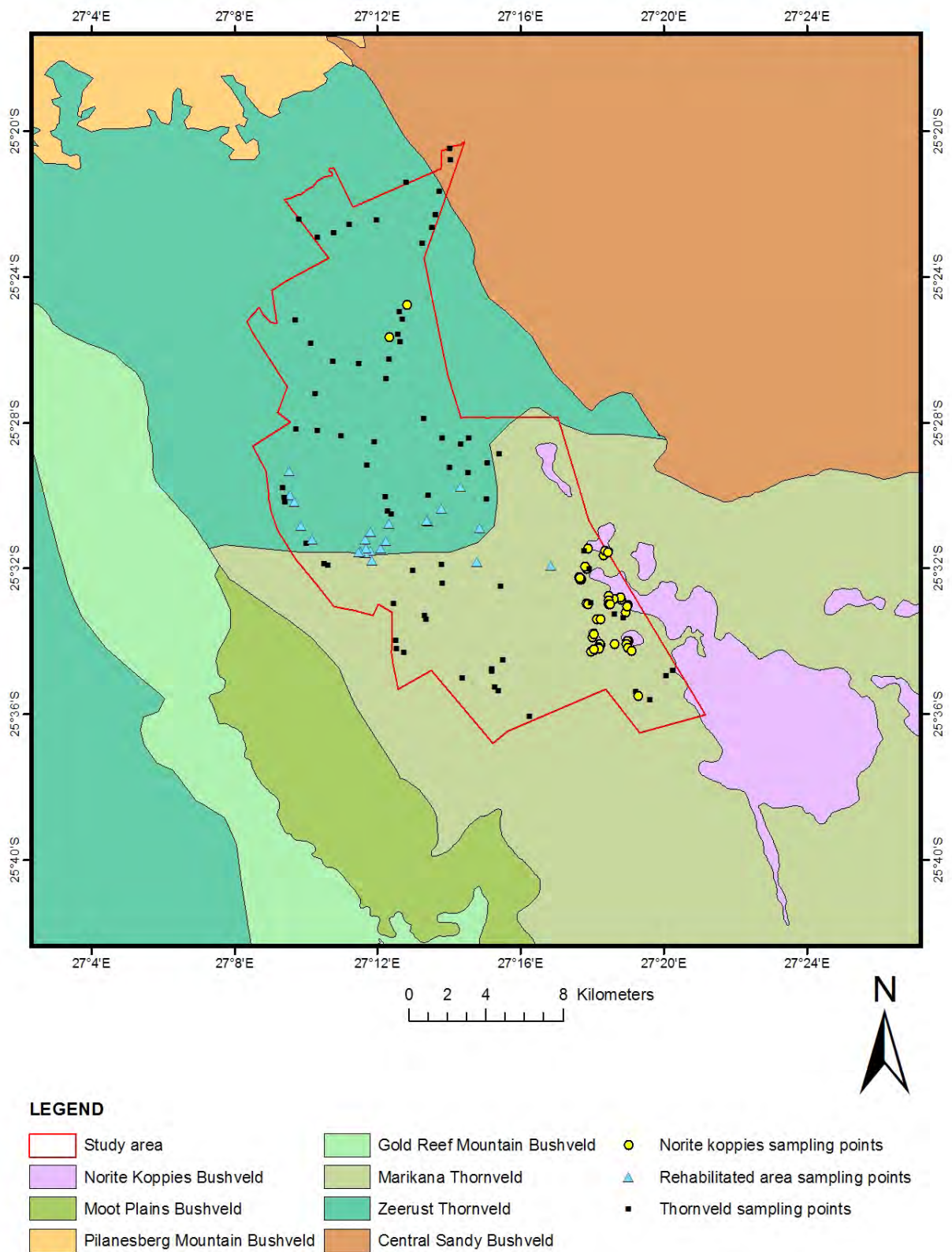
### **3.2. Materials and Methods**

The Impala Platinum mining area was stratified into three main categories based on the type of landscape, main vegetation types and land-use type, namely: norite koppies; thornveld and rehabilitated areas. The Braun Blanquet vegetation sampling approach (Mueller-Dombois & Ellenberg, 1974) was followed. An example of the data sheet used during the surveys is provided in the appendix (Data Sheet A1). Homogenous units based on physiognomy and species composition were identified in each of the three main categories through visual observations and aerial photography. One hundred and thirty nine (139) stratified random relevés of 400m<sup>2</sup> each were surveyed (Figure 3.1) using Braun Blanquet cover-abundance values (Kent & Coker, 2000; Mueller-Dombois & Ellenberg, 1974). Species-area curves were constructed to determine the minimum area for a relevé (Kent &

Coker, 2000). Environmental characteristics (aspect, slope, soil type and depth, percentage soil surface rockiness) and GPS coordinates were taken at each relevé.

The data collected was entered into the computer database, TURBOVEG (Hennekens, 1996a) which is used for capturing, processing and presentation of phytosociological data as well as into MEGATAB, a visual editor for phytosociological tables (Hennekens, 1996b). TWINSpan was used as a first approximation to construct phytosociological tables and Braun Blanquet procedures were followed for refinement. Subsequent multivariate statistical analyses with the computer software programme, CANOCO (Ter Braak, 1986) were performed in order to verify the plant communities and identify possible environmental gradients that could influence plant community structure and composition.

The plant communities were named by combining a differential and dominant species name and were then further described. No distinction was made between the species *Maytenus undata* and *Maytenus albata* at the time of the survey. It has, however, come to our attention that both are present in the Impala Platinum mining area. They are therefore listed as one species in this study. Species names are according to Germishuizen *et. al.*, (2006). The average species richness, percentage alien species (Germishuizen *et. al.*, 2006), endemic species and species that appear on the Red Data species list of South Africa (SANBI, 2009a) as well as protected species in South Africa (SANBI, 2009b) were listed. Declared weeds and invaders (Henderson, 2001) were also listed. These plant species are grouped into three categories and according to the Conservation of Agriculture Resources Act, 1983 (Act 43 of 1983) (quoted by Henderson, 2001), landowners are legally responsible to take action, in accordance with the category of the species, for the control of these invasive plants on their properties (Henderson, 2001). Category 1 species are prohibited and must be controlled while Category 2 species may be grown in demarcated areas providing that there is a permit and that steps are taken to prevent their spreading. Category 3 species may no longer be planted although existing plants may remain, except in the flood line of watercourses and wetlands, as long as their spreading is prevented. A geo-referenced vegetation map (Figure 3.24) illustrating the geographic presence of the plant communities was created in the program ArcView 9.2 (ESRI, 2006).



**Figure 3.1** Map showing the vegetation types (Mucina & Rutherford, 2006) and Braun-Blanquet sampling points of the three identified categories inside the Impala Platinum mining area.

### 3.3. Results and Discussion

#### 3.3.1. Norite koppies

The norite koppies are unique and form diverse entities with respect to vegetation composition and are identified as large or smaller norite based hills or outcrops reaching out above the surrounding turf soil plains. Although these koppies cover less than 20% of the Impala Platinum mining area, they delivered just as many plant communities as the thornveld landscape category which covers more than twice the geographic area.

Forty three relevés (43) were sampled on these koppies and four plant communities with two sub-communities were identified and described (Table 3.1). Species groups mentioned in the text refer to Table 3.1 and species with low constancy and cover that do not belong to differential groups are listed in the appendix (Table A1).

List of plant communities:

1. *Microchloa caffra*-*Sporobolus stapfianus* Community
2. *Pappea capensis*-*Heteropogon contortus* Community
3. *Setaria lindenbergiana*-*Dombeya rotundifolia* Community
  - 3.1. *Themeda triandra*-*Acacia caffra* Sub-community
  - 3.2. *Ficus burkeii*-*Dombeya rotundifolia* Sub-community
4. *Ficus abutilifolia*-*Croton gratissimus* Community















### 3.3.1.1. Description of plant communities

#### 1. *Microchloa caffra*-*Sporobolus stapfianus* Community

This community (Figure 3.2) is present on rocky dome-shaped outcrops appearing on koppies as well as on areas of exposed sheetrock found in the thornveld between the koppies. The soil is shallow and the percentage soil surface rockiness is very high, varying between 70% and 90%. The degree of surface rock brokenness can vary considerably. For this reason the species composition differs slightly between fragmented outcrops and more solid ones because fragmented surface rock areas form deeper cracks and thus a different habitat with deeper soil and more water penetration for certain species to exploit.

Differential species are indicated by Species Group A. It includes the grasses *Sporobolus stapfianus* and *Oropetium capense* as well as the fern *Selaginella dregei*. The dominant species is the grass *Heteropogon contortus* (Species Group K) and other species include the grass *Melinis repens* (Species Group F); the tree *Sclerocarya birrea* (Species Group F) and the forb species *Chascanum hederaceum* (Species Group B). The grass species *Hyperthelia dissoluta* and *Schizachyrium sanguineum* (both in Species Group A) are two species which can be associated with outcrops that have more fragmented rock surfaces (Figure 3.3). These species will not be present on areas of solid sheetrock.

Protected species: *Boscia albitrunca* (Table A1) (SANBI, 2009b)

Declared weeds and invaders: *Opuntia ficus-indica* (Species Group K) and *Pennisetum setaceum* (Table A1) (both in Category 1) (Henderson, 2001)



Figure 3.2 The *Microchloa caffra*-*Sporobolus stapfianus* Community. GPS: lat 25°35'30.0"S, long 26°19'16.7"E. Notice the dome shaped outcrops of sheetrock and the little amount of soil present. This community is dominated by low growing grass and forbs species.



**Figure 3.3** An illustration of highly fragmented outcrop areas in this community. GPS: lat 25°32'44.5"S, long 27°18'27.0"E. Notice the high degree of rock fragmentation on the surface and grass species such as *Hyperthelia dissoluta* and *Schizachyrium sanguineum* exclusively utilizing such micro-habitats.

The average species richness is 55 species per relevé of which 5% are alien species. The grass layer is the dominant stratum in this community (31% cover). It consists mostly of low growing species with an average height of 0.3 m but in areas of high rock fragmentation certain species can reach 2 m in height. Shrubs and trees are less prominent (15% cover) and the height of the woody component varies from small shrubs (0.3 m) to taller trees of up to 5 m that mostly grow on the edges of these outcrops. The forb layer covers only 9% of the area and mostly consists of very low growing species although some can be up to 2.2 m high.

## **2. *Pappea capensis*-*Heteropogon contortus* Community**

This community (Figure 3.4) is found on north facing slopes which can vary from 10° to 30°. The soil type is Mispah and the percentage soil surface rockiness doesn't exceed 60%. This is relatively low compared to the *Ficus abutilifolia*-*Croton gratissimus* Community which is also found on north facing slopes.

No differential species are found in this community. The community is characterized by the species shared with the *Microchloa caffra*-*Sporobolus stapfianus* Community (Species Group B) and the species shared with the *Setaria lindenbergiana*-*Acacia caffra* Community (Species Group G). The absence of the differential species of the *Setaria lindenbergiana*-*Acacia caffra* Community (Species Group C) which is found on south facing slopes also characterizes this community as a different combination of species. There are therefore no differential species present only in this community on northern slopes which will not be found on south facing slopes. There is, however, a group of differential species present on the southern slopes which are not found on the north facing slopes (Species Group C).

Thus, this community found on northern slopes is not characterized by the presence of a certain species group but rather by the absence of the differential species group of the south facing slopes (Species Group C). The dominant species is the grass *Heteropogon contortus* (Species Group K) while other species include the trees *Sclerocarya birrea* (Species Group F) and *Croton gratissimus* (Species Group J) as well as the shrub *Pouzolzia mixta* (Species Group K).

Red Data List species: *Solanum supinum* (VU) (Species Group J) (SANBI, 2009a)

Protected species: *Boscia albitrunca* (Table A1) (SANBI, 2009b)

Declared weeds and invaders: *Achyranthes aspera* (Species Group J) (Category 1) (Henderson, 2001)



**Figure 3.4** The *Pappea capensis-Heteropogon contortus* Community. GPS: lat 25°35'56.2"S, long 27°19'07.7"E. The community does not have differential species but is rather characterised by the absence of certain species found on the south facing slopes. Notice the low percentage soil surface rockiness of most of the slope compared to the high rockiness of the *Ficus abutilifolia-Croton gratissimus* Community which is encircled in the photograph.

The average species richness is 60 species per relevé of which 6% are alien species. The woody and grass layers cover nearly 90% and are the two dominant strata in this community. Various small shrubs are present but tall trees of up to 7 m high are more prominent, whilst the grass layer found under the tree canopy is mostly low but heights of 2 m can be reached. The forb layer is not as prominent as the other strata (10% cover) and consists mostly of small forbs. Some climbers that can grow high into trees (up to 2 m) are also present.

### 3. *Setaria lindenbergiana-Dombeya rotundifolia* Community

This community is found on south facing slopes but the aspect may vary from west to south-east. The soil type is Mispah and soils are mostly shallow but can be deeper in some places. The percentage soil surface rockiness varies considerably (from 40% to 90%).

Differential species are indicated by Species Group C which includes the grass *Setaria lindenbergiana*; the tree *Celtis africana* and the forb *Scadoxus puniceus* while the dominant species is the tree *Dombeya rotundifolia* (Species Group J). Other species include the grass *Themeda triandra*; the shrub *Euclea crispa* and the woody species *Acacia caffra* (all in Species Group D).

Red Data List species: *Solanum supinum* (VU) (Species Group J) (SANBI, 2009a)

Declared weeds and invaders: *Achyranthes aspera* (Species Group J); *Cestrum laevigatum* (Table A1); *Datura stramonium* (Table A1); *Opuntia ficus-indica* (Species Group K) (all in Category 1); *Cynodon dactylon* (Table A1) (proposed Category 2); *Ipomoea purpurea* (Table A1) (Category 3) (Henderson, 2001)

The average species richness is 40 species per relevé of which 8% are alien species. The woody layer found on the south facing slopes is very dense (64% cover) and consists mostly of tall trees with an average height of 5 m - some even reach a height of up to 10 m. Shrubs only contribute approximately 15% to the woody layer. The grass layer rarely exceeds 1.5 m in height and covers 30%, whilst the forb layer only covers 19%. The forbs present in this community are mostly small, low growing species and also climber species which can reach up to 4 m into trees.

This community can be divided into two sub-communities based on the difference in percentage soil surface rockiness.

### **3.1. *Themeda triandra*-*Acacia caffra* Sub-community**

This is the dominant sub-community (Figure 3.5) found on the southern slopes of koppies. It is present in areas that have a relatively low percentage soil surface rockiness (40%-65%) in comparison with the other sub-community. This is the distinguishing environmental factor between the two sub-communities found on south facing slopes. Soils are mostly shallow but can be deeper in some areas.

Differential species are indicated by Species Group D which includes the grass *Themeda triandra*; the shrub *Euclea crispa* and the forb *Lantana rugosa*. The woody species *Acacia caffra* (Species Group D) is dominant and other species in this sub-community include the shrub *Asparagus suaveolens* (Species Group F); the tree *Dombeya rotundifolia* (Species Group J) and the fern *Pellaea calomelanos* (Species Group K).

Red Data List species: *Solanum supinum* (VU) (Species Group J) (SANBI, 2009a)

Declared weeds and invaders: *Achyranthes aspera* (Species Group J); *Cestrum laevigatum* (Table A1); *Datura stramonium* (Table A1); *Opuntia ficus-indica* (Species Group K) (all in

Category 1); *Cynodon dactylon* (Table A1) (proposed Category 2); *Ipomoea purpurea* (Table A1) (Category 3) (Henderson, 2001)



**Figure 3.5** The *Themeda triandra*-*Acacia caffra* Sub-community. GPS: lat 25°33'02.4"S, long 27°18'58.4"E. Notice the low percentage rock cover and the dense woody layer. The dominant species *Acacia caffra* can be seen in the photograph.

The average species richness is 44 species per relevé of which 4% are alien species. A dense woody stratum is present in this sub-community (63%) of which 47% consists of low to taller trees (up to 7 m) and the rest are shrubs. The grass layer is well developed (48%) but consists mostly of low-growing grasses rarely higher than 1.5 m. Forbs cover only 11% of the area and some species can climb up to 4 m into trees. The reason for the low forb cover and vigorous climbing is a shortage of space and effective sunlight because of high grass and tree cover.

### **3.2. *Ficus burkeii*-*Dombeya rotundifolia* Sub-community**

This sub-community (Figure 3.6) is characterized by steep, rocky cliffs with an aspect that can vary from west to south-east. It is located in areas with slopes of approximately 35° and higher. The percentage soil surface rockiness is very high, varying between 65% and 90% and consists mostly of large solid boulders. As mentioned in the description of the first sub-community, this large percentage of rock cover is what distinguishes the two sub-communities. Soils are very shallow.

Differential species are indicated by Species Group E and it includes the tree *Ficus burkeii*; the forb *Pavetta eylesii* and the grass *Digitaria sanguinalis*. The dominant species is the tree *Dombeya rotundifolia* (Species Group J) while other species also include the forbs *Solanum panduriforme* (Species Group G), *Pupalia lappacea* (Species Group C) and *Abutilon austro-africanum* (Species Group I).

Declared weeds and invaders: *Achyranthes aspera* (Species Group J) (Category 1) (Henderson, 2001)



**Figure 3.6** The *Ficus burkeii-Dombeya rotundifolia* Sub-community. GPS: lat 25°32'15.8"S, long 27°17'38.7"E. Notice the very high percentage rock cover which is mostly in the form of large boulders. The differential species *Ficus burkeii* as well as the dominant species *Dombeya rotundifolia* are present in the photograph.

The average species richness is 35 species per relevé of which 11% are alien species. Trees which grow up to 10 m in height dominate this community (50% cover) while the shrub layer only covers 15% and doesn't grow higher than 1.8 m. A grass layer is nearly absent in this community (5% cover) because of a shortage in soil and sunlight. However, grass species that do occur in this community, seldom grow above 0.8 m in height. Various small forbs and climbers are found in this community (28% cover) which can reach heights of up to 4 m into trees.

#### **4. *Ficus abutilifolia-Croton gratissimus* Community**

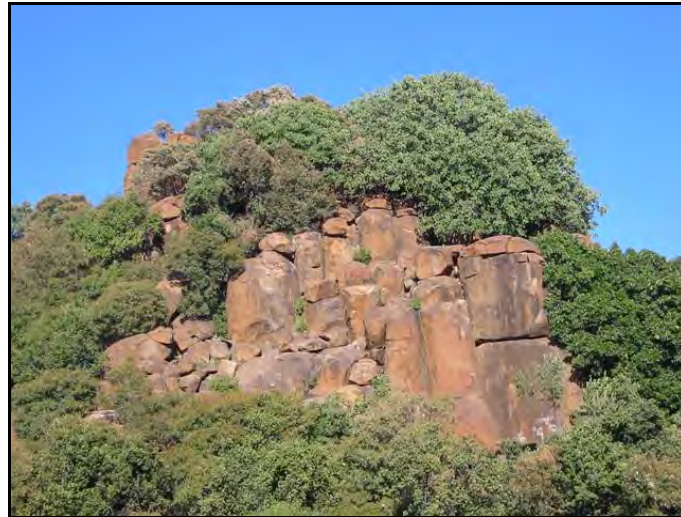
This community (Figure 3.7) is characterized by steep, rocky cliffs facing to the north or north-east. It is located in areas with very steep slopes varying from 30° to 90°. The percentage soil surface rockiness is very high; varying between 60% and 90% and mostly consists of large boulders. As mentioned during the discussion of the *Pappea capensis-Heteropogon contortus* Community, the difference in soil surface rockiness is what distinguishes these two communities found on the north facing slopes of koppies. The soil type is Mispah but little soil, which is very shallow, is present because of the large amount of rock.

Differential species are indicated by Species Group H which includes the trees *Ficus abutilifolia* and *Obetia tenax* and also the grass *Enteropogon macrostachyus* whilst the dominant species is the tree *Croton gratissimus* (Species Group J). Other species include

the forbs *Abutilon austro-africanum* (Species Group I), *Hibiscus subreniformis* and *Cyphostemma sulcatum* (both in Species Group J).

Red Data List species: *Solanum supinum* (VU) (Species Group J) (SANBI, 2009a)

Declared weeds and invaders: *Datura stramonium* (Table A1) and *Opuntia ficus-indica* (Species Group K) (both in Category 1) (Henderson, 2001)



**Figure 3.7** The *Ficus abutilifolia*-*Croton gratissimus* Community. GPS: lat 25°34'13.5"S, long 27°18'08.5"E. Notice the steep rocky cliffs mainly consisting of large boulders. *Ficus abutilifolia*, which is a differential species, is present in this photograph.

The average species richness is relatively low with 25 species per relevé of which 4% are alien species. This community is totally dominated by the woody component (67%). The majority of the woody stratum consists of tall trees that can reach 8 m in height. Because of the lack of sufficient soil and adequate sunlight, the grass cover is only 28% and grasses are never higher than 1.2 m. Only small forbs that rarely grow over 1.2 m are present in this community and their cover doesn't exceed 9%.

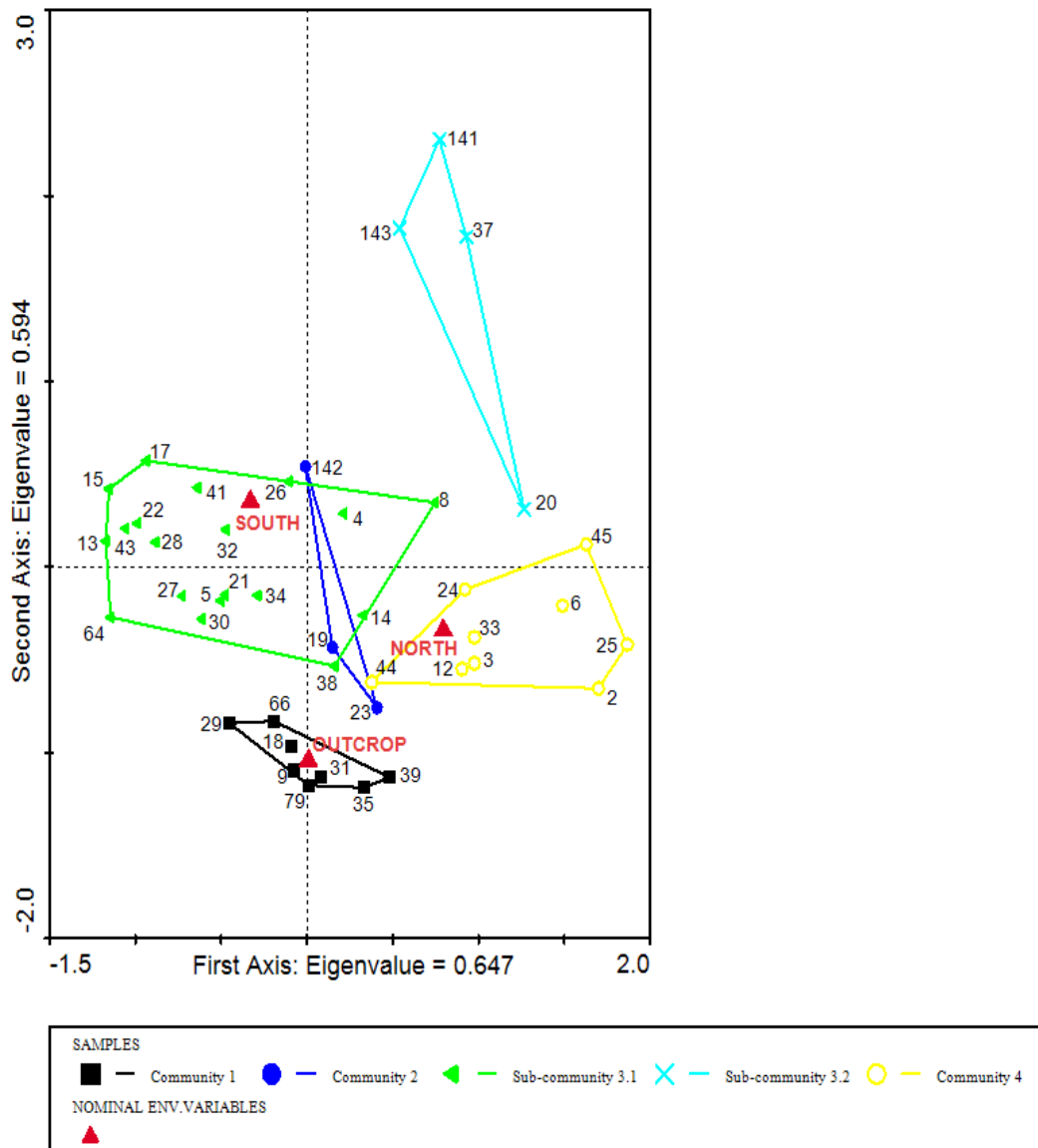
### 3.3.1.2. Ordinations

Correspondence Analysis (CA) ordinations were carried out to verify the plant communities and indicate the correlation in species composition between the plant communities as well as to identify environmental gradients that influence plant community structure and composition (Figures 3.8-3.10).

- The relevés representing Community 1 form a close grouping indicating the strong correlation in species composition between the different relevés (Figure 3.8).
- The relevés representing Community 2 also form a grouping indicating the similarity in species composition between the different relevés (Figure 3.8). The overlapping of certain relevés between Community 2 and Sub-community 3.1 in the ordination supports

the argument that Community 2, found on the northern slopes, shares various species with Sub-community 3.1 which is found on south facing slopes. Community 2 and Sub-community 3.1 are separated by the absence of certain species in Community 2 which are present in Sub-community 3.1.

- The relevés representing Sub-community 3.1 formed a separate larger grouping indicating a lesser correlation in species composition but still distinctive from the other communities (Figure 3.8).

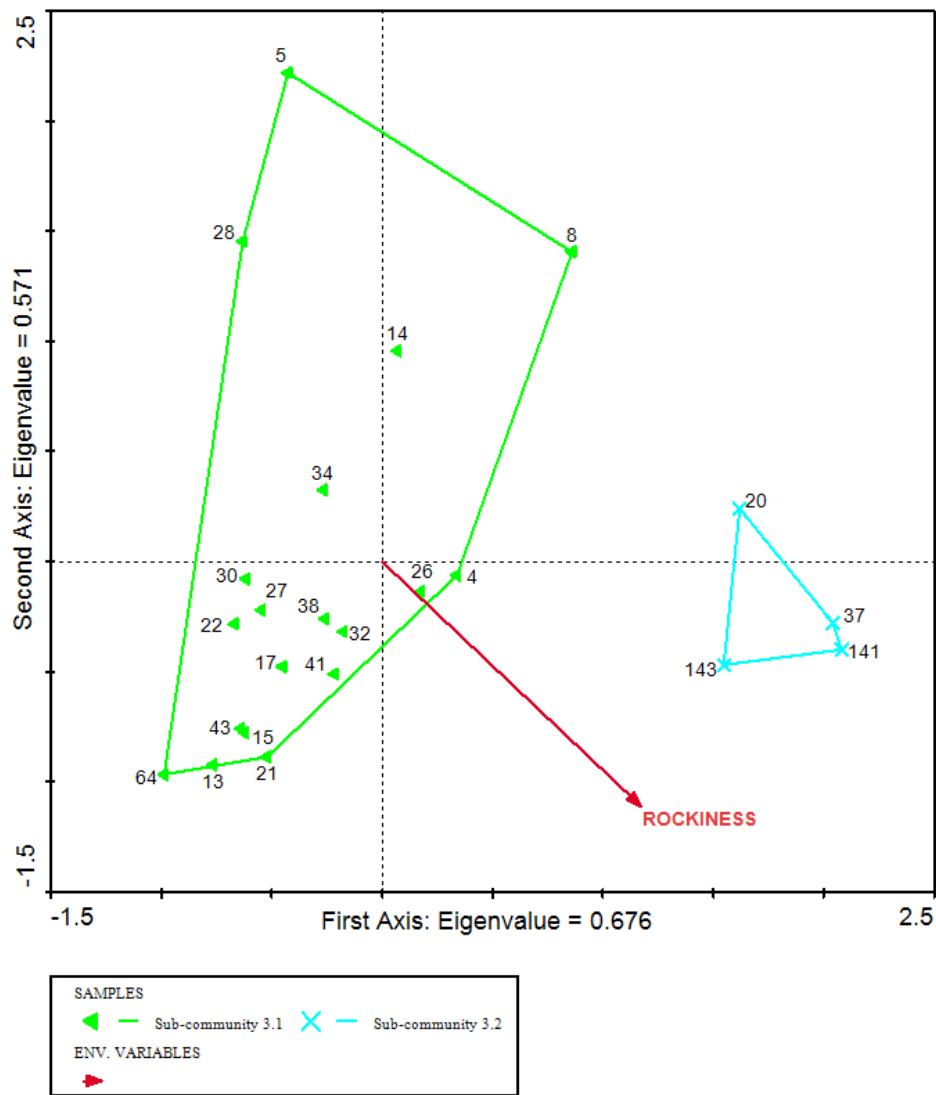


**Figure 3.8 Correspondence Analysis (CA) ordination bi-plot showing the correlations in species composition between the plant communities of the norite koppies and indicating the aspect as the environmental variable influencing plant community structure and composition.**

- The relevés representing Sub-community 3.2 also group together (Figure 3.8). Once again this indicates a correlation in species composition between the different relevés. Relevé number 20 is further away from the cluster of Sub-community 3.2 than the rest of

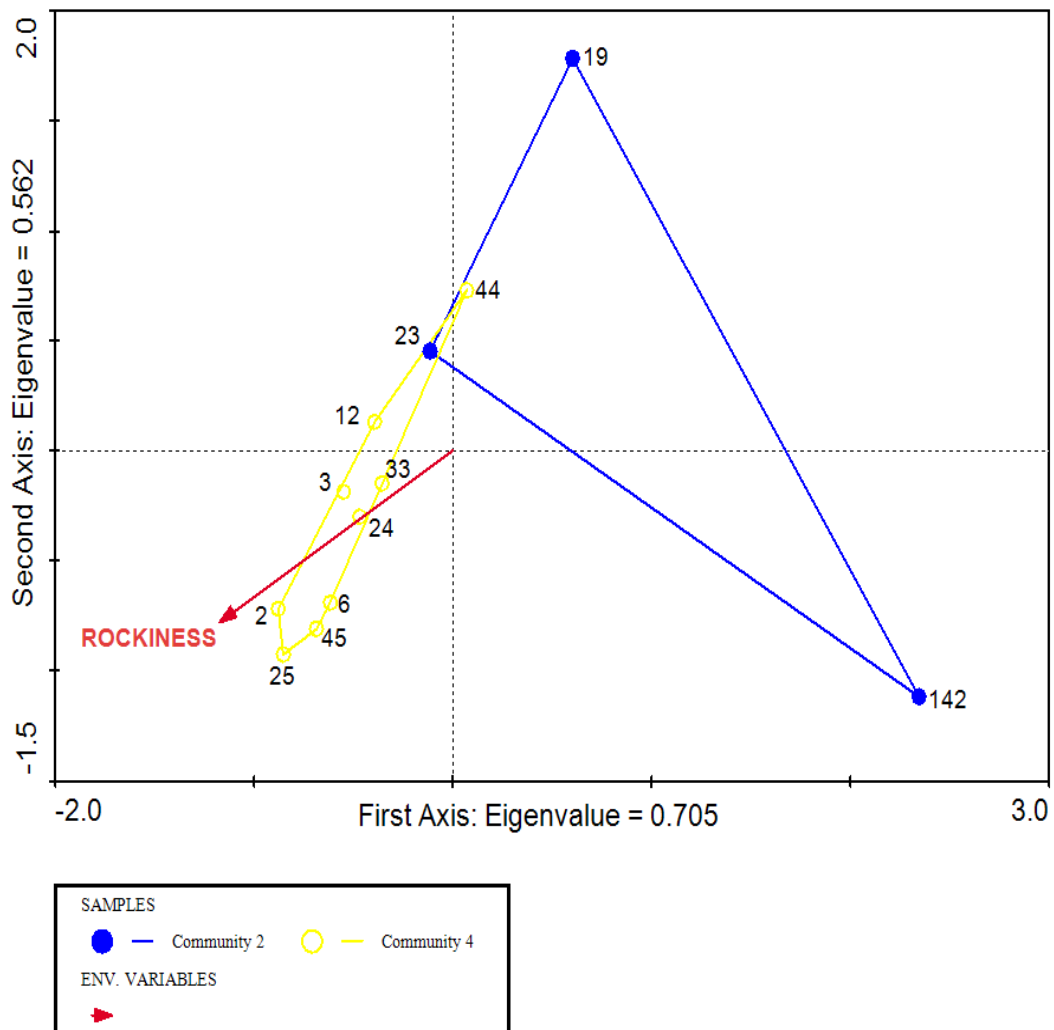
the relevés in the sub-community as it shares very few differential species with the *Setaria lindenbergiana-Dombeya rotundifolia* Community (Species Group C) (Community 3) and the cover abundance values of the species that are indeed shared are low. None of the species from Species Group G which is shared between Community 2 and the *Setaria lindenbergiana-Dombeya rotundifolia* Community (Community 3) are present in relevé number 20. It does, however, include differential species from Sub-community 3.2 and for this reason it forms part of this sub-community.

- A grouping is also formed by the relevés representing Community 4 (Figure 3.8). Relevé number 44 is further away from the cluster than the rest of the relevés but still forms part of the community. The reason for this is that relevé number 44 only shares few differential species with Community 4 (Species Group H) and the ones that are indeed shared, have low cover abundance values. One of the differential species of Community 4, *Ficus abutilifolia*, however, is present in relevé number 44 and has a high cover abundance value.
- Aspect is the main environmental variable that influences community structure and species composition on the norite koppies as is evident from the ordination (Figure 3.8). Community 1 is found on rocky dome-shaped outcrops that have no specific aspect. Communities 2 and 4 are bound to north facing slopes as can be deduced from the ordination and Community 3 (with its two sub-communities) is mainly found on south facing slopes as illustrated by the ordination.
- The percentage soil surface rockiness in Figure 3.9 is positively correlated in the direction of the arrow.
- Sub-community 3.2 is positively correlated with the rockiness (Figure 3.9). It is only found on areas with high percentages of soil surface rockiness on the south facing slopes of norite koppies.
- Sub-community 3.1 on the other hand, is negatively correlated with rockiness (Figure 3.9). This indicates that this sub-community is only found on areas with low percentages of soil surface rockiness on south facing slopes.
- Therefore, the environmental variable which distinguishes the two sub-communities found on southern slopes of norite koppies is the difference in percentage soil surface rockiness.



**Figure 3.9 Correspondence Analysis (CA) ordination bi-plot showing the correlations in species composition between the two sub-communities found on south facing slopes and indicating the percentage soil surface rockiness as the environmental variable influencing plant community structure and composition.**

- The percentage soil surface rockiness in Figure 3.10 is positively correlated in the direction of the arrow.
- Community 4 is positively correlated with the rockiness (Figure 3.10). It is only found on areas with high percentages of soil surface rockiness on the north facing slopes of norite koppies.
- Community 2 on the other hand, is negatively correlated with rockiness (Figure 3.10). This is an indication that Community 2 is only found on areas with low percentages of soil surface rockiness on northern slopes.
- Relevé 44 is further away from the cluster grouping of Community 4 than the rest of the relevés. The reason for this was explained during the discussion of Figure 3.8.



**Figure 3.10** Correspondence Analysis (CA) ordination bi-plot showing the correlations in species composition between the two plant communities found on north facing slopes and indicating the percentage soil surface rockiness as the environmental variable influencing plant community structure and composition.

- The relevés of Community 2 do not group closely together in this ordination (Figure 3.10). The reason for this was explained during the discussion of the *Pappea capensis-Heteropogon contortus* Community. The relevés are however distinctly apart from those of Community 4. This phenomenon - showing that there is a definite variation in species composition and as can be deduced from the ordination - is brought about by the difference in percentage soil surface rockiness found on north facing slopes.
- Similar to the south facing slopes, the rockiness is therefore the environmental variable which distinguishes the two communities found on north facing slopes of norite koppies.

### 3.3.2. Thornveld

This landscape category has a typical Savanna physiognomy (herbaceous component with a prominent woody layer) with numerous variations caused by soil type and anthropogenic disturbances. It covers more than 60% of the Impala Platinum mining area and includes the Zeerust- and Marikana Thornveld as well as the Central Sandy Bushveld vegetation types (Mucina & Rutherford, 2006).

Seventy three relevés (73) were sampled in the thornveld and four plant communities with two sub-communities were identified and described (Table 3.2). Species groups mentioned in the text refer to Table 3.2 and species with low constancy and cover that do not belong to differential groups are listed in the appendix (Table A2).

List of plant communities:

1. *Indigofera heterotricha-Aristida bipartita* Community
2. *Acacia caffra-Bothriochloa insculpta* Community
3. *Eragrostis rigidior-Ziziphus mucronata* Community
4. *Cyperus sexangularis-Cynodon dactylon* Riparian community
  - 4.1. *Searsia lancea-Cyperus sexangularis* Riparian sub-community
  - 4.2. *Paspalum distichum-Cyperus sexangularis* Riparian sub-community





Table 3.2 Phytosociological table of the Thornveld

RELEVÉ NUMBERS	1										2										3										4	
	1										2										3										4.1	4.2
<i>* Malvastrum coromandelianum</i>																																
<i>* Paspalum urvillei</i>																																
<i>Combretum erythrophyllum</i>																																
<i>Cyperus sp.</i>																																
<i>Salix mucronata</i>																																
<b>SPECIES GROUP F</b>																																
<i>* Flaveria bidentis</i>																																
<i>Cyperus congestus</i>																																
<i>* Paspalum dilatatum</i>																																
<i>* Dichanthium aristatum</i>																																
<i>Echinochloa holubii</i>																																
<i>Fimbristylis ferrugine</i>																																
<i>Lemna gibba</i>																																
<i>Sporobolus pyramidalis</i>																																
<i>Juncus rigidus</i>																																
<b>SPECIES GROUP G</b>																																
<i>Ischaemum afrum</i>																																
<i>Brachiaria eruciformis</i>																																
<i>Dichanthium annulatum</i>																																
<i>Setaria incrassata</i>																																
<i>Urelytrum agropyroides</i>																																
<i>Gladiolus elliotii</i>																																
<i>Hemizygia pretoriae</i>																																
<i>Fingerhuthia africana</i>																																
<i>Ziziphus zeyheriana</i>																																
<i>Seddera suffruticosa</i>																																
<i>Thesium utile</i>																																
<i>Tragia minor</i>																																
<i>Kohautia virgata</i>																																
<i>Cyphostemma hardyi</i>																																
<b>SPECIES GROUP H</b>																																
<i>Bothriochloa insculpta</i>																																
<i>Acacia nilotica</i>																																
<i>Aristida bipartita</i>																																
<i>Eragrostis chloromelas</i>																																
<i>Dichrostachys cinerea</i>																																
<i>Tephrosia purpurea</i>																																
<i>Crabbea hirsuta</i>																																





### 3.3.2.1. Description of plant communities

#### 1. *Indigofera heterotricha-Aristida bipartita* Community

This community covers the largest surface area of the Impala Platinum mining area. It has moderate to no slope and is distinguished by a definite, separate grassy and woody layer (Savanna). The woody component consists mainly of *Acacia* species. The community (Figure 3.11) is found on deep Arcadia soils derived from norite and anorthosite with a percentage soil surface rockiness of 10% or less. It includes a wide range of structural diversity. Many old, previously cultivated fields and anthropogenically disturbed areas surrounding informal settlements also form part of this community. These impacted areas have structural variation, especially in the woody component, compared to the natural form of this community but still form part of the *Indigofera heterotricha-Aristida bipartita* Community because of relatively similar species composition. The species composition is for this reason however less correlated than the rest of the plant communities and thus does vary. This will be evident in the ordination results that follow the community discussions.

Differential species are indicated by Species Group A which includes the forbs *Indigofera heterotricha* and *Sesbania transvaalensis* and the grass *Sorghum versicolor*. The dominant species is the grass *Aristida bipartita* (Species Group H). Other species include the trees *Acacia nilotica* (Species Group H) and *Acacia tortilis* (Species Group I) as well as the grass *Ischaemum afrum* (Species Group G).

Red Data List species: *Boopbone disticha* (Declining) (Table A2); *Cyphostemma hardyi* (VU) (Species Group G) (SANBI, 2009a)

Declared weeds and invaders: *Achyranthes aspera* (Species Group I) and *Opuntia ficus-indica* (Species Group C) (both in Category 1); *Cynodon dactylon* (Species Group L) (proposed Category 2) (Henderson, 2001)

*Dichrostachys cinerea* (Species Group H), which is found in this community, is an indigenous species to South Africa but is responsible for decreasing veld conditions throughout various parts of South Africa because of bush encroachment (Moleele *et. al.*, 2002). The grazing capacity of areas is decreased by the establishment of this species and its spreading and increase thereof must thus be monitored and minimized.



**Figure 3.11** The *Indigofera heterotricha-Aristida bipartita* Community. GPS: lat 25°25'48.5"S, long 27°10'07.9"E. Notice the typical Savanna physiognomy. The area is dominated by *Acacia* species and the soil is classified as Arcadia. The dominant grass and woody species, *Aristida bipartita* and *Acacia tortilis* can be seen in the photograph.

The average species richness is 31 species per relevé of which 8% are alien species. As is expected from a typical Savanna area, the community is dominated by a grass layer (66% cover) that rarely exceeds 1.7 m in height and it also features a well developed woody component that may exceed 30% cover. The height of the woody stratum is mostly less than 6 m. A forb layer of approximately 10% cover is also present in this community with species that grow up to 1.5 m high.

The area south of the Bospoort dam is classified as part of this community although it is very diverse and shares species with the *Eragrostis rigidior-Ziziphus mucronata* Community as well as with plant communities from the norite koppies such as the *Pappea capensis-Heteropogon contortus-* and *Setaria lindenbergiana-Dombeya rotundifolia* Communities. There are multiple areas where soil types derived from norite mother materials and outcrops mixed with Arcadia soils are visible. This influences the species composition in a unique way and therefore various groups of species, shared between different communities, are found. This area south of the Bospoort dam can also possibly be seen as a wide ecotone between the norite koppies and the thornveld. It should, however, be sampled more comprehensively in future monitoring studies to ensure a better understanding of its ecological functionality.

## **2. *Acacia caffra-Bothriochloa insculpta* Community**

This community (Figure 3.12) covers a small surface area compared to the other plant communities found in the thornveld. It is mostly confined to a specific geographic location in the south-west of the Impala Platinum mining area but is also found further north on moderate rocky ridges inside the *Indigofera heterotricha-Aristida bipartita* Community. The soil type present in this community is shallow Shortlands situated on an old alluvial plain.

The underground plant available water is therefore low because of the shallow soils. The percentage soil surface rockiness is mostly low but can reach 50% on the rocky ridge areas and this surface rock is derived from Quartzite.

The woody species *Acacia caffra* is differential whilst the dominant species is the grass *Bothriochloa insculpta* (Species Group H). Other species include the grasses *Cymbopogon pospischilii* (Species Group H) and *Themeda triandra* (Species Group H) as well as the tree *Acacia tortilis* (Species Group I).

Red Data List species: *Cyphostemma hardyi* (VU) (Species Group G) (SANBI, 2009a)



**Figure 3.12** The *Acacia caffra-Bothriochloa insculpta* Community. GPS: lat 25°32'55.4"S, long 27°18'44.5"E. Notice the dominance of the woody species *Acacia caffra*. The grass species, *Bothriochloa insculpta* can also be seen dominating the herbaceous layer in the photograph.

The average species richness is 36 species per relevé of which 2% are alien species. The woody layer (45% cover) is dominated by *Acacia caffra* shrubs and trees varying between 1 m and 5 m in height. The grass layer is the dominant stratum with a cover of 63% while the forbs layer covers only 8%. The grass layer can reach 2 m in height while the forb layer is mostly comprised of low growing species. Few climber species are however present and can grow 3 m up into trees.

### **3. *Eragrostis rigidior-Ziziphus mucronata* Community**

This community (Figure 3.13) is found on deep red-brown Shortlands and Oakleaf soils derived from norite with a low percentage soil surface rockiness (with Quartzite origin) that rarely exceeds 20%. The soil depth and therefore also the increase in underground plant available water is what distinguishes this community from the *Acacia caffra-Bothriochloa insculpta* Community which is also found on Shortlands soil. Because of this availability, the woody layer is significantly denser and is not dominated by *Acacia* species like the first two

thornveld plant communities but rather consists of a variety of broadleaved and fine leaved species.

Differential species are indicated by Species Group C. They include the grasses *Eragrostis rigidior* and *Urochloa mosambicensis* and the forb *Felicia muricata*. The dominant species is the tree *Ziziphus mucronata* (Species Group I) while other species also include the tree *Searsia pyroides* (Species Group I); the shrub *Grewia flava* (Species Group J) and the grass *Panicum maximum* (Species Group K).

Red Data List species: *Lotononis globulosa* (VU) (Table A2); *Solanum supinum* (VU) (Table A2) (SANBI, 2009a)

Protected species: *Boscia albitrunca* (Table A2); *Combretum imberbe* (Table A2) (SANBI, 2009b)

Declared weeds and invaders: *Achyranthes aspera* (Species Group I); *Opuntia ficus-indica* (Species Group C); *Tecoma stans* (Table A2) and *Nicotiana glauca* (Table A2) (all in Category 1); *Cynodon dactylon* (Species Group L) (proposed Category 2); *Jacaranda mimosifolia* (Table A2) (Category 3); *Schinus molle* (Table A2) (proposed Category 3) (Henderson, 2001)

*Dichrostachys cinerea* (Species Group H) is also found in this community. The presence of this species could later cause a decrease in veld condition (Moleele *et. al.*, 2002) especially if its density starts increasing. Its spreading should therefore be closely monitored.



**Figure 3.13** The *Eragrostis rigidior-Ziziphus mucronata* Community. GPS: lat 25°33'57.6"S, long 27°12'31.0"E. Notice the dense woody layer that includes broad - and fine leaved species. The red-brown Shortlands and Oakleaf soils on which this community is found is also seen in the photograph.

The average species richness is 51 species per relevé of which 7% are alien species. As has been mentioned, the woody component of this community is significantly denser (60% cover) than the other thornveld plant communities that have been described. It is the

dominant stratum of this community with a fairly equal mixture of trees and shrubs that can grow up to 7 m high. The grass layer is also prominent (49% cover) with mostly low growing grasses but some species can reach 2 m in height. A well developed forbs layer (13% cover) is also present because of less intense exposure to direct sunlight caused by the prominent woody layer.

#### **4. *Cyperus sexangularis-Cynodon dactylon* Riparian community**

This community is found in and around rivers and small streams. The rivers/streams can flow seasonal or all year long. This interrupted seasonal flow in certain areas enables the establishment of vegetation on river/stream beds in the dry seasons. Oakleaf soil is present in a narrow strip on the river- and stream banks while the river bed consists of Tukulu, Willowbrook and Rensburg soils which are mostly high in organic content. The percentage soil surface rockiness is less than 5%.

Differential species are indicated by Species Group D. It includes the forb *Cyperus sexangularis* as well as the grasses *Paspalum distichum* and *Bothriochloa bladhii*. The dominant species is the grass *Cynodon dactylon* (Species Group L) and other species include the forbs *Flaveria bidentis* (Species Group F), *Cyperus esculentus* (Species Group E) and *Verbena bonariensis* (Species Group E).

Declared weeds and invaders: *Achyranthes aspera* (Species Group I); *Sesbania punicea* (Species Group E); *Xanthium strumarium* (Species Group E) and *Tithonia rotundifolia* (Table A2) (all in Category 1); *Cynodon dactylon* (Species Group L) (proposed Category 2); *Morus nigra* (Table A2) (proposed Category 3) (Henderson, 2001)

The average species richness is 22 species per relevé of which 32% are alien species. The grass layer is dominant with a cover of 50%. Certain grass species found in this community can reach a height of 2.2 m. The woody component rarely exceeds 20% cover and is mostly comprised of trees that can reach 6 m in height and also few shrubs. The forbs layer is very well developed (40% cover) especially because of being close to water and having adequate protection from direct sunlight. Hydrophytic forbs species dominate this stratum.

This community can be divided into two sub-communities based on the consistency of flow of the water source.

##### **4.1. *Searsia lancea-Cyperus sexangularis* Riparian sub-community**

This sub-community (Figure 3.14) is found on the banks of perennial rivers. It is characterized by the riparian vegetation around the river edge and a definite woody component that features all along the banks of rivers. A well developed woody component,

because of constant all year water flow, is what separates this sub-community from the second sub-community. This woody component can extend up to 30m into the surrounding thornveld. Soil surface rockiness is less than 5%.

Differential species are indicated by Species Group E which includes the forbs *Xanthium strumarium* and *Persicaria lapathifolia*. However, this group consists mostly of exotic species and the indigenous species that are present have low cover abundance values. Therefore this sub-community is rather characterized by a high abundance of the tree *Searsia lancea* (Species Group I), although not a differential species, which is absent in Sub-community 4.2. The dominant species is the forb *Cyperus sexangularis* (Species Group D) and other species include the trees *Acacia karroo*, *Searsia pyroides* and *Ziziphus mucronata* (all in Species Group I).

Declared weeds and invaders: *Achyranthes aspera* (Species Group I); *Sesbania punicea* (Species Group E); *Xanthium strumarium* (Species Group E) and *Tithonia rotundifolia* (Table A2) (all in Category 1); *Cynodon dactylon* (Species Group L) (proposed Category 2); *Morus nigra* (Table A2) (proposed Category 3) (Henderson, 2001)



**Figure 3.14** The *Searsia lancea*-*Cyperus sexangularis* Riparian sub-community. GPS: lat 25°31'52.0"S, long 27°10'30.4"E. Notice the well developed woody stratum consisting of tall trees on the banks of the river as well as the very tall grass species present. The differential species *Searsia lancea* is also present in the photograph.

The average species richness is 49 species per relevé of which 24% are alien species. The woody component consists mostly of trees rather than shrubs and has a similar cover to the grass layer (45% cover each). Trees can reach 6 m in height and grasses found in these areas are mostly tall species which can grow up to 2.2 m high. The forbs layer is also well developed (28% cover) because of adequate water and protection against intense sunlight. Various hydrophytes and climber species are present.

#### 4.2. *Paspalum distichum*-*Cyperus sexangularis* Riparian sub-community

This sub-community (Figure 3.15) is present on the banks and beds of small streams that have interrupted seasonal flow. The river beds are thus dry for a large part of the year and this enables the periodic establishment of vegetation. The lack of a reliable constant water source during the year restricts the establishment of a woody component and this factor is what distinguishes this sub-community from the first one. Hardly any soil surface rockiness is present (less than 5%).

Differential species are indicated by Species Group F which includes the grass *Paspalum distichum* (Species Group D) and the forbs *Flaveria bidentis* and *Cyperus congestus*. The dominant species is the forb *Cyperus sexangularis* (Species Group D) and other species include the grasses *Cynodon dactylon* (Species Group L) and *Bothriochloa bladhii* (Species Group D) as well as the forb *Typha capensis* (Species Group D).

Declared weeds and invaders: *Achyranthes aspera* (Species Group I); *Sesbania punicea* (Species Group E) and *Xanthium strumarium* (Species Group E) (all in Category 1); *Cynodon dactylon* (Species Group L) (proposed Category 2) (Henderson, 2001)



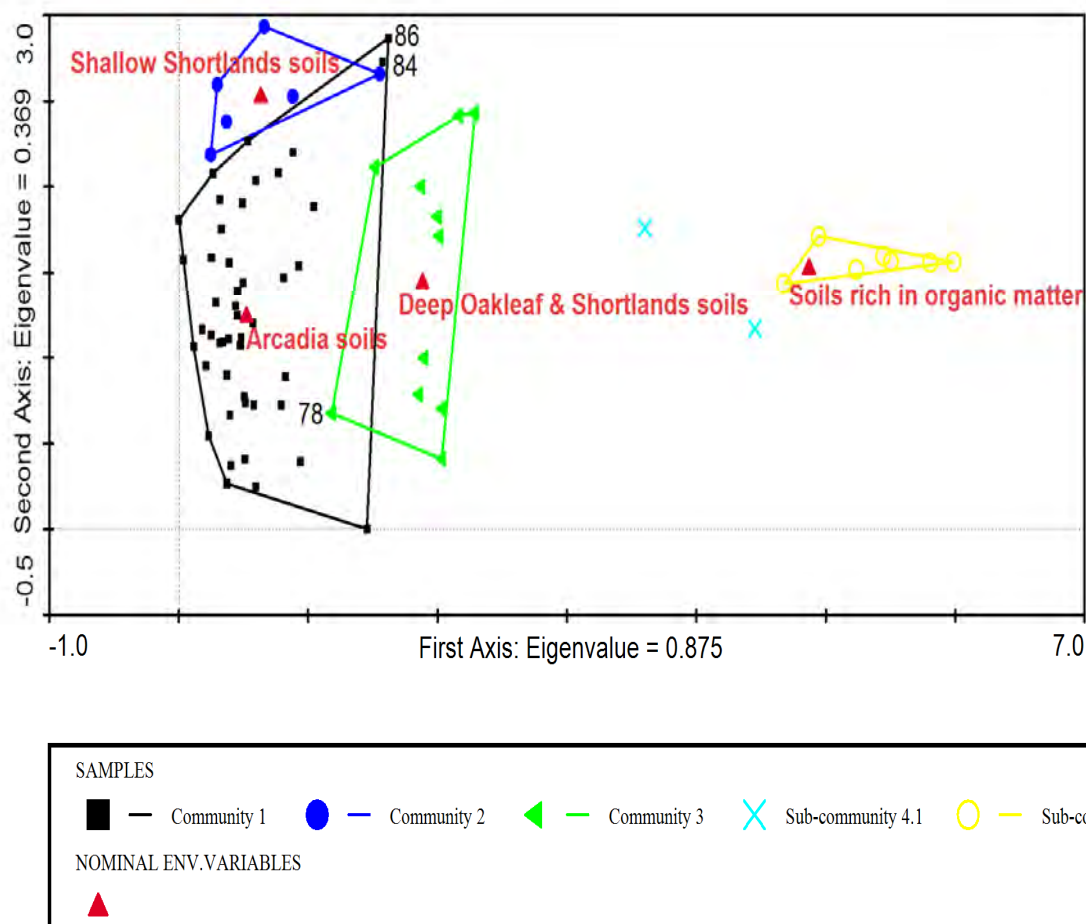
**Figure 3.15**The *Paspalum distichum*-*Cyperus sexangularis* Riparian sub-community. GPS: lat 25°26'19.1"S, 27°10'45.6"E. Notice the absence of a woody layer which distinguishes it from sub-community 4.1. Also notice the dominance of the forb *Cyperus sexangularis* along the banks.

The average species richness is 15 species per relevé of which 24% are alien species. There is almost no woody layer present in this sub-community (1% cover) and it exclusively consists of shrubs less than 1 m in height. There are no trees present because of the lack of an adequate, constant water supply. The grass (50% cover) and forbs layer (40% cover) are prominent in these areas. Various water forbs and grass species account for the high percentage cover. Grass species seldom grow higher than 1.6 m.

### 3.3.2.2. Ordinations

Detrended Correspondence Analysis (DCA) ordinations were carried out to verify the plant communities and indicate the correlation in species composition between the plant communities as well as to identify environmental gradients that influence plant community structure and composition (Figure 3.16).

- Relevé number 126 was identified as an outlier and was therefore left out of the ordination (Figure 3.16). The reason for this phenomenon is that it only had one diagnostic species from Sub-community 4.2 (Species Group F) although containing a number of diagnostic species from community 4 (Species Group D). At the time when relevé number 126 was surveyed, this particular stream had more water than the rest of the seasonal streams that were sampled and this could serve as a possible reason for the absence of many of the diagnostic species.



**Figure 3.16** Detrended Correspondence Analysis (DCA) ordination bi-plot showing the correlations in species composition between the plant communities of the thornveld and indicating the soil type as the environmental variable influencing plant community structure and composition.

- The relevés representing Community 1 form a larger grouping than the rest of the communities (Figure 3.16). Relevé numbers 84 and 86 are further away from the cluster of Community 1 than the rest of the relevés in the community. The reason for this is that these two relevés were sampled in an area situated around informal settlements where development is taking place. It is therefore very disturbed and over-grazed.
- The relevés representing Communities 2 and 3 also form close groupings (Figure 3.16). Relevé number 78 is however further away from the grouping formed by the relevés of Community 3 and is found closer to the cluster of Community 1. The reason for this is that relevé number 78 was sampled in the area south of the Bospoort dam and the uniqueness of that area was explained in the community discussion.
- Close groupings are also formed by the relevés representing Sub-communities 4.1 and 4.2 confirming their similarities in species composition (Figure 3.16).
- The soil type is the main environmental variable that influences plant community structure and composition in the thornveld as is evident from the ordination results. Community 1 is present on deep Arcadia soils while Community 2 is found only on shallow Shortlands soils. Community 3, on the other hand is found on deep Shortlands and Oakleaf soils and Sub-communities 4.1 and 4.2 on Oakleaf, Tukulu, Willowbrook and Rensburg soils that are mostly high in organic content.
- A moisture gradient which increases from left to right on the first axis is also visible. Community 4 is found in and around water sources while Communities 1, 2 and 3 are found in the drier thornveld areas.

### 3.3.3. Rehabilitated areas

The rehabilitated areas that were sampled in the Impala Platinum mining area consist of the old platinum tailings dam (operation ceased in the 1970's but according to the head of Impala Platinum's Environmental Department, Mr. G van Dyk, no proper records were kept of rehabilitation processes), the new tailings dam (which is currently in use but the side slopes are rehabilitated on a continuous basis) and areas where old opencast-mines have been rehabilitated (started approximately seven years ago and is still ongoing according to Mr. G van Dyk).

Twenty three relevés (23) were sampled in these rehabilitated areas and three plant communities with three sub-communities were identified and described (Table 3.3). Species groups mentioned in the text refer to Table 3.3 and species with low constancy and cover that do not belong to differential groups are listed in the appendix (Table A3).

List of plant communities:

1. *Acacia galpinii-Chloris gayana* Community
2. *Hyparrhenia hirta-Cenchrus ciliaris* Community
  - 2.1. *Pseudognaphalium luteo-album-Arundo donax* Sub-community
  - 2.2. *Dodonaea angustifolia-Cenchrus ciliaris* Sub-community
  - 2.3. *Imperata cylindrica-Tamarix ramosissima* Sub-community
3. *Aristida bipartita-Bothriochloa insculpta* Community

**Table 3.3 Phytosociological table of the Rehabilitated areas**

RELEVÉ NUMBERS	5	4	4	4	5	5	5	5	6	5	5	4	5	5	6	6	7	7	6	6	9	9	
	4	6	7	9	0	2	3	7	8	1	5	6	8	9	1	0	7	1	2	8	9	1	3
PLANT COMMUNITIES	1				2			3															
					2.1		2.2	2.3															
<b>SPECIES GROUP A</b>																							
<i>Acacia galpinii</i>	b	b	a	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Faidherbia albida</i>	.	1	b	b	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Panicum maximum</i>	.	+	1	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Withania somnifera</i>	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Pseudognaphalium undulatum</i>	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Searsia pyroides</i>	.	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Acacia robusta</i>	a	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Asparagus suaveolens</i>	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Lantana rugosa</i>	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
* <i>Morus nigra</i>	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
* <i>Tecoma stans</i>	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Acacia xanthophloea</i>	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Acacia burkei</i>	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<b>SPECIES GROUP B</b>																							
<i>Hyparrhenia hirta</i>	+	.	.	.	.	1	.	a	a	+	+	.	+	1	1	1	.	.	.	.	.	.	
<i>Gomphocarpus fruticosus</i>	.	.	.	.	.	.	.	+	+	.	+	1	+	+	+	+	+	.	+	.	+	+	
<i>Polygala hottentotta</i>	.	.	.	.	.	+	.	+	+	.	+	+	+	+	+	+	.	.	.	.	.	.	
<b>SPECIES GROUP C</b>																							
* <i>Arundo donax</i>	.	.	.	.	.	1	4	3	4	a	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Pseudognaphalium luteo-album</i>	.	+	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Chamaecrista mimosoides</i>	.	.	.	.	.	+	.	+	1	.	.	.	.	.	.	.	.	.	.	.	+	.	
<i>Mundulea sericea</i>	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Sida rhombifolia</i>	.	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	
<b>SPECIES GROUP D</b>																							
<i>Dodonaea angustifolia</i>	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	1	.	.	.	.	.	.	
<i>Momordica boivinii</i>	+	.	+	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	
* <i>Zinnia peruviana</i>	.	+	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	+	
* <i>Solanum nigrum</i>	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	
<b>SPECIES GROUP E</b>																							
* <i>Conyza bonariensis</i>	.	.	+	.	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	
<i>Pellaea calomelanos</i>	.	.	.	.	.	.	.	.	+	1	.	.	+	.	+	.	.	.	.	.	.	.	
<i>Eragrostis trichophora</i>	.	+	.	.	+	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Heteropogon contortus</i>	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	1	.	+	.	.	.	
* <i>Schkuhria pinnata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Cheilanthes viridis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	
<b>SPECIES GROUP F</b>																							
<i>Imperata cylindrica</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	a	3	3	a	.	.	.	.	
* <i>Pennisetum setaceum</i>	.	+	+	1	+	.	.	.	.	.	.	.	.	.	a	.	a	a	.	.	.	+	
<i>Kyphocarpa angustifolia</i>	.	.	.	.	.	+	.	.	+	.	.	.	.	.	+	+	+	+	.	.	.	.	
<i>Seriphium plumosum</i>	1	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	1	.	.	.	.	.	
<i>Aristida congesta s. barbicollis</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	
<i>Andropogon eucomus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	
<i>Aristida congesta s. congesta</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	
<i>Dicoma macrocephala</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	
<i>Helichrysum caespitium</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	
<b>SPECIES GROUP G</b>																							
<i>Chloris gayana</i>	1	b	b	+	1	+	1	+	+	1	.	+	+	1	+	1	.	.	.	.	.	.	
<i>Melinis repens</i>	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	+
<i>Cenchrus ciliaris</i>	4	a	1	+	.	3	b	+	.	3	3	4	.	a	.	1	.	.	.	.	.	.	
<i>Pogonarthria squarrosa</i>	.	+	.	b	3	a	+	a	1	b	.	.	.	1	1	+	a	.	.	.	.	.	
<i>Felicia muricata</i>	+	+	.	.	+	+	1	+	1	+	+	.	.	.	+	+	.	.	.	.	.	.	
<i>Eragrostis curvula</i>	+	.	+	.	+	1	+	1	1	.	.	.	.	1	+	a	+	.	.	.	.	.	
* <i>Bidens bipinnata</i>	+	+	+	+	1	.	+	.	.	+	1	+	.	.	.	.	.	.	.	.	.	.	

Table 3.3 Phytosociological table of the Rehabilitated areas

RELEVÉ NUMBERS	5	4	4	4	5	5	5	5	6	5	5	4	5	5	6	6	7	7	6	6	9	9				
	4	6	7	9	0	2	3	7	8	1	5	6	8	9	1	0	7	1	2	8	9	1	3			
PLANT COMMUNITIES	2																									
	1				2.1			2.2		2.3			3													
	* <i>Tamarix ramosissima</i>	1	1	1	1	1	.	.	.	.	+	a	.	a	.	b	b	.	.	.	.	.	.			
<i>Enneapogon cenchroides</i>	.	+	+	1	a	.	.	.	+	1	+	.	+	.	.	.	.	.	.	.	.	.				
<i>Digitaria eriantha</i>	+	a	+	+	.	.	+	.	.	.	.	+	+	1	.	.	.	.	.	.	.	.				
<i>Pentarrhinum inspidum</i>	.	1	+	1	+	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.				
<i>Searsia lancea</i>	+	+	1	.	+	.	.	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.				
<i>Aloe greatheadii</i>	+	+	.	.	.	.	+	+	.	.	+	.	+	+	.	.	.	.	.	.	.	.				
<i>Eragrostis rigidior</i>	.	.	.	1	.	.	.	+	.	+	.	.	+	+	.	.	.	.	.	.	.	.				
<i>Clematis brachiata</i>	.	.	1	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.				
<b>SPECIES GROUP H</b>																										
<i>Bothriochloa insculpta</i>	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	3	b	4	4	a	1	+	
<i>Aristida bipartita</i>	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	b	3	a	a	1	3	b	
<i>Rhynchosia minima</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	a	1	1	1	
<i>Eragrostis chloromelas</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	+	+	+	.	
<i>Acacia nilotica</i>	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	+	+	+	
<i>Hibiscus trionum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	
<i>Ischaemum afrum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	1	+	1	1	
<i>Brachiaria eruciformis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	b	a	1	
<i>Sesbania transvaalensis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	1	1	1	1	
<i>Tephrosia purpurea</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	
<i>Dichanthium annulatum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	+	
<i>Sorghum versicolor</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	1	1	
<i>Setaria incrassata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	1	b	.	
<i>Corchorus asplenifolius</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	+	
<i>Urochloa mosambicensis</i>	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	+	+	
<i>Hermannia coccocarpa</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	
<i>Jatropha schlechteri</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	.	.	
<i>Gladiolus elliotii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	+	
<i>Dichrostachys cinerea</i>	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	
<i>Ziziphus mucronata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	
<i>Convolvulus sagittatus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	1	
<i>Cymbopogon pospischilii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	+	.	+	
<i>Indigofera heterotricha</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	+	
<i>Turbina oblongata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	
<i>Acacia mellifera</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	
<i>Nidorella anomala</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	
<i>Themeda triandra</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	
<i>Solanum panduriforme</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	
<i>Asparagus setaceus</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	
<i>Crabbea hirsuta</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	
<i>Jamesbrittenia aurantiaca</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	
<i>Laggera decurrens</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	
<i>Salvia runcinata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	
<i>Phyllanthus maderaspatensis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	1
<i>Cucumis zeyheri</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	a	
<i>Panicum volutans</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	
<i>Asparagus laricinus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	
<i>Fingerhuthia africana</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	
<i>Euphorbia inaequilatera</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	
<i>Crotalaria lotoides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	
<b>SPECIES GROUP I</b>																										
<i>Cynodon dactylon</i>	.	1	b	+	+	.	.	+	+	+	+	1	.	.	.	.	+	.	.	1	+	+	1	+	+	
* <i>Tagetes minuta</i>	+	+	+	+	a	.	.	+	1	+	1	1	+	.	1	.	.	.	.	.	.	.	+	+	+	
<i>Acacia tortilis</i>	1	.	.	.	.	1	.	.	.	.	.	1	.	.	1	.	.	+	+	+	+	.	.	.		
* <i>Flaveria bidentis</i>	.	+	+	+	+	.	.	.	.	+	1	+	.	.	1	.	.	+	.	.	.	.	.	.	+	
<i>Acacia karroo</i>	1	.	1	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	+	+	.	.	.	.	+	
<i>Vernonia poskeana</i>	.	.	+	.	.	.	+	1	.	.	.	.	+	+	.	.	.	.	.	.	.	+	.	.	+	
* indicates an alien species																										

### 3.3.3.1. Description of plant communities

#### 1. *Acacia galpinii*-*Chloris gayana* Community

This community (Figure 3.17) is present on the plateaus of the tailings dams. The soil found on the tailings dams is classified as Witbank soil which consists of fine mine sludge and for this reason no soil surface rockiness is present.

Differential species are indicated by Species Group A. They include the trees *Acacia galpinii* and *Faidherbia albida* as well as the grass *Panicum maximum*. The dominant species is the grass *Chloris gayana* (Species Group G) and other species in this community include the grass *Cenchrus ciliaris* (Species Group G); the tree *Tamarix ramosissima* (Species Group G) and the forb *Tagetes minuta* (Species Group I).

Declared weeds and invaders: *Achyranthes aspera* (Table A3); *Pennisetum setaceum* (Species Group F); *Tamarix ramosissima* (Species Group G); *Tecoma stans* (Species Group A) and *Nicotiana glauca* (Table A3) (all in Category 1); *Cynodon dactylon* (Species Group I) (proposed Category 2); *Jacaranda mimosifolia* (Table A3) (Category 3); *Morus nigra* (Species Group A); *Schinus molle* (Table A3) (both proposed Category 3) (Henderson, 2001)



**Figure 3.17**The *Acacia galpinii*-*Chloris gayana* Community. GPS: lat 25°31'31.1"S, long 27°11'49.2"E. Notice the dominant grass layer with a well developed woody component consisting mainly of the differential species *Acacia galpinii* and *Faidherbia albida* which do not occur in the surrounding natural areas.

Woody species such as *Acacia galpinii*, *A. xanthophloea* and *Faidherbia albida* (all in Species Group A) are indigenous species to South Africa (Germishuizen *et. al.*, 2006). These species do however not occur in the surrounding natural plant communities. *Seriphium plumosum* (Species Group F) is also an indigenous species but is responsible for major damages throughout various parts of South Africa because of bush encroachment (Hatting, 1953). The grazing capacity of areas is decreased by the establishment of this

species. Its presence in this community is however low and therefore it doesn't pose an immediate threat if these areas were ever to be utilized as grazing in future.

The average species richness is 29 species per relevé of which 23% are alien species. The grass layer is the dominant stratum (55% cover) because favourable conditions for an herbaceous layer were created and a large number and variety of grass seeds were sown in during the rehabilitation processes. A prominent tree layer (27% cover) reaching up to 15 m in height has established because multiple trees were also planted during the rehabilitation processes more than 30 years ago. As is expected in normal woody grasslands, the forb layer is not as prominent as the other strata (8% cover) and is confined mainly to growing close to the ground. However some climber species grow up to 4 m into trees.

## **2. *Hyparrhenia hirta-Cenchrus ciliaris* Community**

This community is found on the plateaus and the embankments (20°- 40°) of the tailings dams and therefore the soil type is also Witbank.

Differential species are indicated by Species Group B. They include the grass *Hyparrhenia hirta* and the forbs *Gomphocarpus fruticosus* and *Polygala hottentotta*. The dominant species is the grass *Cenchrus ciliaris* (Species Group G) and other species include the grasses *Pogonarthria squarrosa* (Species Group G) and *Chloris gayana* (Species Group G) and the forb *Felicia muricata* (Species Group G).

Declared weeds and invaders: *Cynodon dactylon* (Species Group I) (proposed Category 2); *Eucalyptus camaldulensis* (Table A3) (Category 2); *Arundo donax* (Species Group C), *Achyranthes aspera* (Table A3); *Cirsium vulgare* (Table A3); *Tamarix ramosissima* (Species Group G); *Tecoma stans* (Species Group A), *Nicotiana glauca* (Table A3) and *Pennisetum setaceum* (Species Group F) (all in Category 1) (Henderson, 2001). The problematic bush encroachment species, *Seriphium plumosum* (Species Group F) is present in this community too.

The average species richness is 26 species per relevé of which 21% are alien species. The areas where no trees were initially planted during the rehabilitation processes are dominated by grasses (57% cover) and some very tall grass species which can grow up to 5 m high are found in certain sub-communities. The forbs layer on the other hand only covers 5% and mostly consists of low growing species as can be expected from such open grasslands. The woody component covers less than 10% of the community but tall trees are sporadically found. Some climber species tend to grow in this sparse woody layer and can grow as high as 3 m into trees.

This community can be divided into three sub-communities.

## 2.1. *Pseudognaphalium luteo-album*-*Arundo donax* Sub-community

This sub-community (Figure 3.18) is found on the embankments of the tailings dams and no soil surface rock cover is present. It is found in areas with slopes varying from 25°-40° and can be distinguished from the other two sub-communities by the absence of Species Groups D and F.

Differential species are indicated by Species Group C which includes the forbs *Pseudognaphalium luteo-album* and *Chamaecrista mimosoides* as well as the grass *Arundo donax* which is also the dominant species. Other species include the grass *Eragrostis curvula* (Species Group G) as well as the forbs *Conyza bonariensis* (Species Group E) and *Felicia muricata* (Species Group G).

Declared weeds and invaders: *Arundo donax* (Species Group C) and *Tamarix ramosissima* (Species Group G) (both in Category 1); *Cynodon dactylon* (Species Group I) (proposed Category 2); *Eucalyptus camaldulensis* (Table A3) (Category 2) (Henderson, 2001)

It must be noted that *Arundo donax*, which is the dominant species in this sub-community is a Category 1 alien weed species in South Africa (Henderson, 2001). *Seriphium plumosum* (Species Group F) is also found in low abundances in this sub-community.



**Figure 3.18**The *Pseudognaphalium luteo-album*-*Arundo donax* Sub-community. GPS: lat 25°30'41.2"S, long 27°13'23.4"E. Notice the total dominance of the grass species, *Arundo donax* which is listed as a category 1 declared weed and invader. This species reaches up to 5m in height in many parts of the sub-community.

The average species richness is 24 species per relevé of which 21% are alien species. This sub-community is dominated by tall grass species (65% cover) that reach 5 m in height but smaller grasses can also be prominent in some areas. The combined cover of the woody component and the forb layer is less than 10% of the area and most trees are less than 6 m

high with no climber species present. The forb layer is made up of low growing species that rarely exceed 1 m in height.

## 2.2. *Dodonaea angustifolia*-*Cenchrus ciliaris* Sub-community

The second sub-community (Figure 3.19) is found on the embankments (20°- 40°) of the tailings dams. It can be distinguished from the third sub-community by the absence of Species Group F.

Differential species are indicated by Species Group D. They include the shrub *Dodonaea angustifolia* and the forbs *Momordica boivinii* and *Zinnia peruviana* while the dominant species is the grass *Cenchrus ciliaris* (Species Group G). Other species include the forbs *Tagetes minuta* (Species Group I) and *Gomphocarpus fruticosus* (Species Group B) as well as the grass *Melinis repens* (Species Group G).

Declared weeds and invaders: *Achyranthes aspera* (Table A3); *Cirsium vulgare* (Table A3); *Tamarix ramosissima* (Species Group G); *Tecoma stans* (Species Group A) and *Nicotiana glauca* (Table A3) (all in Category 1); *Cynodon dactylon* (Species Group I) (proposed Category 2) (Henderson, 2001). *Seriphium plumosum* (Species Group F) is once again present in this sub-community.



**Figure 3.19** The *Dodonaea angustifolia*-*Cenchrus ciliaris* Sub-community. GPS: lat 25°31'49.0"S, long 27°14'47.5"E. Notice the significantly lower growing grass species than in sub-community 2.1. The dominant species, the grass *Cenchrus ciliaris* can be seen in the photograph.

The average species richness is 30 species per relevé of which 23% are alien species. A low growing grass layer which rarely exceeds 1.5 m in height is the dominant stratum in this community (65% cover). The woody and forb layers cover less than 10% each and the woody component rarely exceeds 5 m in height whilst the forb species are mostly small and occasionally climber species are found which reach 3 m up into trees.

### 2.3. *Imperata cylindrica*-*Tamarix ramosissima* Sub-community

The third sub-community (Figure 3.20) is only found on the plateaus and horizontal terraces of the tailings dams. Its presence is mostly confined to the central parts of the tailings plateaus, where the salinity is higher due to finer soil texture, rather than on the outskirts.

Differential species are indicated by Species Group F which includes the grasses *Imperata cylindrica* and *Pennisetum setaceum* and the forb *Kyphocarpa angustifolia*. The dominant species is the shrub *Tamarix ramosissima* (Species Group G) and other species include the grasses *Pogonarthria squarrosa* (Species Group G), *Eragrostis curvula* (Species Group G) and *Hyparrhenia hirta* (Species Group B).

Declared weeds and invaders: *Cynodon dactylon* (Species Group I) (proposed Category 2); *Pennisetum setaceum* (Species Group F) and *Tamarix ramosissima* (Species Group G) (both in Category 1) (Henderson, 2001)

*Seriphium plumosum* (Species Group F) and the Category 1 invader species *Tamarix ramosissima* (Species Group G) (Henderson, 2001) are present in higher abundance than in the other sub-communities. This is also evident from Figure 3.20. *Tamarix ramosissima* (Species Group G) is capable of germinating in soils with high salinity and for this reason it is largely present in this sub-community rather than in the others which have soils with salinities too low for its germination. The plateau areas of the tailings dams offer potential for future grazing practices and if this is to be considered, the spreading and increase of these species must be monitored and minimized.



Figure 3.20 The *Imperata cylindrica*-*Tamarix ramosissima* Sub-community. GPS: lat 25°31'00.2"S, long 27°11'48.6"E. Notice the large areas of bare soil on the surface. The differential grass species, *Imperata cylindrica* can be seen in the photograph and the dominant species, the shrub *Tamarix ramosissima* is also present in the background. Also notice the presence of the problematic encroachment species, *Seriphium plumosum*.

The average species richness is 24 species per relevé of which 8% are alien species. The grass layer covers 37% while the woody component combined with the forb layer covers about 25%. The grass layer can reach 1.5 m in height while the woody layer consists mainly of shrubs and small trees that are less than 3.5 m in height. The forb layer never exceeds 1.8 m. More than half of the soil surface in this sub-community is bare ground and this indicates that re-establishment of vegetation after rehabilitation was not very successful in these areas. Such areas can be identified as possible erosion hazards.

### 3. *Aristida bipartita-Bothriochloa insculpta* Community

This community (Figure 3.21) characterizes the opencast mining areas that have been rehabilitated. The percentage soil surface rockiness is very low, varying between 2% and 5% and the soil type found in this community is Witbank (which refers to the top soil used to cover the mine spoils). There is variation in the ages of these rehabilitated opencast areas and for this reason the species composition and ecological status of species can differ slightly between sampled sites.

Differential species are indicated by Species Group H. They include the grasses *Aristida bipartita* and *Bothriochloa insculpta* as well as the forb *Rhynchosia minima*. *Bothriochloa insculpta* (Species Group H) is also the dominant species in this community. Other species include the grass *Cynodon dactylon* (Species Group I); the tree *Acacia tortilis* (Species Group I) and the forb *Gomphocarpus fruticosus* (Species Group B).

Declared weeds and invaders: *Cirsium vulgare* (Table A3) and *Pennisetum setaceum* (Species Group F) (both in Category 1); *Cynodon dactylon* (Species Group I) (proposed Category 2); *Ricinus communis* (Table A3) (Category 2) (Henderson, 2001)



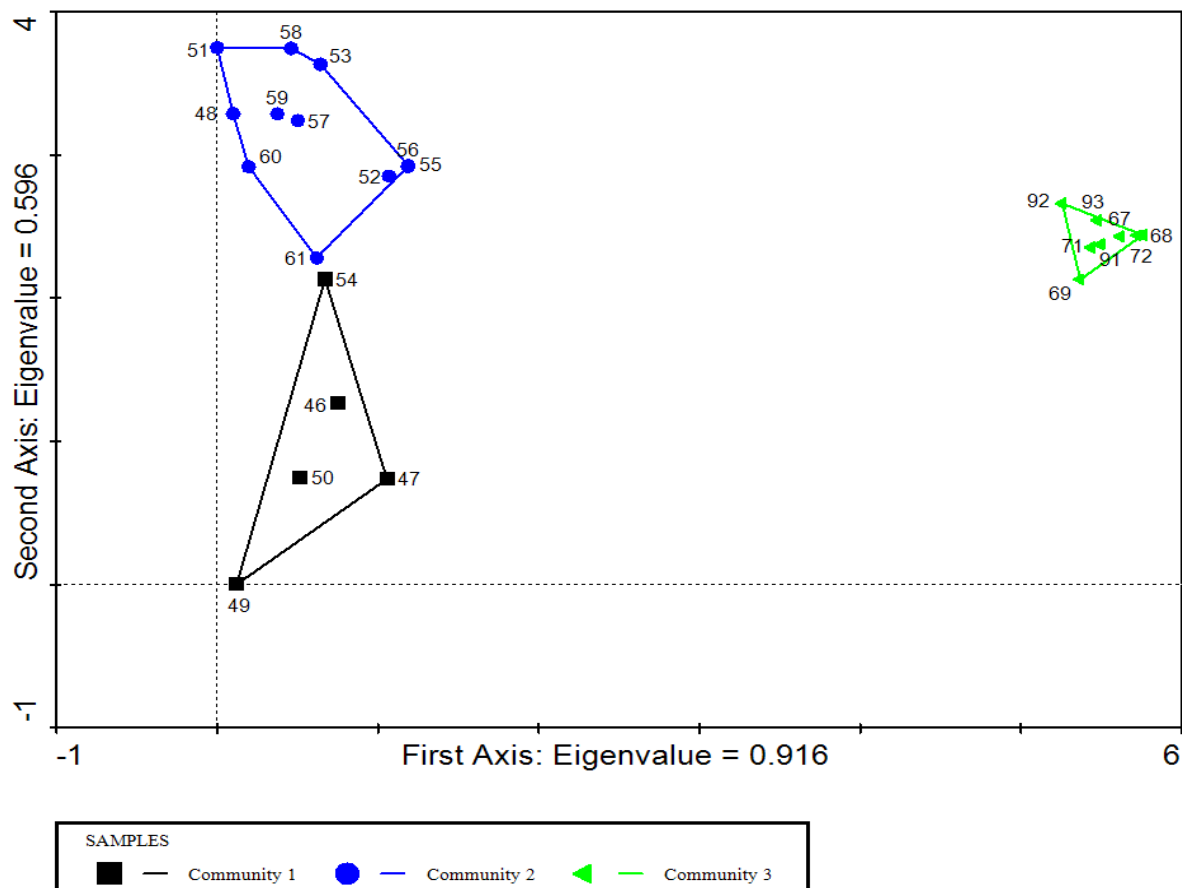
Figure 3.21 The *Aristida bipartita-Bothriochloa insculpta* Community. GPS: lat 25°31'12.4"S, long 27°10'11.3"E. Notice the lack of a well established woody component although bush encroachment is taking place mostly in the form of *Acacia* species.

The average species richness is 30 species per relevé of which 6% are alien species. This community is dominated by the grass layer (69% cover) which doesn't grow more than 1.2 m tall. There are almost no trees present (1% cover) that are higher than 2.5 m and the shrub layer has a cover of 7% and hardly ever exceeds 1.5 m in height. The very low cover percentage of the woody component and the fact that there are no tall trees or shrubs present indicates that the rehabilitation in most of these areas took place fairly recently. A woody component has started to establish in these areas which indicates that the rehabilitation was done well and that species from the surrounding natural veld are starting to re-establish in these areas. The very low percentage of tree cover and the higher percentage of shrub cover indicate that the process of bush-encroachment (Smit *et. al.*, 1999:246.) is taking place in this community (woody species from the natural surrounding vegetation are slowly re-establishing in these rehabilitated areas). This is indicated by woody species like *Acacia nilotica* (Species Group H); *Acacia tortilis* (Species Group I) and *Acacia karroo* (Species Group I) which are only found as shrubs in this community. The forbs layer is not very prominent (6% cover) as would be expected from a grassland but it is expected that it will increase as the area becomes more naturalized.

### 3.3.3.2. Ordinations

Detrended Correspondence Analysis (DCA) ordinations were carried out to verify the plant communities and indicate the correlation in species composition between the plant communities. A Correspondence Analysis (CA) ordination was then carried out to also indicate the correlation in species composition between the sub-communities of Community 2 (Figures 3.22 & 3.23).

- The relevés representing Community 1 form a grouping indicating the correlation in species composition between the different relevés and the same occurred for the relevés of Community 2 (Figure 3.22). Relevé number 54 is closer to the cluster formed by the relevés of Community 2 than the other relevés in Community 1. The reason for this is that it contains many species that are present in Species Group G which is shared between Communities 1 and 2. Various species present in the diagnostic species group of Community 1 (Species Group A) are however present in this relevé which makes it part of Community 1. Relevé number 61 is also closer to the cluster of Community 1 but the same reason can be given for its inclusion in Community 2. Relevé number 61 contains many species from Species Group G but also a number of species from the diagnostic species group of Community 2 and Sub-community 2.1 (Species Groups B and C).



**Figure 3.22 Detrended Correspondence Analysis (DCA) ordination bi-plot showing the correlations in species composition between the communities of the rehabilitated areas.**

- The relevés representing Community 3 form a dense separate grouping indicating the strong correlation in species composition between the different relevés (Figure 3.22). Community 3 represents the rehabilitated open cast mining areas and for this reason a totally different species composition from the other two communities which are present on the two tailings dams is found here. This is evident from the very large distance between the cluster formed by Community 3 and those of the other two communities.
- A grouping is formed by the relevés representing Sub-community 2.1 (Figure 3.23). Relevé numbers 52 and 61 are however further away from the rest of the cluster of Sub-community 2.1 and closer to the grouping formed by the relevés of Sub-community 2.2. The reason for this is that they contain various species present in Species Group E (*Conyza bonariensis*, *Eragrostis trichophora* and *Heteropogon contortus*) which is shared between the two sub-communities. The absence however of Species Group D (diagnostic to Sub-community 2.2) and the presence of Species Group C (diagnostic to Sub-community 2.1) in these two relevés, as explained in the community discussions, results in them forming part of Sub-community 2.1.

- The contrary is true for relevé numbers 55 and 56 which form Sub-community 2.2 (Figure 3.23).

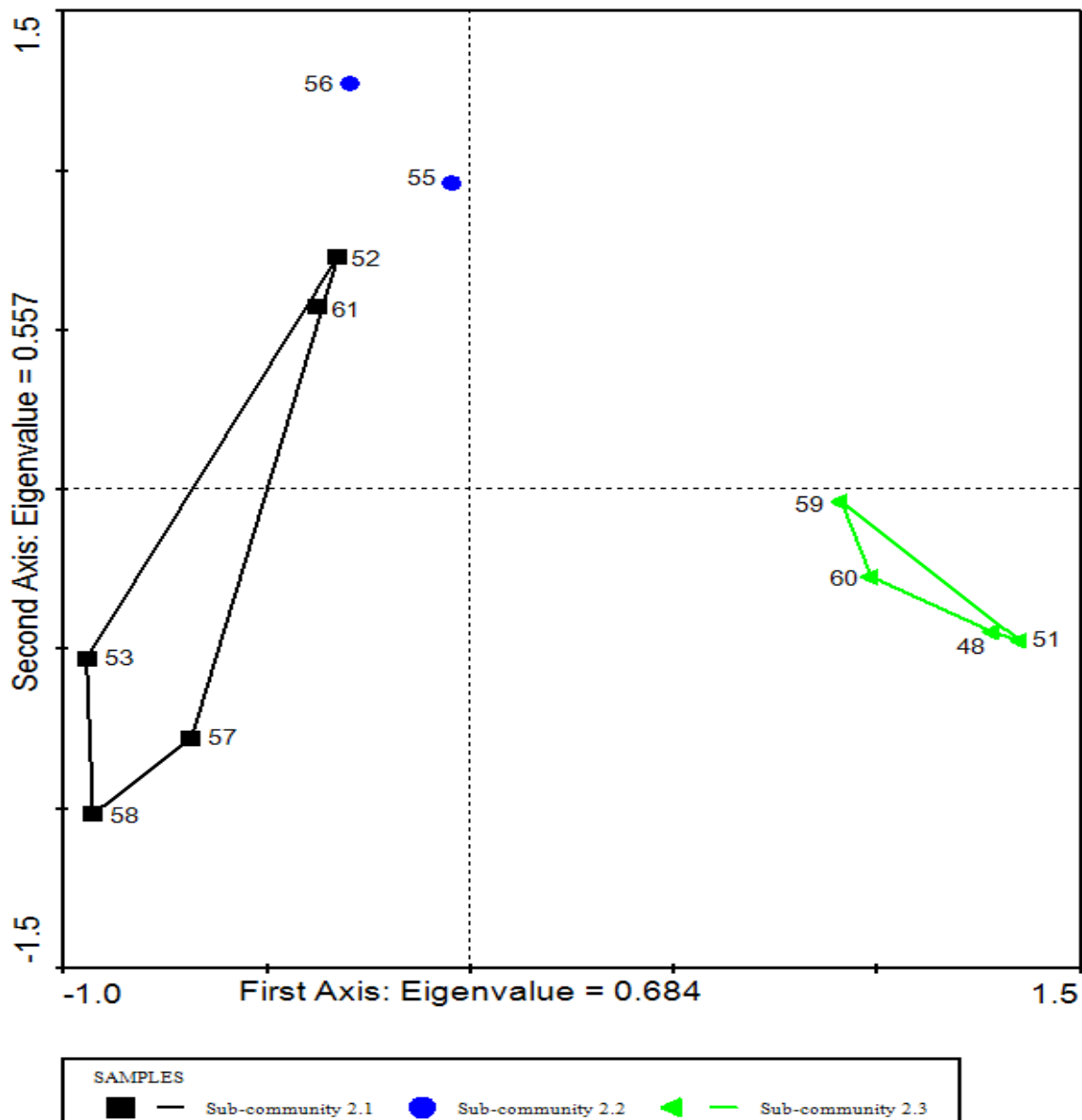


Figure 3.23 Correspondence Analysis (CA) ordination bi-plot showing the correlation in species composition between the sub-communities of Community 2.

- The relevés representing Sub-community 2.3 form a separate dense grouping indicating the strong correlation in species composition between the different relevés (Figure 3.23). The total absence of Species Groups C and D (diagnostic to the other two sub-communities) and the strong presence of Species Group F (diagnostic to Sub-community 2.3) are the main reasons for this separate grouping.
- This Correspondence Analysis ordination therefore supports the argument that there are three sub-communities present in Community 2.

### 3.3.4. Vegetation map of the Impala Platinum mining area

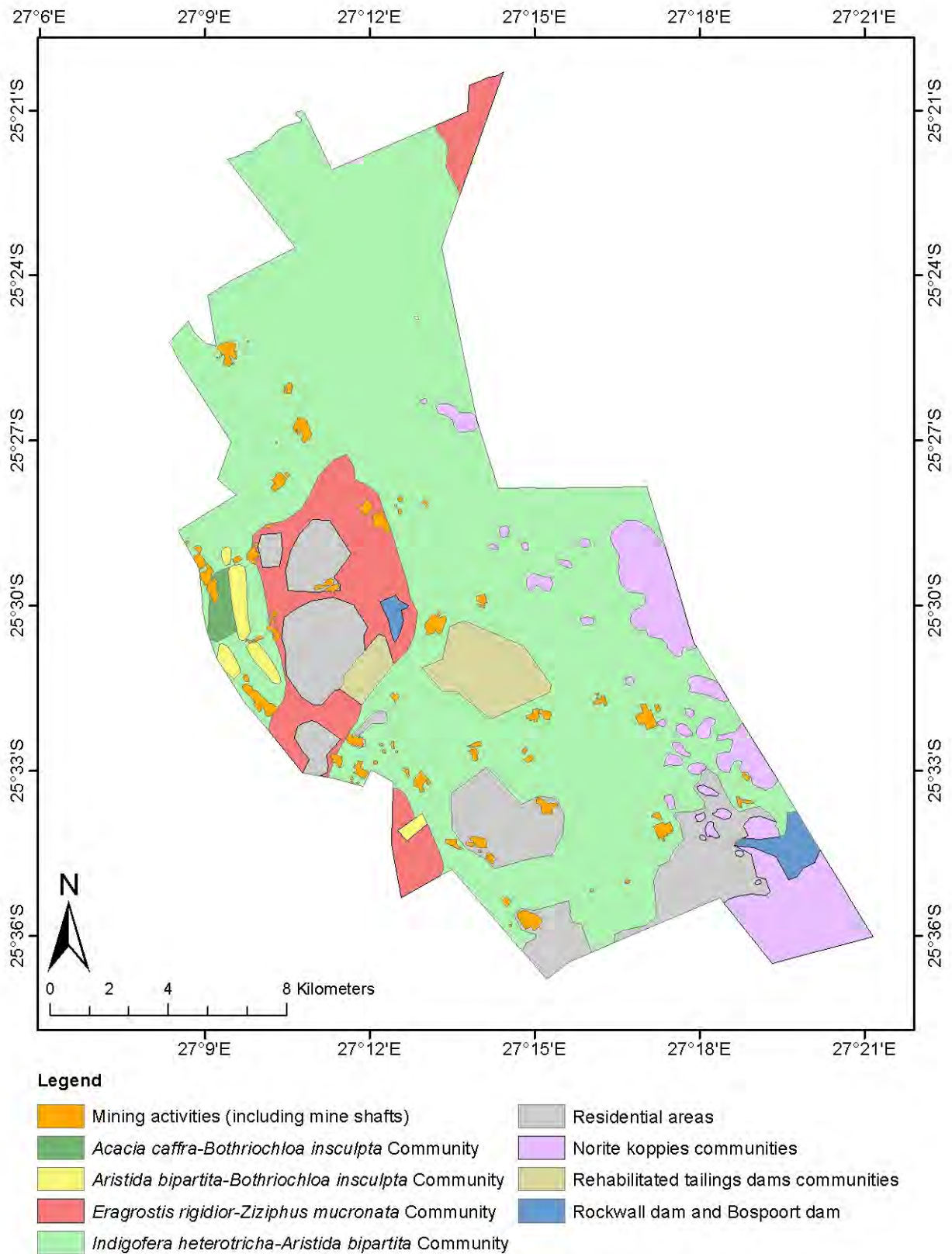


Figure 3.24 Vegetation map of the Impala Platinum mining area.

### Discussion of the vegetation map of the Impala Platinum mining area (Figure 3.24)

- The *Acacia caffra-Bothriochloa insculpta* Community is found on shallow Shortlands soils. It only covers a small area of the study site and is under constant threat of anthropogenic activities such as infrastructure development and cattle grazing taking place. It must therefore be viewed and managed as a unique zone and ought to be set aside for conservational management purposes.
- The *Aristida bipartita-Bothriochloa insculpta* Community represents the rehabilitated opencast mining areas. This community technically forms part of the rehabilitated areas but because it is not located on the tailings dams like the rest of the plant communities from the rehabilitated areas, it has been illustrated separately on the vegetation map (Figure 3.24).
- The *Eragrostis rigidior-Ziziphus mucronata* Community is found on deep Shortlands and Oakleaf soils. It doesn't cover a large part of the Impala Platinum mining area but because of the favourable potential for development on the soil type, those areas are being anthropogenically disturbed and developed intensely as is illustrated by the informal settlements on the vegetation map (Figure 3.24). For this reason much of the habitat for the *Eragrostis rigidior-Ziziphus mucronata* Community is being destroyed. A designated area of this community will have to be set aside for conservational management purposes in order to ensure its continued existence.
- The *Indigofera heterotricha-Aristida bipartita* Community, which is the dominant thornveld plant community, covers a very large part of the Impala Platinum mining area and is found on deep Arcadia soils. It has a wide range of structural diversity but the species composition ultimately stays relatively constant.
- Residential areas include all developed urban areas as well as informal settlements on the urban fringes.
- Four communities with two sub-communities were identified and described in the norite koppies but because of the significantly smaller geographic scale of these communities compared to the thornveld communities, they were not individually illustrated on the vegetation map (Figure 3.24) but rather as a unit. The detailed descriptions of the locations of these communities were explained in the community discussions.
- The same procedure was followed for the two communities and the three sub-communities found on the rehabilitated tailings dams (the old dam to the west and the new dam to the east) present in the Impala Platinum mining area.
- The two large water sources in the Impala Platinum mining area, the Rockwall dam to the north-west and the Bospoort dam to the south-east, are also illustrated on the vegetation map (Figure 3.24).

- The *Cyperus sexangularis-Cynodon dactylon* Riparian community, which is not illustrated on the vegetation map (Figure 3.24), is found in and around all water sources in the Impala Platinum mining area. This includes the two large dams and all rivers and seasonal streams.

### 3.3.5. Comparison of the three landscape categories

The norite koppies landscape category has the highest species richness with 45 species per relevé (6% alien species) on average while the thornveld has an average of 35 species per relevé (12% alien species) and the rehabilitated areas only 28 species per relevé (17% alien species) (Figure 3.25). One Red Data List species (vulnerable), one protected species and seven declared weeds and invaders are present in the norite koppies whilst the thornveld has four Red Data List species (one declining and three vulnerable), two protected species and eleven declared weeds and invaders (Figure 3.25). The rehabilitated areas have no Red Data List- or protected species (Figure 3.25). There are however thirteen declared weeds and invaders present (Figure 3.25). The names of these Red Data List-, Protected- as well as Declared weeds and invader species are listed in Table 3.4.

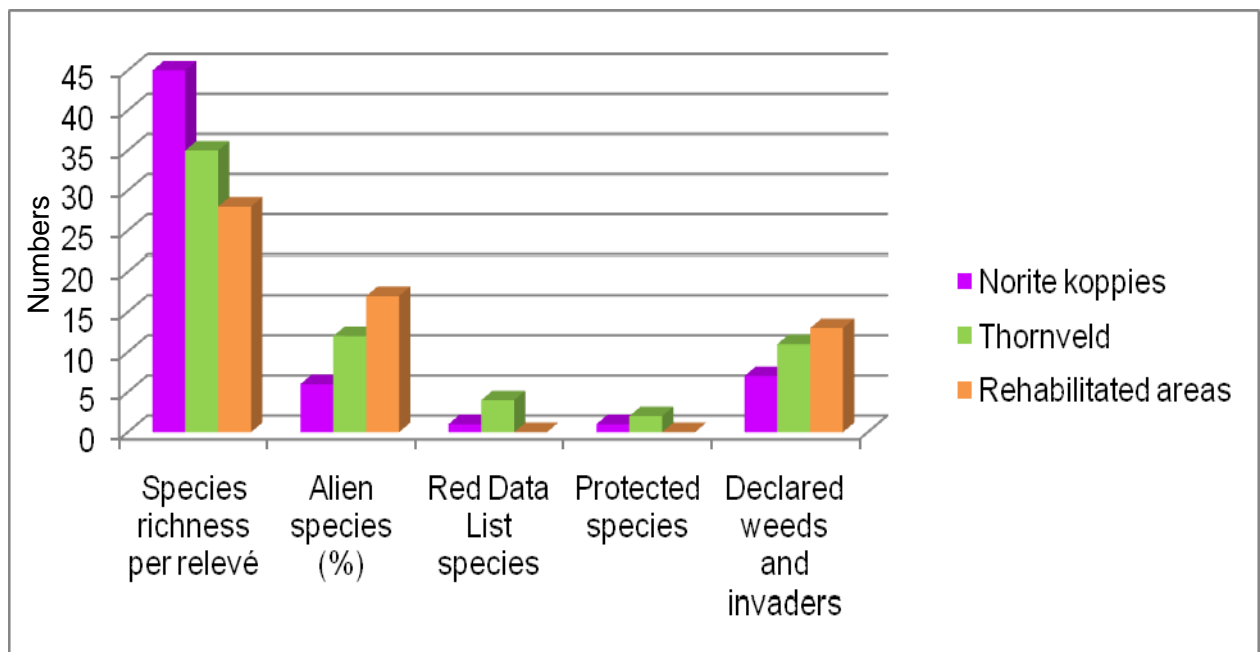


Figure 3.25A comparison of plant community characteristics of the three landscape categories.

**Table 3.4 Red Data List-, Protected- as well as Declared weeds and invader species of the three landscape categories.**

	<b>Norite koppies</b>	<b>Thornveld</b>	<b>Rehabilitated areas</b>
<b>Red Data List species</b>	<i>Solanum supinum</i> (vulnerable)	<i>Boophone disticha</i> (declining) <i>Cyphostemma hardyi</i> (vulnerable) <i>Lotononis globulosa</i> (vulnerable) <i>Solanum supinum</i> (vulnerable)	None
<b>Protected species</b>	<i>Boscia albitrunca</i>	<i>Boscia albitrunca</i> <i>Combretum imberbe</i>	None
<b>Declared weeds and invaders</b>	<i>Achyranthes aspera</i> <i>Cestrum laevigatum</i> <i>Datura stramonium</i> <i>Opuntia ficus-indica</i> <i>Cynodon dactylon</i> <i>Ipomoea purpurea</i> <i>Pennisetum setaceum</i>	<i>Achyranthes aspera</i> <i>Opuntia ficus-indica</i> <i>Cynodon dactylon</i> <i>Tecoma stans</i> <i>Nicotiana glauca</i> <i>Jacaranda mimosifolia</i> <i>Schinus molle</i> <i>Morus nigra</i> <i>Xanthium strumarium</i> <i>Tithonia rotundifolia</i> <i>Sesbania punicea</i>	<i>Achyranthes aspera</i> <i>Pennisetum setaceum</i> <i>Tamarix ramosissima</i> <i>Tecoma stans</i> <i>Nicotiana glauca</i> <i>Cynodon dactylon</i> <i>Jacaranda mimosifolia</i> <i>Morus nigra</i> <i>Schinus molle</i> <i>Eucalyptus camaldulensis</i> <i>Arundo donax</i> <i>Cirsium vulgare</i> <i>Ricinus communis</i>

### 3.4. Conclusions

Eleven plant communities with seven sub-communities were ultimately identified, described and mapped in the Impala Platinum mining area. Clear distinctions were found between the species compositions of the identified plant communities which could be linked to a number of main environmental factors namely, the geographical aspect and percentage soil surface rockiness in the norite koppies and the soil type in the thornveld landscape category. The three plant communities and three sub-communities identified in the rehabilitated areas were mainly present due to anthropogenic influences rather than environmental variables. Soil salinity did, however, seem to play a role in the distribution of Sub-community 2.3. The phytosociological classification was, therefore, significant and it then served as a basis for

identifying certain areas and plant communities for further quantitative studies. The quantitative assessment of veld conditions can be used as an important instrument when it comes to planning for potential future land-use. The results of the phytosociological study also formed the basic guidelines in accordance with which various other biodiversity studies were carried out in the Impala Platinum mining area namely, that of birds, reptiles, amphibians, small mammals and butterflies.

### **Previously described plant communities**

The Norite Koppies Bushveld vegetation type (Mucina & Rutherford, 2006) was described by Van der Meulen (1979) and Panagos (1996). Van der Meulen classified and described one vegetation association namely a *Croton gratissimus-Setaria lindenbergiana* Woodland consisting of a low, semi open to closed woodland not exceeding 5m in height with the substratum comprised mainly of rocks and large boulders but hardly any soil. A *Helinus integrifolius* variation of this association is found on norite koppies. This classification by Van der Meulen (1979) corresponds with the plant communities described in the current study area in that various important differential and dominant species are shared with the *Setaria lindenbergiana-Dombeya rotundifolia*-, the *Pappea capensis-Heteropogon contortus*- and the *Ficus abutilifolia-Croton gratissimus* communities. Examples of such species include the grass *Setaria lindenbergiana*; the woody species *Dombeya rotundifolia*, *Combretum molle*, *Pappea capensis*, *Croton gratissimus*, *Ficus species*, *Vitex zeyheri* and *Obetia tenax*; the succulent tree *Euphorbia cooperi*; the forbs *Cyphostemma lanigerum*, *Hibiscus subreniformis*, *Hermannia floribunda*, *Helinus integrifolius* and others. The physiognomy and environmental factors described by Van der Meulen (1979) also corresponds with the conditions encountered in the current study such as high percentages of soil surface rockiness and very little soil which is mostly shallow. Van der Meulen describes the *Helinus integrifolius* variation as having a woody cover varying from 20-60% and rarely exceeding 3-4 m in height which corresponds with the 48% and 6 m average cover and height recorded in the current study area.

Panagos (1996) described a *Clerodendrum glabrum-Setaria lindenbergiana* short closed woodland Community which also corresponds with the norite koppies plant communities described in the current study. Although the plant community described by Panagos (1996) was restricted to three hills in his study site, it also shares various physiognomic and environmental attributes with the plant communities of the current study. The mean surface rockiness of 55.7% and shallow soil described by Panagos (1996) correspond with the 60% average soil surface rockiness and shallow soils recorded in the Impala Platinum mining area. Panagos (1996) also mentions a woody cover of 66.5% which corresponds with the high woody cover recorded in the current study. Similar to the association described by Van

der Meulen (1979), this community shares various differential and dominant species with the plant communities described for the norite koppies in the Impala Platinum mining area for example the grasses *Setaria lindenbergiana*, *Themeda triandra*, *Heteropogon contortus*; the woody species *Combretum molle*, *Vitex zeyheri*, *Acacia caffra*, *Pouzolzia mixta*, *Dombeya rotundifolia*; the forbs *Hibiscus subreniformis*, *Pupalia lappacea*, *Helinus integrifolius*, *Hypoestes forskoolii* and others.

The association and variation described by Van der Meulen (1979) and the plant community described by Panagos (1996) are however only broad classifications of the vegetation in the Norite Koppies Bushveld vegetation type (Mucina & Rutherford, 2006) while the classification conducted in the Impala Platinum mining area provides a refined and therefore more accurate understanding of the phytosociology of norite koppies.

A similar association to the *Indigofera heterotricha-Aristida bipartita* Community, present in the thornveld landscape category of the current study area, was described by Van der Meulen (1979). This *Acacia tortilis-Aristida bipartita* association falls under an *Acacia tortilis-Panicum maximum* Woodland Order and is classified as an open to semi open thorny woodland occurring on black vertic clays (usually referred to as black turf) derived from norite and gabbros. The species richness of 20 species per relevé is relatively low and the woody stratum is dominated by *Acacia* species such as *A. tortilis*, *A. nilotica* and *A. mellifera* similar to the *Indigofera heterotricha-Aristida bipartita* Community (31 species per relevé). The woody stratum covers 5-15% and does not exceed 5 m in height. This also corresponds with the plant community in the current study area which rarely exceeds 30% cover and reaches a height of 6 m. A continuous grass layer dominates the area and frequently occurring differential species include the grasses *Aristida bipartita*, *Ischaemum afrum* and *Eragrostis chloromelas* as well as the forb *Hibiscus trionum*. The grass *Sorghum versicolor* is a less frequently occurring differential species. This grass layer described by Van der Meulen (1979) reaches up to 1.5 m in height and covers 45% similar to the *Indigofera heterotricha-Aristida bipartita* Community (66% cover and up to 1.7m).

Van der Meulen (1979) also described a *Combretum erythrophyllum-Acacia karroo* Gallery Forest under a *Combretum erythrophyllum-Celtis africana* Forest Alliance which corresponds with the *Searsia lancea-Cyperus sexangularis* Riparian sub-community identified in the current study. Dominant and differential woody species shared between them include *Searsia lancea*, *S. pyroides*, *Combretum erythrophyllum*, *Acacia karroo* and *Ziziphus mucronata* whilst there is also a number of differential forb species shared such as *Xanthium strumarium*, *Paspalum urvillei*, *Veronica anagallis-aquatica* and others. This forest gallery (Van der Meulen, 1979) has a woody cover of 60-70% which reaches 5-12 m in

height and is found on alluvial soils while the sub-community of the current study has a woody cover of 45%, a height of 6 m and is also found on soils high in organic content. There are therefore noticeable correspondences, especially between the species composition but also the physiognomy and environmental characteristics of these two descriptions of riparian vegetation. Van der Meulen (1979) however mentions that such gallery forests with several of these prominent woody species are widely distributed over South Africa.

### 3.5. References

- Cleaver, G., Brown, L.R. & Bredenkamp, G.J. 2005.** The phytosociology of the Vermaak, Marnewicks and Buffelsklip valleys of the Kammanassie Nature Reserve, Western Cape. *Koedoe*, 48 (1): 1-16.
- Dengler, J., Chytry, M. & Ewald, J. 2008.** Phytosociology. (*In Encyclopedia of Ecology*, 4. p. 2767-2779.)
- Driver, A., Cowling, R.M. & Maze, K. 2003.** Planning for living landscapes: Perspectives and lessons from South Africa. Botanical Society of South Africa, Cape Town.
- ESRI (Environmental Systems Research Institute). 2006.** ArcView 9.2. www.esri.com Redlands, CA: USA.
- Germishuizen, G., Meyer, N.L., Steenkamp, Y. & Keith, M. (eds.) 2006.** A checklist of South African plants. Southern African Botanical Diversity Network Report No. 41. SABONET, Pretoria.
- Götze, A.R., Cilliers, S.S., Bezuidenhout, H. & Kellner, K. 2003.** Analysis of the riparian vegetation (la land type) of the proposed Vhembe Dongola National Park, Limpopo Province, South Africa. *Koedoe*, 46 (2): 45-64, November.
- Grobler, C.H., Bredenkamp, G.J. & Brown, L.R. 2006.** Primary grassland communities of urban open spaces in Gauteng, South Africa. *South African Journal of Botany*, 72 (3): 367-377, August.
- Hatting, E.R. 1953.** Observations on the Ecology of *Seriphium plumosum* Levyns. Empire. *Journal of Experimental Agriculture*, 21: 84.
- Henderson, L. 2001.** Alien Weeds and Invasive plants: A complete guide to declared weeds and invaders in South Africa. Plant Protection Research Institute Agricultural Research Council.
- Hennekens, S.M. 1996a.** TURBOVEG: Software package for input, processing and presentation of phytosociological data. IBN-DLO, University of Lancaster.
- Hennekens, S.M. 1996b.** MEGATAB: A visual editor for phytosociological tables. Giesen & Gertus, Ulft.

- Kent, M. & Coker, P. 2000.** Vegetation description and analysis: A practical approach. John Wiley & Sons, New York.
- Moleele, N.M., Ringrose, S. & Matheson, W. 2002.** More woody plants? The status of bush encroachment in Botswana's grazing areas. *Journal of Environmental Management*, 64(1): 3-11, January.
- Morgenthal, T.L., Cilliers, S.S., Kellner, K., Van Hamburg, H. & Michael, M.D. 2001.** The vegetation of ash disposal sites at Hendrina power station 1: Phytosociology. *South African Journal of Botany*, 67(1): 506-519, January.
- Mucina, L. & Rutherford, M.C. (eds.) 2006.** The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.
- Mueller-Dombois, D. & Ellenberg, H. 1974.** Aims and Methods of Vegetation Ecology. Wiley, New York.
- Panagos, M.D. 1996.** The natural plant communities of the Onderstepoort Nature Reserve. Unpublished Report, ARC Onderstepoort Veterinary Research Institute, Pretoria.
- Pierce, S.M., Cowling, R.M., Knight, A.T., Lombard, A.T., Rouget, M. & Wolf, T. 2005.** Systematic conservation planning products for land-use planning: Interpretation for implementation. *Journal of Biological Conservation*, 125: 441-458.
- Smit, G.N., Richter, C.G.F. & Aucamp, A.J. 1999.** Bush encroachment: An approach to understanding and managing the problem. (*In* Tainton, N., ed. Veld management in South Africa. 1<sup>st</sup> Ed. University of Natal Press, Pietermaritzburg. p. 246-260.)
- South African National Biodiversity Institute (SANBI). 2009a.** Interim Red Data List of South African Plant Taxa. [Web:] <http://www.sanbi.org/biodeiversity/Red%20List%2003-02-2009.xls>. [Date of use: 19 October 2009.]
- South African National Biodiversity Institute (SANBI). 2009b.** Protected Plants and Plant Permits in South Africa. [Web:] <http://www.sanbi.org/frames/tspfram.htm>. [Date of use: 19 October 2009.]
- Swanepoel, B.A. & Bredenkamp, G.J. 2007.** The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspuit, South Africa. *South African Journal of Botany*, 74 (2): 315-316, April.
- Ter Braak, C.J.F. 1986.** Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 65 (5).
- Van der Meulen, F. 1979.** Plant sociology of the western Transvaal bushveld, South Africa: A syntaxonomic and synecological study. A. Gantner, Vaduz.
- Van Staden, P.J. & Bredenkamp, G.J. 2005.** Major plant communities of the Marakele National Park. *Koedoe*, 48 (2): 59-70, August.
- Zietsman, M.M. & Bredenkamp, G.J. 2006.** Dune vegetation and coastal thicket plant communities in threatened limestone Fynbos of Andrew's Field and Tsaba-Tsaba Nature Reserve, Struisbaai, Western Cape. *Koedoe*, 49 (1): 33-47, July.

## CHAPTER 4

### Veld condition assessment, grazing and browsing capacity

#### 4.1. Introduction

One of the major objectives of systematic conservation planning for specific areas lies in determining future land-use potential as well as developing and implementing management strategies (Driver *et. al.*, 2003). In the case of mining areas, future land-use can often be very limited. By assessing veld conditions and determining grazing and browsing capacities, a better perspective can be gained regarding the agricultural potential or conservational importance of areas. Monitoring of these conditions over time plays an important role in determining the success of implemented management practices and therefore forms a vital component of studies linked to conservation planning. The decisions of which biodiversity indicators to assess and which monitoring strategies to follow can, however, become quite complicated as it requires a good conception of a client's/user's exact needs or objectives with a project, as well as knowledge of the resources available such as time and funding (Smyth & James, 2004).

Various techniques are described in the literature for assessing veld conditions and carrying capacities. The methodologies to be used will depend on the ecological needs to be assessed and what the goal and timeframe of the survey is. While the main objective of the study at Impala Platinum was to collect biodiversity and potential land-use data for the establishment of a conservation plan, the specific objectives for the second part of the study were to determine veld conditions, grazing and browsing capacities and landscape functionality of selected plant communities. A plant diversity study was completed during 2009 and the Fixed Point Monitoring of Vegetation Methodology- FIXMOVE (Morgenthal & Kellner, 2008) was then chosen to be used in combination with the phytosociological results from 2009 (see Chapter 3) to assess land-use potential. The FIXMOVE method was developed with the intent of providing information with regard to veld condition, carrying capacity, occurrence of alien and weed species, bush encroachment and general habitat degradation (Morgenthal & Kellner, 2008). It therefore provides a holistic view of the ecological potential of an area regarding the natural resources. This method is based on a combination of more than fifteen sampling methodologies with similar aim, which have been applied and approved in practice (Morgenthal & Kellner, 2008). The quantitative veld condition and carrying capacity data obtained during 2010 using the FIXMOVE method, together with the spatial plant diversity data from the phytosociological study in 2009,

provided adequate results for the identification of and recommendation towards management and conservation plans and strategies within the study area. This data can ultimately be incorporated into the official conservation action plan for the Impala Platinum Company's mining area.

Species composition and ecological status of species are often considered the most important characteristics when defining the ecological condition of an area and the importance of the functionality of landscapes is often overlooked. To understand the functioning of a landscape, and why landscapes may be deemed functional or dysfunctional, knowledge of the processes taking place inside a landscape is required (Tongway & Hindley, 2004). The biophysical ability of areas to retain and recycle resources within a system proves to be a vital characteristic in sustaining a landscape (Ludwig & Tongway, 1997) and this is dependant on the unique patchiness or mosaic of patches (Cadenasso *et al.*, 2003; McGarical & Marks, 1995) present inside each landscape on earth. A patch may be defined as a discrete, identifiable unit that differs structurally, functionally and positional from adjacent areas and retains resources that pass through a system (Tongway & Hindley, 2004; Cadenasso *et al.*, 2003). An interpatch, on the other hand, is described as a unit between patches where the retention of vital resources does not occur and are eventually lost from a system (Tongway & Hindley, 2004). Natural patchiness can be created by vegetation and other physical structures such as rocks or dead organic material.

The necessity for a methodology with which the functionality of a landscape could be quantitatively measured, ultimately lead to the development of the Landscape Function Analysis (LFA) method (Tongway & Hindley, 2004). The assessment of a number of important soil surface indicators gained through the soil surface assessment (SSA) within the LFA monitoring methodology aids in determining the success of an area's functionality as a biophysical entity (Razaei *et al.*, 2005; Tongway & Hindley, 2004). Additional quantitative data obtained by applying this method in the Impala Platinum mining area could be used to support the conclusions drawn regarding the veld condition assessment, degradation and stability processes and ultimately land-use potential of various plant communities.

## **4.2. Materials and Methods**

Four plant communities identified and described during 2009 (Chapter 3) were selected for quantitative studies during 2010. These communities were identified as areas with potentially adequate grazing and browsing conditions for future land-use. The four plant

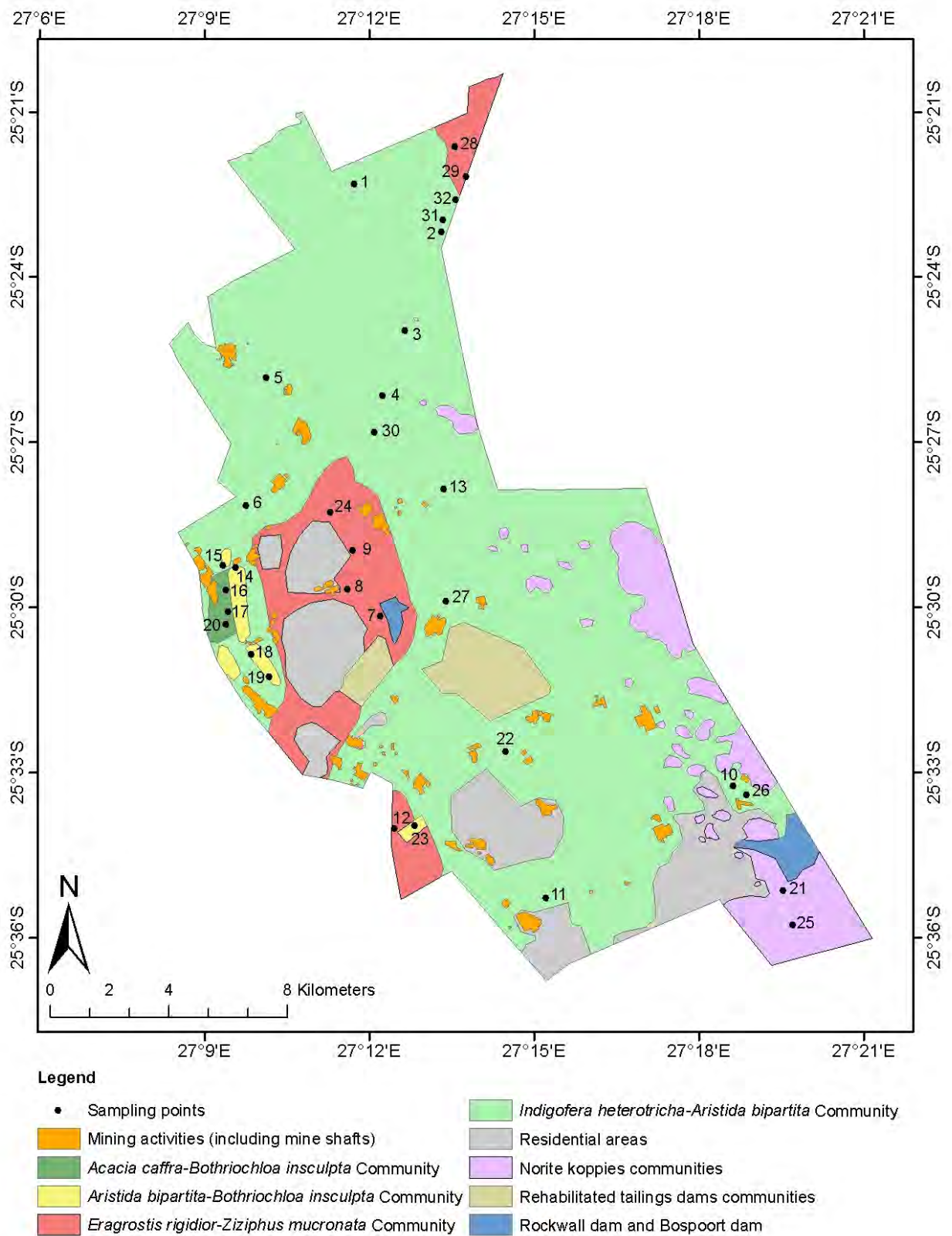
communities are the *Aristida bipartita-Bothriochloa insculpta* Community in the rehabilitated opencast mining areas and the *Indigofera heterotricha-Aristida bipartita*, *Acacia caffra-Bothriochloa insculpta* and *Eragrostis rigidior-Ziziphus mucronata* Communities in the thornveld. The plant communities on the norite koppies and rehabilitated tailings dams were, therefore, excluded in this study.

FIXMOVE (Morgenthal & Kellner, 2008) was used to sample 32 stratified random plots in the four plant communities (Figure 4.1). The number of plots sampled per plant community was determined by the relative size of each inside the Impala Platinum mining area. Seventeen plots were sampled in the *Indigofera heterotricha-Aristida bipartita* Community; seven in the *Eragrostis rigidior-Ziziphus mucronata* Community; five in the *Aristida bipartita-Bothriochloa insculpta* Community and three in the *Acacia caffra-Bothriochloa insculpta* Community.

Data were recorded for the herbaceous as well as the woody components of each plant community. An example of the data sheet used during the surveys is provided in the appendix (Data Sheet A2). Species richness and diversities were also recorded. Shannon's diversity index (Begon *et. al.*, 2006) was used to calculate species diversity values for the four plant communities.

Frequencies of the herbaceous species as well as the rocky, litter and bare patches were calculated. Grass species were grouped according to ecological status (Decreaser species; Increaser 1, 2 and 3 species) and grazing value (production, palatability, nutritional value, growth vigour and digestibility) (Van Oudtshoorn, 2004). Grazing capacities (Moussa *et. al.*, 2009) were calculated in hectares per large stock unit (ha/LSU) using the herbaceous biomass which was measured with a disc pasture meter in accordance with the FIXMOVE (Morgenthal & Kellner, 2008). Erosion factors (Vetter, 2003) and percentage basal cover were also determined.

Frequencies of the woody species were calculated and the percentages of palatable species were determined for the individuals present (Van Wyk & Van Wyk, 2010; Smit, 2008; Van Wyk *et al.*, 2008). Average heights, densities (Trollope *et al.*, 2004), canopy cover (Smit, 1989) and leaf biomass (Smit, 1989) per hectare were also determined for the woody strata in two height classes namely: higher than 2 m and lower than 2 m. The latter was carried out in order to determine the structure and browsing capacities (Smit, 2006) in hectares per browsing unit (ha/BU) of the woody component for the two height classes.



**Figure 4.1** Vegetation map (from Chapter 3) and FIXMOVE sampling points inside the Impala Platinum mining area.

All the data of the herbaceous and woody components were then compared between the four plant communities in order to determine their potential for future land-use. Additionally, landscape functionality in the four plant communities was determined by Van der Walt (2010). The Landscape Function Analysis (LFA) method (Tongway & Hindley, 2004) was used for this. This methodology assigns calculated indices between 0-100 to three main biophysical functionality categories namely stability, infiltration and nutrient cycling in order to determine the total functionality of an area (Tongway & Hindley, 2004). Although the LFA study is not included in this chapter, important data and conclusions obtained from these surveys (Van der Walt, 2010) are included to support the results of the chapter.

Multivariate statistic analyses, with the computer software programme CANOCO (Ter Braak, 1986), were performed to indicate possible degradation gradients between the plant communities. Statistical significance of variations in the data was also determined by performing one-way analyses of variance (ANOVA) and subsequent Tukey Honest Significant Difference for unequal N post-hoc tests with the computer software programme STATISTICA version 9.0 (STATSOFT, Inc., 2009).

## **4.3. Results and Discussion**

### **4.3.1. Discussion of veld conditions as well as grazing and browsing capacities of the four plant communities**

#### **4.3.1.1. *Indigofera heterotricha-Aristida bipartita* Community**

The discussion to follow refers to the data summarized in Tables A4-A7 in the appendix.

A total of 58 species were recorded in this thornveld community at an average of 16 species per sampling plot.

#### **The herbaceous layer (Tables A4 & A5)**

##### **Ecological status**

The five dominant and most frequently occurring herbaceous species (grasses) (Table A4) including their ecological status and grazing values are:

- *Aristida bipartita* (Ecological status: Increaser 2; Grazing value: Low)
- *Ischaemum afrum* (Ecological status: Increaser 2; Grazing value: Medium)
- *Urelytrum agropyroides* (Ecological status: Increaser 1; Grazing value: Low)
- *Eragrostis chloromelas* (Ecological status: Increaser 2; Grazing value: Medium)
- *Themeda triandra* (Ecological status: Decreaser; Grazing value: High)

The larger part of the herbaceous layer of this community, namely three of the five dominant species, are Increaser 2 type of grass species which indicate a state of over-grazing (Van Oudtshoorn, 2004). The over-grazed state is characterized by the dominance of the grass species *Aristida bipartita* (Van Oudtshoorn, 2004). *Ischaemum afrum* (turf grass), which is also an Increaser 2 species, is the second most frequently occurring grass species but is rarely preferred by animals for grazing (Van Oudtshoorn, 2004). The *Indigofera heterotricha-Aristida bipartita* Community covers the largest surface area (more than 60%) of all the plant communities in the Impala Platinum mining area and is therefore primarily being used by the local communities as the grazing areas for their livestock. Over-utilization is however occurring in and around most of these communally managed areas due to a lack in well established grazing strategies through a rotational grazing system with fenced paddocks. Continuous selective grazing practices of livestock (Tainton, 1999) are, therefore, occurring with no form of rotational rest for the vegetation.

Various Increaser 1 and Decreaser species are found in certain remote areas of this community (two of the five dominant herbaceous species respectively). These are species which indicate good or under utilization of areas in terms of grazing practices (Van Oudtshoorn, 2004). This suggests that areas which are less reachable by livestock are not being over-grazed. The residential settlements are all located in the central and southern parts of the Impala Platinum mining area (Figure 4.1). These areas tend to be more degraded and over-utilized with higher frequencies of Increaser 2 species (Table A5). Plots 2, 3, 4, 31 & 32, which are present in the northern parts of the Impala Platinum mining area (Figure 4.1), and which are not close to any settlements or developments, show higher relative frequencies of Increaser 1 and Decreaser type species and lower frequencies of Increaser 2 species (Table A5). Certain sites located close to residential areas (Figure 4.1), such as plots 11, 21, 22, 25 & 26, tend to have relatively high frequencies of Decreaser species. However, the lack of Increaser 1 species and abundance of Increaser 2 species still indicate a degree of over-utilization in the form of grazing. This supports the initial argument that there is a lack of an adequate rotational grazing system around communal areas to promote high quality grazing for livestock through resting periods.

### **Veld condition and grazing capacity**

The average grazing capacity of this community is only 4.9 ha/LSU due to the low grass biomass (average 2447.8 kg/ha) and low grazing value (Van Oudtshoorn, 2004) of grass species present (grasses with low grazing value make up 51.2% of the herbaceous layer). The grass biomasses and grazing capacities of most sites tend to be relatively similar regardless of the proximity to residential settlements with the exception of plots 11, 21

(Figure 4.2), 25 & 30 (grass biomass of less than 2100 kg/ha), which are located close to settlements and are intensely over-grazed (Table A5). Although plot number 11 is included in this group of sites with low grass biomass, it still has a high calculated grazing capacity because of high frequencies of species with high grazing value (Decreaser species such as *Themeda triandra* and *Setaria incrassata*) (Table A5). As is the case in plot 11, Decreaser species can occur in relative frequencies in over-grazed areas but individuals are then mostly small with low basal cover because of constant removal of the above ground material by livestock. Plot number 31 (Figure 4.1), which also has a grass biomass of less than 2100 kg/ha (Table A5), was sampled on the farm north of the R556 main road which is situated in the far north of the Impala Platinum mining area. This also indicates possible over-grazing on that farm. Due to the high frequency of the Increaser 1 species, *Urelytrum agropyroides*, it is however more plausible to assume that the biomass might have been decreased by grazing shortly before the site was sampled rather than continuous over-grazing in the long term. Plot number 22 (Figure 4.3) has the highest grazing capacity relative to the other plots in this community because of its unusually high grass biomass. The high biomass in plot 22 is caused by a lack of grazing because it is located close to the new tailings dam (Figure 4.1). It is therefore fairly inaccessible to livestock.



**Figure 4.2** Plot number 21. GPS: lat 25°35'08.6"S, long 27°19'32.4"E. This plot is located in the south of the Impala Platinum mining area and serves as an example of areas close to residential settlements which are intensely exploited for grazing. Notice the low herbaceous biomass and bush encroachment mostly by *Acacia karroo*.

The *Indigofera heterotricha-Aristida bipartita* Community has a relatively low frequency of bare patches (average 28.7%) which, together with high basal cover (average 17%) and short point to tuft distances (average 3.3 cm) (Vetter, 2003), indicates a low erosion risk (Table A5). The basal cover does not vary considerably between sites in the north and sites closer to settlements (Table A5). The same is true for the frequency of bare patches. Plot number 10, which has the lowest basal cover, is however located close to a residential area

and so too are plots 6 & 30 (Figure 4.1) which have the highest bare patch frequency values relative to the other sites (Table A5).



**Figure 4.3 Plot number 22. GPS: lat 25°32'37.0"S, long 27°14'28.7"E. This plot has the highest grazing capacity in the *Indigofera heterotricha-Aristida bipartita* Community. Notice the high herbaceous biomass and the lower density of the woody component compared to Figure 4.2.**

Soil surface indicators assessed with the LFA method of Tongway & Hindley (2004) also showed that sites located away from residential settlements which have less anthropogenic disturbances have higher biophysical functionality. Plots 1, 13 and 22 (Figure 4.1) are not close to settlements except for number 22 (which as mentioned earlier is however inaccessible to livestock). These plots have the highest overall functionality indices of all the plots in this plant community (41.4; 37.8 & 40.2) (Van der Walt, 2010). The higher presence of organic litter in these plots can act as a rain-splash protection method whereby the impact of raindrops is decreased which together with the slowing down of runoff water may lead to an increase in the stability of these plots. The organic litter also increases infiltration into the soils and increases soil nutrient cycling by its decomposition. Plots 25, 26 and 30 are located near residential areas (Figure 4.1) and have the lowest overall functionalities in this community (32.8; 32.6 & 31.7) (Van der Walt, 2010).

#### **The woody layer (Tables A6 & A7)**

The five dominant and most frequently occurring woody species (Table A6) including their palatability are:

- *Acacia tortilis* (Palatable)
- *Acacia karroo* (Palatable)
- *Acacia nilotica* (Palatable)

- *Dichrostachys cinerea* (Palatable)
- *Acacia mellifera* (Palatable)

The average woody density for the stratum under 2 m in height in this community is 463.9 plants/ha (Table A7). The density of the woody layer above 2 m is however significantly lower (11.6 plants/ha). This large difference between the stratum under 2 m and above 2 m of the woody layer is also reflected in the leaf biomass, browsing capacity and canopy spread (Table A7). Only 46.7 kg/ha of leaf material is available on average above 2 m for browsing by larger game species which constitutes a low browsing capacity of 76.7 ha/BU. Nearly seventy seven hectares are needed to sustain one browsing animal and this low biomass would therefore not be able to sustain large numbers of game. The canopy cover of the stratum under 2 m in height is more than six times higher than the stratum above 2 m (Table A7).

Sampling plots located close to developed areas and residential settlements, such as numbers 6 and 30 in the central parts and 11, 21 and 25 in the south (Figure 4.1), have considerably lower woody densities relative to the other plots and therefore low leaf biomass and canopy cover spreads in the above 2 m stratum (<10 plants/ha; <31 kg/ha; <60 m<sup>2</sup>/ha). This can be attributed to anthropogenic disturbances as the local communities mostly utilize the woody layer for burning fuel and other purposes such as building material. These types of practices are depleting the woody layer, especially in the above 2 m stratum, as such larger individuals are mostly harvested instead of the smaller trees. The anthropogenic impacts will have to be further assessed and discussed during the development of the conservation plan for the Impala Platinum mining area. The reason for the low woody densities in plots 4 and 13, although being further away from settlements (Figure 4.1), is that they are in lower-lying water drainage areas where fewer trees usually establish. Plots 31 and 32, which are located on the farm north of the R556 main road (Figure 4.1), also have low woody densities, leaf biomass and canopy spread for the stratum above 2 m (Table A7). It, however, seems more likely that the owner has implemented de-bushing practices in the past in order to increase the grazing potential on his farm rather than the woody layer being over-utilized for firewood or building material. This must be confirmed during further social studies for the conservation plan.

#### 4.3.1.2. *Aristida bipartita-Bothriochloa insculpta* Community

The discussion to follow refers to the data summarized in Tables A8-A11 in the appendix.

A total of 34 species were recorded in this community of the rehabilitated opencast mining areas at an average of 16 species per sampling plot.

##### **The herbaceous layer (Tables A8 & A9)**

##### **Ecological status**

The five dominant and most frequently occurring herbaceous species (grasses) (Table A8) including their ecological status and grazing values are:

- *Aristida bipartita* (Ecological status: Increaser 2; Grazing value: Low)
- *Bothriochloa insculpta* (Ecological status: Increaser 2; Grazing value: Medium)
- *Cynodon dactylon* (Ecological status: Increaser 2; Grazing value: High)
- *Eragrostis chloromelas* (Ecological status: Increaser 2; Grazing value: Medium)
- *Sorghum versicolor* (Ecological status: Increaser 2; Grazing value: Medium)

The grass species *Panicum volutans* is dominant in plot number 23 (Figure 4.4) but does not occur frequently in other plots in this community. This species is therefore not listed above as one of the five dominant herbaceous species of the *Aristida bipartita-Bothriochloa insculpta* Community. The reason for the dominance of *Panicum volutans* in plot number 23 can be ascribed to the fact that this plot was rehabilitated more recently than the rest of the plots in this community. *Panicum volutans* is an annual pioneer grass that occurs on disturbed turf soils (Van Oudtshoorn, 2004) and is one of the first species to colonize recently disturbed areas. Therefore, because of the chronological difference of the rehabilitation processes, plot number 23 has virtually no woody component and a very different herbaceous species composition compared to the rest of the plots in the rehabilitated open cast areas. Due to its outlying properties, the data of plot number 23 is included in Tables A8-A11 but not in the rest of the discussion, calculations and ordinations conducted for this community. Figures 4.4 and 4.5 illustrate the difference between plot 23 (outlier) and plot 15 (which serves as the “type plot” for the community).

The herbaceous layer of this community is dominated by Increaser 2 species (four of the five dominant herbaceous species). This was expected as this community constitutes the rehabilitated opencast mining areas which have been intensely disturbed due to mining practices. The Increaser 2 ecological status category mostly includes pioneer and sub-climax species (Van Oudtshoorn, 2004) which are primarily species that initially colonize and re-establish in areas after disturbance – therefore the dominance of this species category. The other three ecological status categories are currently not well represented in

this plant community. Over time, however, these rehabilitated areas could become progressively more naturalized and the abundances of climax species such as Decreaser species and Increaser 1's and 3's are expected to increase. The low relative total species richness should also increase as natural succession progresses with time.

The occurrence of Increaser 1 and Decreaser species in low frequencies in this community may indicate slight under utilization by grazing of these areas. These areas are surrounded by developed mining infrastructure and are, therefore, not frequently burned or utilized by livestock for grazing.



**Figure 4.4** Plot number 23. GPS: lat 25°33'57.8"S, long 27°12'49.5"E. Notice the dominance of the annual grass species *Panicum volutans* as well as the forbs *Cirsium vulgare* and *Tagetes minuta*. All these species are mostly found on newly disturbed areas.



**Figure 4.5** Plot number 15. GPS: lat 25°29'14.3"S, long 27°09'20.3"E. Notice the high herbaceous biomass and the presence of the dominant perennial grass species *Bothriochloa insculpta*. Species present are mostly sub-climax species which indicate that ecological succession has progressed more in this plot than in plot number 23.

### **Veld condition and grazing capacity**

The average grazing capacity of the *Aristida bipartita-Bothriochloa insculpta* Community is 1.9 ha/LSU when plot number 23 is excluded (Table A9). The reason for this high value is because of high grass biomass (average 3643 kg/ha) and high frequencies of grass species with adequate grazing values (grasses with low grazing value constitute only 40.8% of the herbaceous layer) (Table A9). Plot number 14 has a grass biomass of only 2698 kg/ha (Table A9) which is below average and low compared to the other plots. However, because of the high frequency of grass species with high grazing value (33.6%) relative to the other plots (Table A9), plot 14 still has a high grazing capacity. The high frequency of the palatable grass species, *Cynodon dactylon* in this plot is mainly responsible for this. As was already mentioned, little grazing is currently taking place in these rehabilitated areas because of their inconvenient locations and due to these low grazing impacts, the vegetation receives long resting periods and can easily recover and increase in biomass production. The latter is the reason for the high grazing potential of this plant community.

The risk of erosion in the *Aristida bipartita-Bothriochloa insculpta* Community is low mostly because of the small point to tuft distances (average 3.8 cm) (Vetter, 2003). The high basal cover (average 15.2%) and low frequency of bare patches (30.2%) (Table A9) are also factors that contribute to the relative low risk of degradation due to erosion in the *Aristida bipartita-Bothriochloa insculpta* Community. Plot number 14 has the highest frequency of bare patches (48%) which is considerably above average as well as the lowest basal cover (12.8%) (Table A9). Except for plot number 14 which contains no organic litter on the soil surface, the organic litter frequency (average 9.4%) (Table A9) is very high in this community because of an absence of fires and intense grazing as mentioned earlier which would remove above ground material. Although having a positive effect on decreasing the risk of erosion, this abundance of organic litter poses a serious threat as a potential fire hazard. The risk involved in creating controlled fires may also be high because this plant community is mainly situated in and around developed mining areas. These rehabilitated areas should therefore be more effectively utilized for grazing in order to reduce the biomass and, by that, the risk of fires.

Although plot number 23 mostly contains herbaceous species with low ecological status, as discussed above, it showed the best functionality of all the plots in this community (index: 39.9) according to the soil surface assessment parameters done by Van der Walt (2010) in accordance with the LFA monitoring method (Tongway & Hindley, 2004). The highest measured stability (index: 53.2) was in plot number 23 mainly due to high organic litter cover (mostly in the form of the grass species *Panicum volutans*), better micro-topography, and

intact soil crusts, which account for less erosion (Van der Walt, 2010). The infiltration (37.4) and nutrient cycling (29.2) indices of the soil of plot 23 were also positively influenced by the abundance of organic litter. The presence of *Panicum volutans* in such high frequencies therefore increases the biophysical functionality of the area but decreases the ecological status of species as well as the grazing potential. With the exception of plot number 14, which had a total functionality index of only 29, the rest of the plots in this community were very similar in functionality.

### **The woody layer (Tables A10 & A11)**

The five dominant and most frequently occurring woody species (Table A10) including their palatability are:

- *Acacia tortilis* (Palatable)
- *Acacia mellifera* (Palatable)
- *Acacia karroo* (Palatable)
- *Acacia nilotica* (Palatable)
- *Ziziphus mucronata* (Palatable)

The average woody densities of the *Aristida bipartita-Bothriochloa insculpta* Community for the stratum under 2 m and especially the stratum above 2 m are very low (294 plants/ha <2 m <0.6 plants/ha) (Table A11). This was expected from these areas as they were rehabilitated fairly recently (started approximately seven years ago and is still ongoing according to Mr. G van Dyk, the head of Impala Platinum's Environmental Department). The same is true for the leaf biomass and canopy cover spread (92.3 kg/ha <2 m <1.5 kg/ha and 412 m<sup>2</sup>/ha <2 m <2.1 m<sup>2</sup>/ha) of the community (Table A11). The reason for the lack of a well established woody layer in this plant community is that the re-establishment of woody species requires a longer timeframe after an area has intensely been disturbed. For this reason the majority of the woody layer is still less than 2 m in height and the average height of individuals in the above 2 m stratum is only 2.3 m (Table A11). The density, leaf biomass, canopy spread and average individual height of the woody layer is however expected to increase over time if left undisturbed.

#### **4.3.1.3. *Eragrostis rigidior-Ziziphus mucronata* Community**

The discussion to follow refers to the data summarized in Tables A12-A15 in the appendix.

A total of 66 species were recorded in this thornveld community at an average of 29 species per sampling plot.

## The herbaceous layer (Table A12 & A13)

### Ecological status

The five dominant and most frequently occurring herbaceous species (grasses) (Table A12) including their ecological status and grazing values are:

- *Heteropogon contortus* (Ecological status: Increaser 2; Grazing value: Medium)
- *Themeda triandra* (Ecological status: Decreaser; Grazing value: High)
- *Panicum coloratum* (Ecological status: Decreaser; Grazing value: High)
- *Bothriochloa insculpta* (Ecological status: Increaser 2; Grazing value: Medium)
- *Aristida congesta* (Ecological status: Increaser 2; Grazing value: Low)

Species belonging to the Increaser 2 ecological status category are the most dominant in the herbaceous layer of this community. A degree of disturbance and over-grazing is, therefore, evident which is expected due to the fact that most of the developed areas and residential settlements are located in and around this plant community (Figure 4.1). Unlike the soil of the *Indigofera heterotricha-Aristida bipartita* Community (Arcadia soils; see Chapter 3), the soil of the *Eragrostis rigidior-Ziziphus mucronata* Community is suitable for building and development and for this reason local communities tend to establish residential settlements in this plant community and therefore utilize large parts of it. This not only poses a threat to the ecological integrity of this plant community, but also contributes to intense transformation and fragmentation which decreases the relative size of this plant community in the Impala Platinum mining area.

Although being dominant, Increaser 2 species constitute less than half of the herbaceous layer of the *Eragrostis rigidior-Ziziphus mucronata* Community (Table A13). Increaser 1, Decreaser and forb species also have high relative abundances (two of the three dominant herbaceous species are Decreaser type of species) which is an indication of lower utilization pressures and potentially a more advanced stage of ecological succession in this community (Van Oudtshoorn, 2004). The argument is also supported by the presence of large relative frequencies of Increaser 3 species (Table A13), which are mostly climax species (Van Oudtshoorn, 2004). Sites located further away from residential settlements tend to be less disturbed and have more climax and sub-climax species. Plots 28 and 29, which are present in the north of the Impala Platinum mining area (Figure 4.1), have high frequencies of Increaser 1 species relative to the other sites (Table A13). This indicates less disturbance and better utilization by grazing of these areas. Plot number 28 also has the highest occurrence of Decreaser species (32%) which is above the average of 22.5% (Table A13), therefore supporting the latter argument. Plot number 12 has the highest frequencies

of Increaser 3 and Decreaser species and the lowest frequencies of Increaser 2 species (Table A13) and is also located further away from settlements (Figure 4.1).

### **Veld condition and grazing capacity**

The average grazing capacity of the *Eragrostis rigidior-Ziziphus mucronata* Community is 2.5 ha/LSU (Table A13). The variation in grazing capacity between the plots sampled is low with the lowest being 3.7 ha/LSU recorded in plot number 9 and the highest of 1.6 ha/LSU recorded in plot number 28 (Table A13). This low variation is evident from the standard deviation indicated later under 4.3.2. The reason for the high grazing capacity in this plant community is partly due to high herbaceous biomass (average 2861.9 kg/ha) but mainly because the majority of grass species have high grazing values (such species constitute 58% of the herbaceous layer according to Table A13). Plots located in the less disturbed areas; away from settlements (numbers 12, 28 and 29) have the highest grass biomass and also the best grazing capacity compared to the other sites (Table A13). Plot number 9 has the lowest herbaceous biomass (1444 kg/ha) by a considerable margin which contributes to the low grazing capacity of this plot. It is situated in close proximity of an informal settlement and disturbance in the form of over-grazing is evident.

The *Eragrostis rigidior-Ziziphus mucronata* Community has a very high frequency of bare patches (average 32.7%) and an average basal cover and point to tuft distance of 13.1% and 5.8 cm respectively (Table A13). This categorizes a medium erosion hazard (Vetter, 2003). In addition to its low grazing capacity, plot number 9 also exhibits the highest risk of erosion (Vetter, 2003) and degradation because of the large sizes and high frequency of bare patches (48%), low basal cover (8%) and large point to tuft distances (5.8 cm) (Figure 4.6). Plots not located in the vicinity of residential settlements (12, 28 and 29) which have the highest grazing capacities, as mentioned, have the lowest frequencies of bare patches (Table A13). The relatively high frequency of rocky patches on the soil surface in the *Eragrostis rigidior-Ziziphus mucronata* Community (average 2.9%), however, helps in breaking the impact and loosening effect that raindrops have on the soil surface (rain-splash protection) and also slows down run-off water which decreases the loss of top soil due to it being transported away by water. The risk of erosion is therefore slightly decreased by the rockiness of the soil surface in this community.

Plots 12, 28 and 29 show significantly higher measured biophysical functionality than the other plots in this community (indices: 35.2; 45.8 & 45.3) according to Van der Walt (2010). The abundance of organic litter in these plots cause higher stability, infiltration and nutrient cycling (Van der Walt, 2010). As has been mentioned, these three plots occur in areas

further away from residential settlements that are less impacted by anthropogenic factors. The decrease in functionality of plots surrounding settlements, therefore, adds to the argument that such areas are more disturbed. The significant difference in the functionalities of the plots of this community is evident in the standard deviation of the functionality indices, which is indicated later under 4.3.2.



**Figure 4.6** Plot number 9. GPS: lat 25°28'55.1"S, long 27°11'41.6"E. Notice the low herbaceous basal cover as well as the large sizes and high frequency of bare patches.

#### **The woody layer (Table A14 & A15)**

The five dominant and most frequently occurring woody species (Table A14) including their palatability are:

- *Acacia tortilis* (Palatable)
- *Ziziphus mucronata* (Palatable)
- *Acacia nilotica* (Palatable)
- *Dichrostachys cinerea* (Palatable)
- *Grewia flava* (Palatable)

The density, leaf biomass and canopy spread of the woody layer in the *Eragrostis rigidior-Ziziphus mucronata* Community are high. The average woody density and leaf biomass for the stratum under 2 m is 824.2 plants/ha and 502.3 kg/ha respectively and for the stratum above 2 m, 106 plants/ha and 861.2 kg/ha respectively which results in the high browsing capacity (4.2 ha/BU) of this community (Table A15). Higher woody densities, leaf biomass, canopy spread values and, therefore, browsing capacities were recorded in the natural, less disturbed areas (plots 28 and 29) for the stratum above 2 m (Table A15). Similar to the previously described *Indigofera heterotricha-Aristida bipartita* Community, the absence of woody individuals over 2 m in height in most communal areas can be ascribed to the

continuous removal of woody material by the local communities mainly for firewood and construction purposes. Only remote areas of this plant community situated far from residential settlements are not affected by such anthropogenic impacts. Plot number 12 is also not close to any residential area, as mentioned (Figure 4.1), and was thus also expected to have a high density for the woody stratum over 2 m in height. This was however not the case as the woody density for the stratum above 2 m for plot number 12 was only 55.6 plants/ha, which is lower than in many of the intensely disturbed plots (Table A15). This plot is situated on a privately owned farm where the farmer has likely implemented de-bushing strategies in the past to enhance the herbaceous layer of his veld for a higher grazing capacity which could account for the low woody densities. The latter has to be confirmed during further social studies. The leaf biomass and canopy spread for the above 2 m stratum of plot number 12 were significantly higher than expected when compared with other plots with similar, low woody densities (Table A15). This implies that the individuals present in this plot are large and not continuously cut down for firewood which supports the argument that the farmer merely implemented random de-bushing strategies. The variation in the woody layers of different plots is evident in the high standard deviations of this community discussed under 4.3.2. To conclude; it is evident from this plant community that the herbaceous and woody layers of areas surrounding residential settlements are the most exploited.

#### **4.3.1.4. *Acacia caffra-Bothriochloa insculpta* Community**

The discussion to follow refers to the data summarized in Tables A16-A19 in the appendix. A total of 39 species were recorded in this thornveld community at an average of 24 species per sampling plot.

##### **The herbaceous layer (Tables A16 & A17)**

###### **Ecological status**

The six dominant and most frequently occurring herbaceous species (grasses) (Table A16) including their ecological status and grazing values are:

- *Heteropogon contortus* (Ecological status: Increaser 2; Grazing value: Medium)
- *Bothriochloa insculpta* (Ecological status: Increaser 2; Grazing value: Medium)
- *Themeda triandra* (Ecological status: Decreaser; Grazing value: High)
- *Aristida bipartita* (Ecological status: Increaser 2; Grazing value: Low)
- *Cymbopogon pospischilii* (Ecological status: Increaser 3; Grazing value: low)
- *Ischaemum afrum* (Ecological status: Increaser 2; Grazing value: Medium)

The *Acacia caffra-Bothriochloa insculpta* Community only covers a small area of the Impala Platinum mining area and is threatened by continuous development pressures in the immediate surroundings of the community. Although the herbaceous layer of this plant community is dominated by Increaser 2 species, the high frequencies of Increaser 3 species (Table A17), which are characterized as climax species according to Van Oudtshoorn (2004), indicate fewer disturbances and therefore high relative ecological status of species in this community. The high abundance of Decreaser type species (Table A17) also supports this observation and indicates that this area is relatively unaffected by over-grazing practices. Plot number 16 has the lowest frequency of Increaser 3 species but the highest abundance of Decreaser species of the plots (Table A17) mainly due to the higher frequency of the grass *Themeda triandra* (Table A16).

### **Veld condition and grazing capacity**

The herbaceous species composition of the *Acacia caffra-Bothriochloa insculpta* Community mostly contains grass species with high and medium grazing values. Only 23.5% of the grass species have low grazing value which, combined with a high average herbaceous biomass of 2950 kg/ha, results in the high grazing capacity (average is 1.8 ha/LSU) of this plant community (Table A17). Although plot number 20 has a grass biomass of 3453 kg/ha which is significantly above the aforementioned average, it has the highest frequencies of species with low grazing value which is why the grazing capacity of 1.7 ha/LSU of this plot is not significantly higher than the other plots (Table A17).

The low average basal cover of 12.8% (Table A17) together with the high frequency of bare patches (43.5%) and low surface rock cover (1.1%) (Table A17) will increase the potential risk of erosion in the *Acacia caffra-Bothriochloa insculpta* Community. The community is, however, still categorized as an area with low erosion risk (Vetter, 2003) because it has an average point to tuft distance of only 4.5 cm which indicates that bare patches in this community are relatively small although occurring frequently. Plot 20 had the highest measured basal cover (16%), the lowest frequency of bare patches (32.8%) and the smallest point to tuft distances (3.7 cm) in this plant community (Table A17) which was expected due to the high measured grass biomass in this plot. The remaining two plots are more closely correlated (Table A17).

The Landscape functionality differed significantly between the various plots of this community (Van der Walt, 2010) and this is evident from the standard deviation of the functionality indices indicated later under 4.3.2. The small number of plots sampled in this community is provided by Van der Walt (2010) as a potential reason for the high deviation. A

weak soil crust causes a low stability of the plots and because of a lack of organic litter and shallow micro-topography, the infiltration and nutrient cycling indices are also low (Van der Walt, 2010). The overall biophysical functionality of the *Acacia caffra-Bothriochloa insculpta* Community is therefore low.

#### **The woody layer (Tables A18 & A19)**

The five dominant and most frequently occurring woody species (Table A18) including their palatability are:

- *Acacia caffra* (Palatable)
- *Acacia tortilis* (Palatable)
- *Acacia nilotica* (Palatable)
- *Dichrostachys cinerea* (Palatable)
- *Grewia flava* (Palatable)

The *Acacia caffra-Bothriochloa insculpta* Community has an average woody density of 548.1 plants/ha for the under 2 m stratum and 111.4 plants/ha for the above 2 m stratum (Table A19). Plot number 17 has a woody density of 870.2 plants/ha for the stratum under 2 m (Table A19) which is significantly higher than the average. It, however, has the lowest density of woody species for the above 2 m stratum relative to the other plots in this community. Plot number 17 also differs from the other plots in terms of leaf biomass, browsing capacity and canopy spread (Table A19). As mentioned for the landscape functionality of this community, the standard deviations of all woody attributes discussed later under 4.3.2 are high, likely because of the small number of plots sampled.

Although the average woody density for the stratum above 2 m is high in this community, the leaf biomass and browsing capacity is unexpectedly low (Table A19). This indicates that woody individuals in the stratum above 2 m are relatively small and carry less leaf material despite the high density. The argument is supported by the low canopy spread (447.1 m<sup>2</sup>/ha) and average height of woody individuals (2.7 m) for this stratum. Reasons for this occurrence will be discussed during the comparison of the four plant communities.

#### **4.3.2. Comparison of veld conditions as well as grazing and browsing capacities of the four plant communities**

The comparisons to follow refer to the data summarized in Tables 4.1-4.4 & A20-A24.

A total of 110 species were recorded in the four communities.

The *Indigofera heterotricha-Aristida bipartita* Community is referred to in figures and tables as Community 3.1.1.

The *Aristida bipartita-Bothriochloa insculpta* Community is referred to in figures and tables as Community 3.1.2.

The *Eragrostis rigidior-Ziziphus mucronata* Community is referred to in figures and tables as Community 3.1.3.

The *Acacia caffra-Bothriochloa insculpta* Community is referred to in figures and tables as Community 3.1.4.

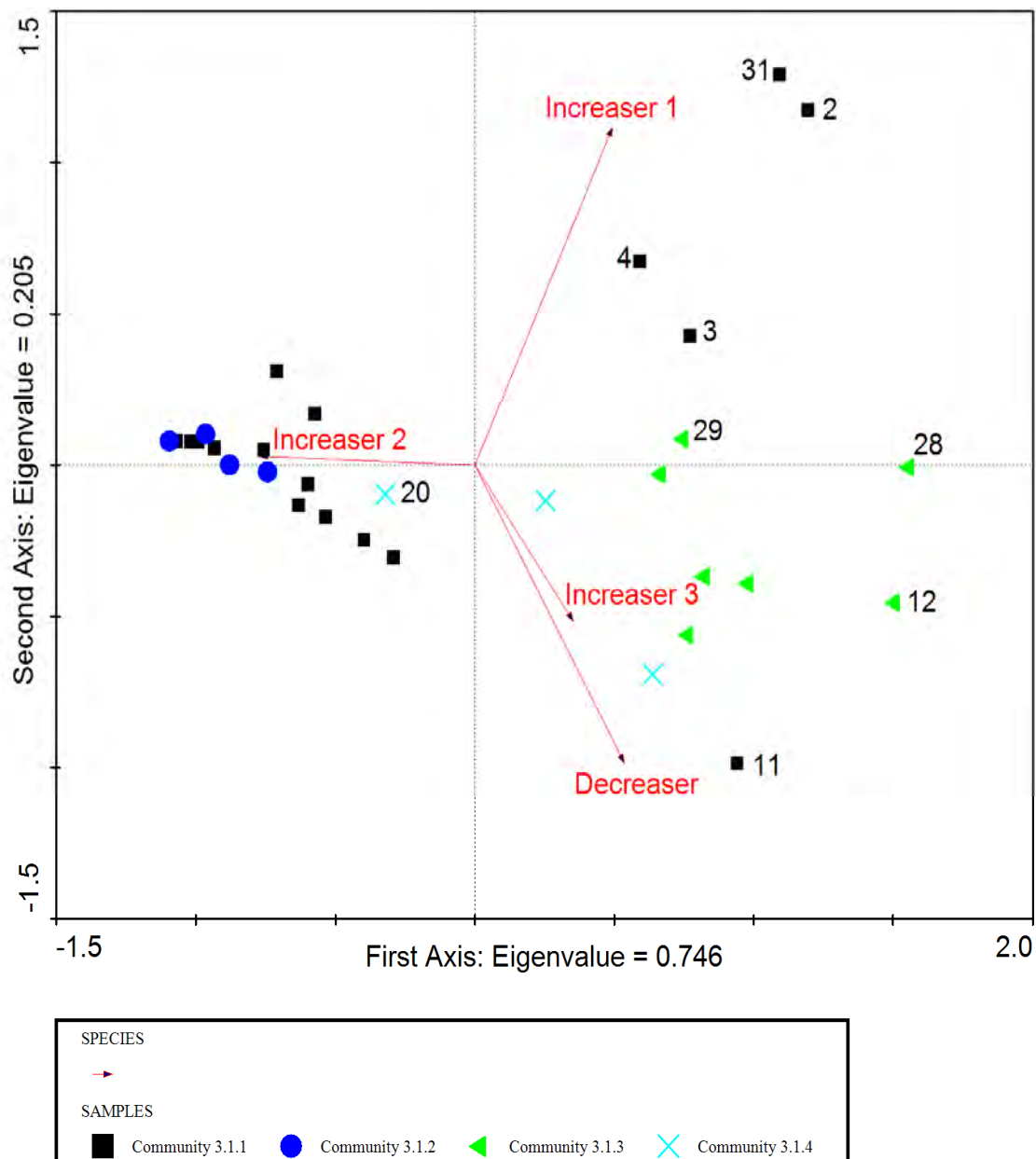
### **The herbaceous layers (Figures 4.7-4.10 & Tables 4.1, 4.2 & A20)**

#### **Ecological status**

Principle Component Analysis (PCA) ordinations were carried out in order to determine correlations in the herbaceous species composition in terms of ecological status on a degradation gradient.

The eigenvalue of the first axis of Figure 4.7 is very high (0.746) which indicates that difference in ecological status and species composition between the various plots of the four plant communities is strongly correlated to the first axis. The frequencies of Increaser 2 species increase to the left while the frequencies of Increaser 1, 3 and Decreaser species increase to the right on the first axis. The first axis of this ordination bi-plot, therefore, indicates a degradation gradient for the plant communities and their individual plots with high levels on the left and low levels on the right.

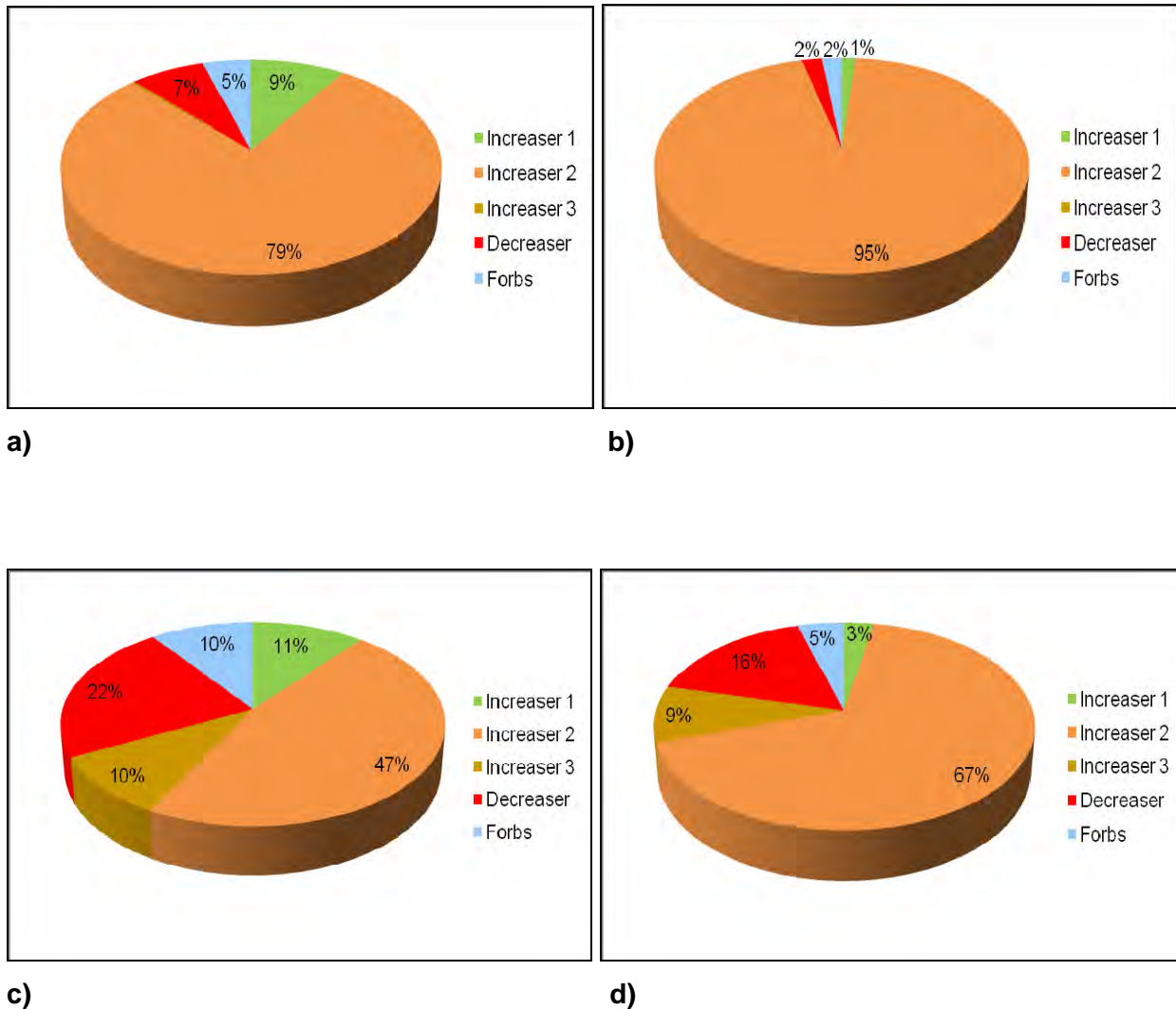
The *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities have the highest frequencies of Increaser 2 type of species (78.3 & 94.6 respectively) relative to the other two plant communities (Figures 4.7 & 4.8 & Table 4.1). This indicates that a less desired ecological status of species and higher levels of disturbance occurred in these two communities (Van Oudtshoorn, 2004). The higher frequencies of Increaser 1 species (indicating well or under utilized areas according to Van Oudtshoorn, 2004) in plots 2, 3, 4 & 31, as is evident from the ordination in Figure 4.7, supports the argument discussed earlier under 4.3.1.1 that areas of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) further away from residential settlements are less disturbed and not as over-grazed. Plot number 11 as discussed under 4.3.1.1 has high frequencies of Decreaser species and it is, therefore, separate from the other plots of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) in Figure 4.7.



**Figure 4.7 Principle Component Analysis (PCA) ordination bi-plot indicating the correlation between the herbaceous species composition of the sampling plots in terms of ecological status of the species for the four plant communities. Certain plots are numbered in the ordination and will be referred to in the text.**

The *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities show lower frequencies of Increaser 2 type of species (46.9% & 67.2% respectively) relative to the first two mentioned communities (Figures 4.7 & 4.8 & Table 4.1). This indicates that the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities are less degraded and are, therefore, characterized by a higher ecological status of species than the *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities. The *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta*

(3.1.4) Communities also exhibit higher abundances of climax and sub-climax species such as Increaser 3 and Decreaser species relative to the other two communities (Figures 4.7 & 4.8 & Table 4.1) which further supports the argument that they are less degraded than the *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities and not as over-grazed as the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1).



**Figure 4.8** Species frequencies for the different ecological status categories of the (a) *Indigofera heterotricha-Aristida bipartita* Community (3.1.1); (b) *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2); (c) *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) and (d) *Acacia caffra-Bothriochloa insculpta* Community (3.1.4).

**Table 4.1 Frequencies of the herbaceous species of the four plant communities**

<b>Species</b>	<b>Ecological Status</b>	<b>Com 3.1.1</b>	<b>Com 3.1.2</b>	<b>Com 3.1.3</b>	<b>Com 3.1.4</b>
<i>Aloe greatheadii</i>	Forb	0	0	2.6	1.1
<i>Aptosimum procumbens</i>	Forb	0	0	0	0.5
<i>Aristida bipartita</i>	Increaser 2	41.5	31.7	0.2	8.3
<i>Aristida canescens</i>	Increaser 2	0.1	0	3.9	1.6
<i>Aristida congesta</i>	Increaser 2	0	0	7.1	1.6
<i>Aristida stipitata</i>	Increaser 2	0	0	0.8	0
<i>Asparagus suaveolens</i>	Forb	0	0	0.1	0
<i>Barleria macrocephala</i>	Forb	0	0	0.1	0
<i>Bidens bipinnata</i>	Forb	0.1	0	0	0
<i>Blepharis integrifolia</i>	Forb	0	0	0.1	0
<i>Bothriochloa insculpta</i>	Increaser 2	2.9	25.1	7.2	18.4
<i>Brachiaria eruciformis</i>	Increaser 2	1.6	1.8	0	0
<i>Brachiaria nigropedata</i>	Decreaser	0	0	0.2	0
<i>Chamaecrista mimosoides</i>	Forb	0.1	0.2	0	0
<i>Chascanum hederaceum</i>	Forb	0	0	0.2	0
<i>Chloris virgata</i>	Increaser 2	0	0	0.1	0
<i>Cirsium vulgare</i>	Forb	0	0.2	0	0
<i>Commelina africana</i>	Forb	0	0	0.5	0.8
<i>Convolvulus sagittatis</i>	Forb	0.1	0	0	0
<i>Corchorus asplenifolius</i>	Forb	0.1	0.2	0.5	0
<i>Crabbea hirsuta</i>	Forb	0.1	0	0.1	0
<i>Cymbopogon nardus</i>	Increaser 1	0	0	6.3	0
<i>Cymbopogon pospischilii</i>	Increaser 1/ Increaser 3	0.3	1.1	6.6	7.7
<i>Cynodon dactylon</i>	Increaser 2	0.2	7.4	1.7	0
<i>Dichanthium annulatum</i>	Decreaser	1.3	0	0	0
<i>Digitaria argyrograpta</i>	Decreaser	0	0	0.2	0.8
<i>Digitaria eriantha</i>	Decreaser	0.8	0	0.2	1.1
<i>Diheteropogon amplexans</i>	Decreaser	0	0	0	0.3
<i>Echinochloa holubii</i>	Increaser 2	0.1	0	0	0
<i>Elionurus muticus</i>	Increaser 3	0	0	3.5	0
<i>Enneapogon cenchroides</i>	Increaser 2	0.1	0	0	0
<i>Enneapogon scoparius</i>	Increaser 3	0	0	0.5	1.1
<i>Eragrostis chloromelas</i>	Increaser 2	6.8	6.9	0	6.1
<i>Eragrostis pseudosclerantha</i>	Increaser 2	0	0	0.1	0
<i>Eragrostis rigidior</i>	Increaser 2	0	0	6.3	0.8
<i>Eragrostis superba</i>	Increaser 2	0	0	0.7	0.3
<i>Euphorbia inaequilatera</i>	Forb	0.1	0	0	0
<i>Evolvulus alsinoides</i>	Forb	0	0	0.1	0
<i>Felicia muricata</i>	Forb	0.1	0.2	1.7	1.1
<i>Fingerhuthia africana</i>	Decreaser	0.5	1.1	0.2	2.4
<i>Hemizygia pretoriae</i>	Forb	0.7	0	0	0.3
<i>Hermannia depressa</i>	Forb	0	0	0.1	0
<i>Heteropogon contortus</i>	Increaser 2	0.3	0.2	12.7	22
<i>Hibiscus pusillus</i>	Forb	0	0	0.1	0
<i>Hibiscus trionum</i>	Forb	0	0	0.1	0
<i>Hyparrhenia hirta</i>	Increaser 1	0.1	0	3.4	0
<i>Hyperthelia dissoluta</i>	Increaser 1	0	0	0.2	0

**Table 4.1 Frequencies of the herbaceous species of the four plant communities**

Species	Ecological Status	Com 3.1.1	Com 3.1.2	Com 3.1.3	Com 3.1.4
<i>Indigofera circinnata</i>	Forb	0	0	0.1	0
<i>Indigofera comosa</i>	Forb	0	0	0.3	0
<i>Indigofera heterotricha</i>	Forb	0.5	0	0	0
<i>Ipomoea magnosiana</i>	Forb	0.1	0	0	0
<i>Ischaemum afrum</i>	Increaser 2	22.6	0.6	0	7.7
<i>Kohautia caespitosa</i>	Forb	0.9	0	0	0.3
<i>Kohautia sp.</i>	Forb	0.1	0	0	0
<i>Ledebouria cooperi</i>	Forb	0	0	0.1	0
<i>Ledebouria revoluta</i>	Forb	0	0	0	0.3
<i>Ledebouria sp.</i>	Forb	0	0	0.1	0
<i>Lippia scaberrima</i>	Forb	0	0	0.2	0
<i>Lotononis listii</i>	Forb	0	0	0.1	0
<i>Melinis repens</i>	Increaser 2	0	0	2.5	0
<i>Panicum coloratum</i>	Decreaser	0	0	7.3	2.7
<i>Panicum maximum</i>	Decreaser	0	0	3.9	0.3
<i>Panicum schinzii</i>	Increaser 2	0.9	0.2	0	0
<i>Panicum volutans</i>	Increaser 2	0.1	15	0	0
<i>Rhynchosia minima</i>	Forb	0.1	1	0	0
<i>Ruellia cordata</i>	Forb	0	0	0.1	0
<i>Salvia repens</i>	Forb	0.1	0	0	0
<i>Salvia runcinata</i>	Forb	0.1	0	0	0
<i>Schizachyrium sanguineum</i>	Increaser 1	0	0	0	0.3
<i>Schkuhria pinnata</i>	Forb	0.1	0	0	0
<i>Seddera suffruticosa</i>	Forb	0.1	0	0	0
<i>Senna italica</i>	Forb	0	0	0.1	0
<i>Sesbania transvaalensis</i>	Forb	0.2	0.2	0	0
<i>Setaria incrassata</i>	Decreaser	1.6	1.4	0	0
<i>Sorghum versicolor</i>	Increaser 2	1.2	2.7	0	0
<i>Tagetes minuta</i>	Forb	0	0.2	0	0
<i>Talinum sp.</i>	Forb	0	0	0.1	0
<i>Tephrosia purpurea</i>	Forb	1	2.4	0.2	0
<i>Themeda triandra</i>	Decreaser	3.1	0.2	10.4	9.1
<i>Tragia sp.</i>	Forb	0.1	0	0	0
<i>Tragus berteronianus</i>	Increaser 2	0	0	0	0.3
<i>Urelytrum agropyroides</i>	Increaser 1	9.3	0	0	2.7
<i>Urochloa mosambicensis</i>	Increaser 2	0	0.3	0	0
<i>Vernonia oligocephala</i>	Forb	0.1	0	0	0

The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) has the highest frequencies of climax and sub-climax species such as Increaser 1, 3 and Decreaser species and the lowest abundances of Increaser 2 species of all four communities (Figures 4.7 & 4.8 & Table 4.1). It therefore has the highest ecological status of species of the four communities. It is evident from Figure 4.7 that plots 12, 28 and 29 have the highest ecological status of species due to them being on the right hand side on the first axis of the ordination. As discussed earlier under 4.3.1.3, these plots are located further away from residential areas, which once again supports the argument that areas surrounding the residential settlements

are more disturbed and exploited. The *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) contains more pioneer species (Increaser 2 species) and less climax and sub-climax species than the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) (Figures 4.7 & 4.8 & Table 4.1). It is therefore in a less desired ecological state compared to the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) but still has a higher ecological status of species relative to the *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities. Plot 20 can be regarded as an outlier relative to the other plots of the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (Figure 4.7) due to the higher frequencies of Increaser 2 species and less Increaser 1 and Decreaser species. This plot rather groups to the left on the first axis (Figure 4.7) with the plots of the *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities, which indicates that plot 20 has a less desirable ecological status of species and is more degraded compared to the other plots of the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4).

The variation in ecological conditions of the four plant communities is also supported by the Shannon diversity indices (Begon *et. al.*, 2006) calculated for each community. The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) exhibited the highest measured species richness (66) of the four communities and fairly similar representation of species and their frequencies relative to each other (Table 4.1). For these reasons the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had the highest calculated Shannon diversity index value (2.94) of the four communities. The species frequencies of the different ecological status categories, relative to each other, were also the most evenly represented in this community (Figure 4.8 & Table 4.1).

Although the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) had lower species richness (39) than the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Indigofera heterotricha-Aristida bipartita* (3.1.1) Communities (Table 4.1), this community (3.1.4) exhibited the second highest Shannon diversity index value (2.53) of the four communities. Similar to the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3), the high Shannon diversity index value can be attributed to the fairly similar representation of species and their frequencies relative to each other (Table 4.1). Figure 4.8 & Table 4.1 also indicate that species frequencies of the different ecological status categories, in the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4), were fairly evenly represented relative to each other.

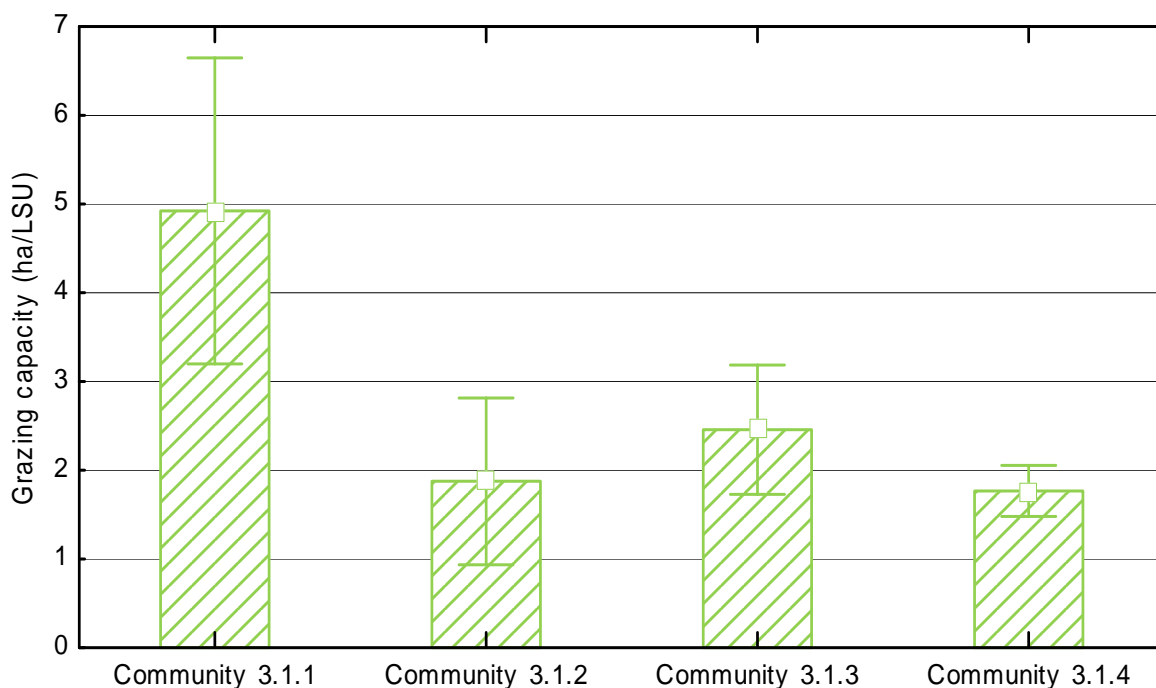
The low Shannon diversity index value (2.02) of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1), despite having the second highest species richness (58), was due to unequal relative representation of species in terms of their frequencies (species such as *Aristida bipartita* and *Ischaemum afrum* dominated the herbaceous layer which causes the diversity index to decrease) (Figures 4.7 & 4.8 & Table 4.1). The different ecological status categories were also not equally represented when comparing species frequencies in this community (Figures 4.7 & 4.8 & Table 4.1).

The *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) had the lowest species richness (34) and despite a more even representation of different species frequencies (Table 4.1) relative to the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) it exhibited the lowest Shannon diversity index of the four plant communities (2.00).

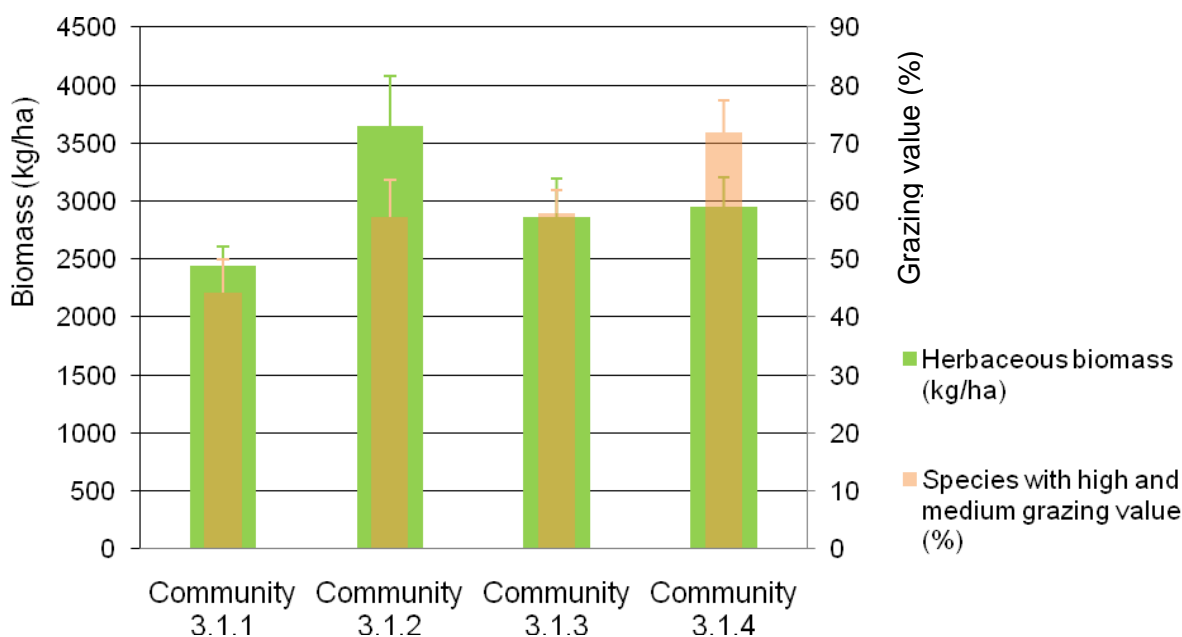
### **Veld condition and grazing capacity**

Figure 4.9 and Table 4.2 illustrate that, with the exception of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1), the other three plant communities all have high and relatively similar grazing capacities. The high standard deviation in grazing capacities between the different plots of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) indicated the heterogeneity in this community (Figure 4.9). The average grass biomass (2447.8 kg/ha) of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1), although being the lowest of the four plant communities, did not indicate a statistically significant difference from the other three communities (3643 kg/ha; 2861.9 kg/ha & 2950 kg/ha) (Figure 4.10 & Tables 4.2 & A20). The major reason for the low grazing capacity (4.9 ha/LSU) of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1), as was also explained earlier under 4.3.1.1, was, therefore, that it had the highest frequencies of grass species with low grazing values (51.2%) of the four communities (Table 4.2).

The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had a grazing capacity of 2.5 ha/LSU, which exhibited a low standard deviation (Figure 4.9 & Table 4.2). Although it was the second lowest value of the four communities, the value was considerably higher than the grazing capacity of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1). The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had the second highest frequencies of grass species with high or medium grazing values (58%) (Figure 4.10 & Table 4.2). It therefore exhibited a high grazing capacity although having the second lowest average grass biomass (2861.9 kg/ha) of the four communities (Figure 4.10 & Table 4.2).



**Figure 4.9 Grazing capacities (ha/LSU) of the four plant communities.**



**Figure 4.10 Herbaceous biomass (kg/ha) and grazing value of the four plant communities.**

The *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) had the highest grazing capacity (1.8 ha/LSU) of the four plant communities (Figure 4.9 & Table 4.2). The high value was as a result of this community having the highest frequencies of grass species with high or medium grazing values (71.8%) although it only had the second highest average grass biomass (2950 kg/ha) of the four communities (Figure 4.10 & Table 4.2). The *Aristida*

*bipartita-Bothriochloa insculpta* Community (3.1.2) had the highest measured average grass biomass (3643 kg/ha) for the reasons explained under 4.3.1.2 but only the second highest grazing capacity (1.9 ha/LSU) because of the frequencies of grass species with high or medium grazing values (57.2%) being considerably lower than that of the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (Figures 4.9 & 4.10 & Table 4.2).

Differences in the average grazing capacities and grass biomass of the four communities, however, all proved to be statistically insignificant because of the large variations between individual plots (Table A20). The grazing capacity values calculated for the four plant communities were also considerably higher than the standard grazing norms set for the Rustenburg area. The likely reason for this was that over estimation of grass biomass could have occurred with the use of the disc pasture meter although this instrument has been scientifically calibrated (Trollope & Potgieter, 1986) and successfully applied in practice for example in studies by Meeske *et. al.*, 2009; Van Niekerk *et. al.*, 2006 and Bodenstein *et. al.*, 2000.

The *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) has the lowest herbaceous basal cover (12.8%) and the highest frequency of bare patches (43.5%) measured in the four communities (Table 4.2). The short point to tuft distances relative to the other communities of 4.5 cm (Table 4.2), however, indicate that although this community exhibits high frequencies of bare patches, these patches are small in size. For this reason the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) was still classified as an area with low erosion risk (Vetter, 2003).

**Table 4.2 Comparison of the herbaceous layers of the four plant communities**

	Grazing potential (Frequency)			Grass biomass (kg/ha)	Grazing capacity (ha/LSU)	Basal cover (%)	Physical parameters (Frequency)			Erosion factor	
	High	Medium	Low				Bare patches	Litter patches	Rock patches	Point to tuft distance (cm)	Erosion risk
<b>Com 3.1.1</b>	7.9	36.2	51.2	2447.8	4.9	17	28.7	1.9	0.1	3.3	Low
<b>Com 3.1.2</b>	10	47.2	40.8	3643	1.9	15.2	30.2	9.4	0	3.8	Low
<b>Com 3.1.3</b>	27.1	30.9	32	2861.9	2.5	13.1	32.7	5.4	2.9	5.8	Medium
<b>Com 3.1.4</b>	13.9	57.9	23.5	2950	1.8	12.8	43.5	0.8	1.1	4.5	Low

The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had the second highest frequency of bare patches (32.7%) and the second lowest herbaceous basal cover (13.1%) which was not significantly higher than that of the *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities (Table 4.2). This community (3.1.3) was, however, classified as an area with medium erosion risk (Vetter,

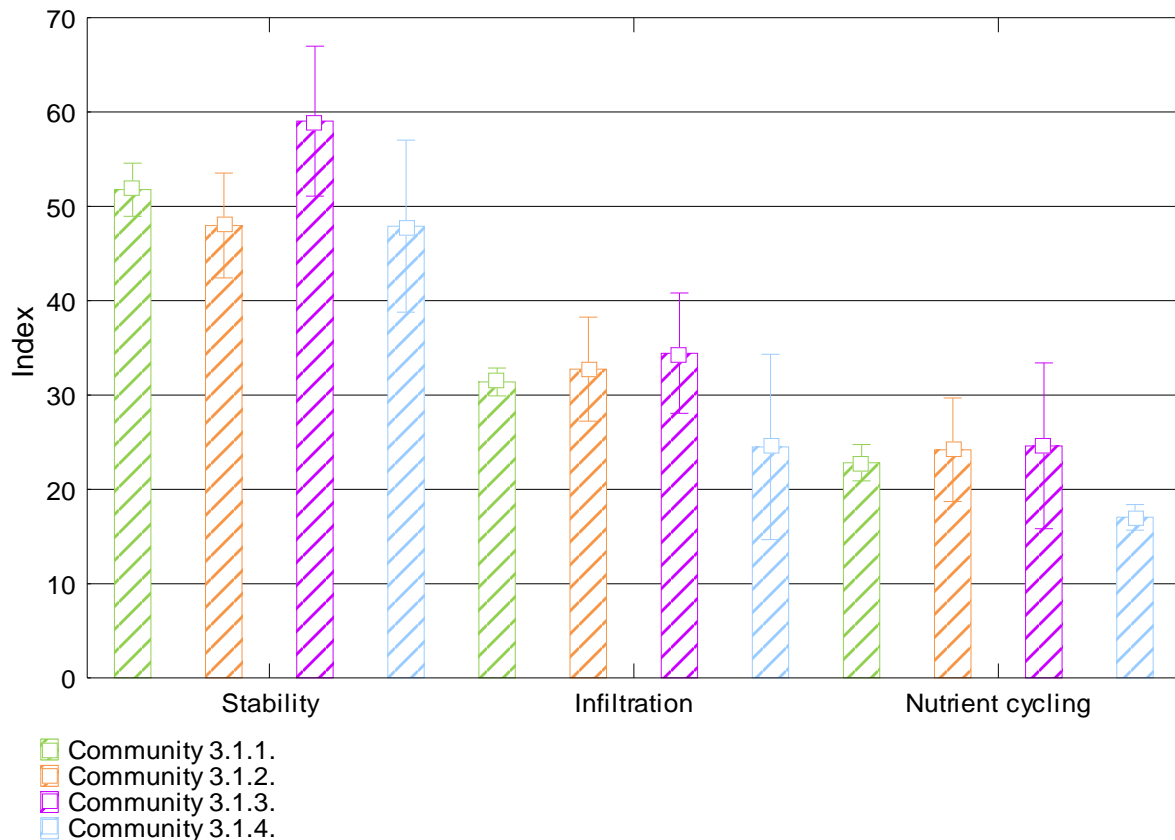
2003) due to the large sizes of bare patches which was deduced from the large point to tuft distances relative to the other communities (5.8 cm) (Table 4.2). This aspect will have to be considered during the development of future management strategies. The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) did, however, have the highest measured relative frequencies of rocky patches (2.9%) as well as the second highest frequencies of organic litter patches (5.4%) (Table 4.2). Although these values were low, rockiness and soil surface litter are both aspects that can control and decrease the effects of erosion.

The *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities were both classified as areas with low erosion risk because of their low point to tuft distances (Vetter, 2003) as well as their high basal covers and low frequencies of bare patches relative to the other communities (Table 4.2). The reasons and potential problems associated with the high frequency of organic litter patches (9.4%) (Table 4.2) in the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) were discussed under 4.3.1.2.

### **Landscape Functionality**

Average stability, infiltration, and nutrient cycling indices were calculated for each of the four plant communities in order to compare their biophysical functionalities (Figure 4.11).

The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had the highest measured stability index (59) of all the plant communities (Figure 4.11). Relative to the other communities, this community had a very stable soil crust which stays mostly intact in the presence of water, meaning that it is less prone to erosion (Van der Walt, 2010). The soil crust of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) (stability index: 51.8) proved to be less stable and, therefore, more susceptible to erosion than the soil of the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3). The average indices of these two communities did, however, not indicate a statistically significant difference according to Van der Walt (2010). The soil crusts for both the *Aristida bipartita-Bothriochloa insculpta* (3.1.2) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities were characterized as extremely unstable (Van der Walt, 2010). This contributed to these two communities having the weakest stability indices (47 & 48 respectively) of the four plant communities (Figure 4.11). Of these two communities, only the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) showed a statistically significant difference from the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) however (Van der Walt, 2010).



**Figure 4.11 Average stability, infiltration and nutrient cycling indices of the four plant communities.**

The infiltration indices of the four plant communities indicated no statistically significant difference according to Van der Walt (2010). The *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) showed the lowest calculated index of only 24.5 (Figure 4.11). The soil texture measured in this community by Van der Walt (2010) indicated slow infiltration rates of water into the soil resulting in the loss of water and nutrients in the form of runoff. Soil compaction and density is also increased through hoof action of grazing livestock and this further decreases water infiltration in the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (Van der Walt, 2010). Although soil compaction by grazing animals also affected the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) and especially the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1), which is intensely over-grazed, the measured soil infiltration indices of these two communities were moderate because of soil textures allowing for better water infiltration (Van der Walt, 2010). This resulted in higher overall infiltration indices for these two communities (34.4 & 31.4 respectively) relative to the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (Figure 4.11). The high overall infiltration index (32.8) of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) relative to the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (Figure 4.11) was mainly due to high organic litter cover in this community (Van der Walt, 2010). Organic litter

captures resources moving through the landscape and slows down water flow which increases infiltration into the soil substrate (Van der Walt, 2010). As discussed earlier, the grazing impact in the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) is low which contributes to lower soil compaction. This, together with the moderate infiltration rate of this specific textured soil type of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2), added to the high infiltration index of this community (Van der Walt, 2010).

Although none of the average nutrient cycling indices of the four communities differed statistically significantly (Van der Walt, 2010), the index of 24.6 of the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) was the highest index of all four communities. The reason for this high value was the large abundances of organic litter measured in the plots of this community. High herbaceous basal cover, together with high organic litter in both the *Aristida bipartita-Bothriochloa insculpta* (3.1.2) and *Indigofera heterotricha-Aristida bipartita* (3.1.1) Communities also resulted in high nutrient cycling indices (24.2 & 22.8 respectively) (Van der Walt, 2010). Lower measured basal cover and larger frequencies of bare ground patches in the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) resulted in less organic litter being present. This together with the weak soil infiltration, as discussed, caused less nutrients and water to be captured in the soil (Van der Walt, 2010). The *Acacia caffra-Bothriochloa insculpta* Community (3.1.4), therefore, has the lowest nutrient cycling index (17) of the four plant communities (Figure 4.11).

To conclude, the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) was overall the least functional of the four communities mainly due to its unstable soil crust as well as low basal and organic litter cover. The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3), on the other hand, achieved the highest overall functionality (Van der Walt, 2010). The high biophysical stability of this community due to a stable soil crust and a soil texture that allows for adequate water infiltration together with good nutrient cycling due to the presence of organic litter contribute to the high functionality of this community. The high standard deviations of these two communities, however, indicate large differences between the functionalities of the various plots sampled for reasons discussed earlier under 4.3.1.3 and 4.3.1.4.

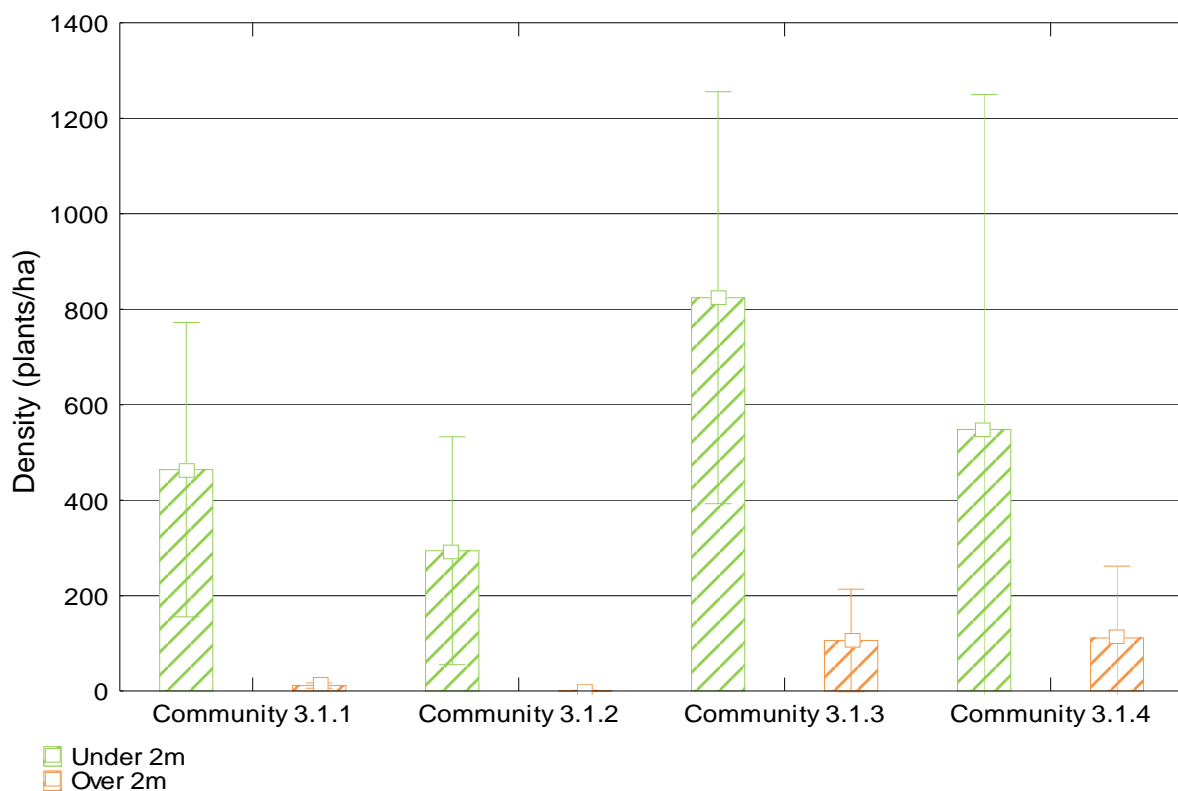
### **The woody layers (Figures 4.12-4.15 & Tables 4.3, 4.4 & A21-A24)**

The woody densities of the four plant communities did not differ significantly for the stratum under 2 m in height (Table A.21) but are considerably higher for this stratum than for the stratum over 2 m in height (Figure 4.12 & Table 4.3). The *Aristida bipartita-Bothriochloa*

*insculpta* Community (3.1.2) had the lowest measured woody density for the stratum under 2 m (294 plants/ha) and a woody layer above 2 m was virtually absent in this community (0.6 plants/ha) due to the disturbance caused by the opencast mining (Figure 4.12 & Table 4.3). The woody density above 2 m is however expected to increase as the area becomes progressively naturalised after the rehabilitation processes. The average height (2.3 m) of the woody component in the above 2 m height stratum for the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) is also considerably lower than in the other three plant communities (Table 4.3).

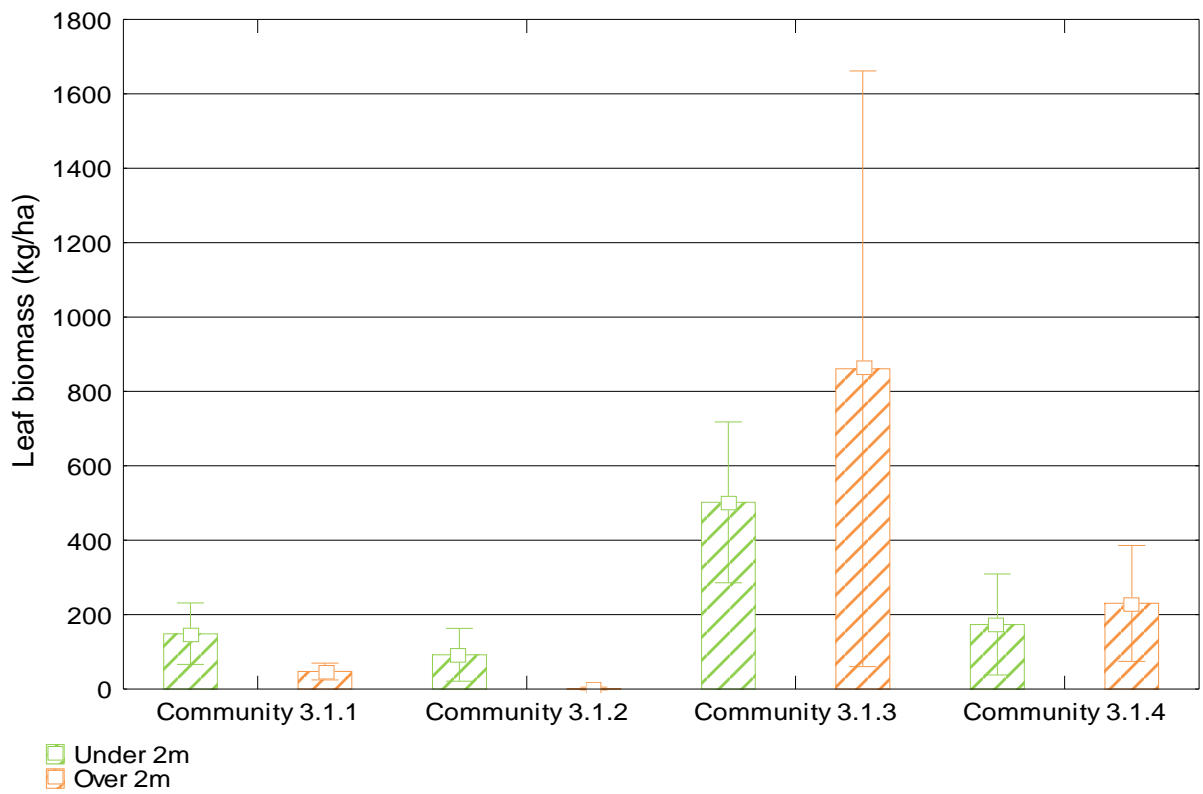
**Table 4.3 Comparison of the woody layers of the four plant communities**

	Palatability (%)		Density (plants/ha)		Leaf biomass (kg/ha)		Browsing capacity (ha/BU)		Canopy spread (m <sup>2</sup> /ha)		Average individual height (m)	
	Palatable	Unpalatable	< 2m	> 2m	< 2m	> 2m	< 2m	> 2m	< 2m	> 2m	< 2m	> 2m
Com 3.1.1	99.3	0.7	463.9	11.6	149.1	47.6	24.5	76.7	610	87.8	0.8	3
Com 3.1.2	99	1	294	0.6	92.3	1.5	45	5490.3	412	2.1	0.9	2.3
Com 3.1.3	92.5	7.5	824.2	106	502.3	861.2	7.3	4.2	1119	673.6	1	3.1
Com 3.1.4	96.4	3.6	548.1	111.4	174	230.4	21	15.8	675.5	447.1	1	2.7

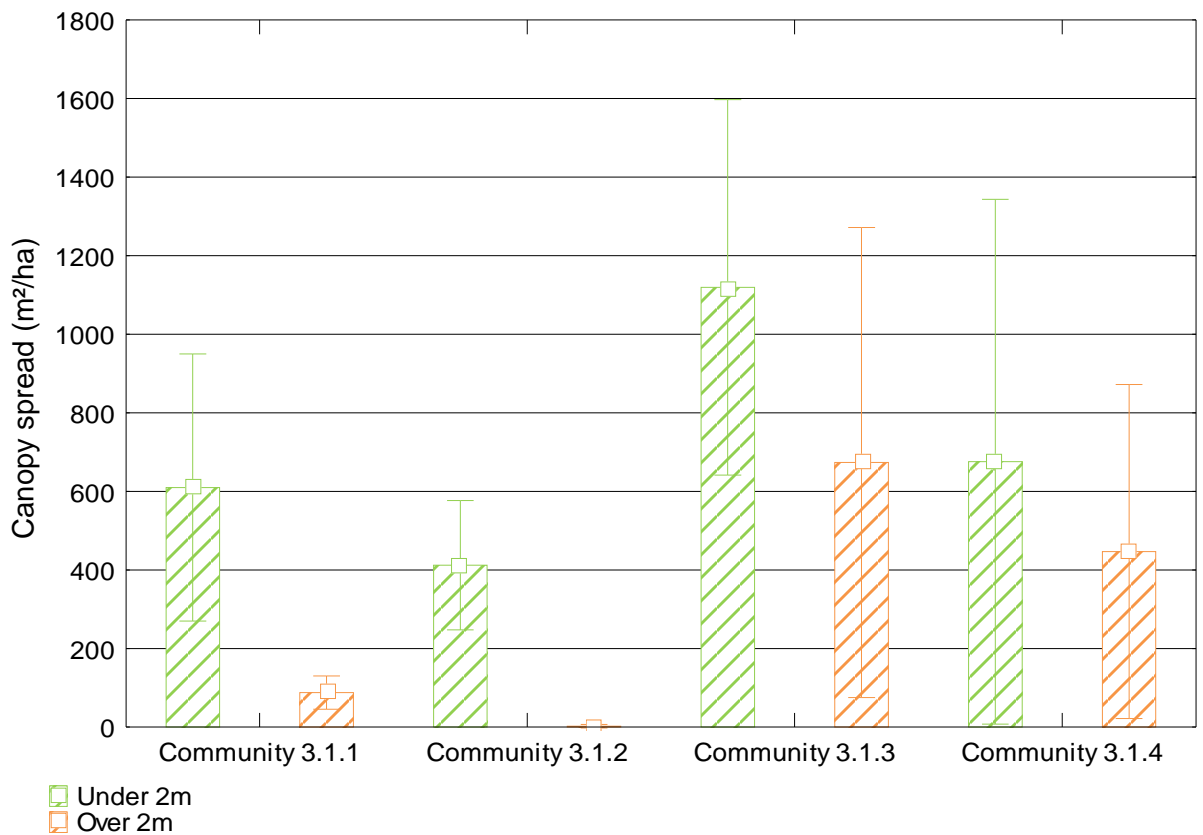


**Figure 4.12 Woody density (plants/ha) of the four plant communities in the strata under and above 2 m.**

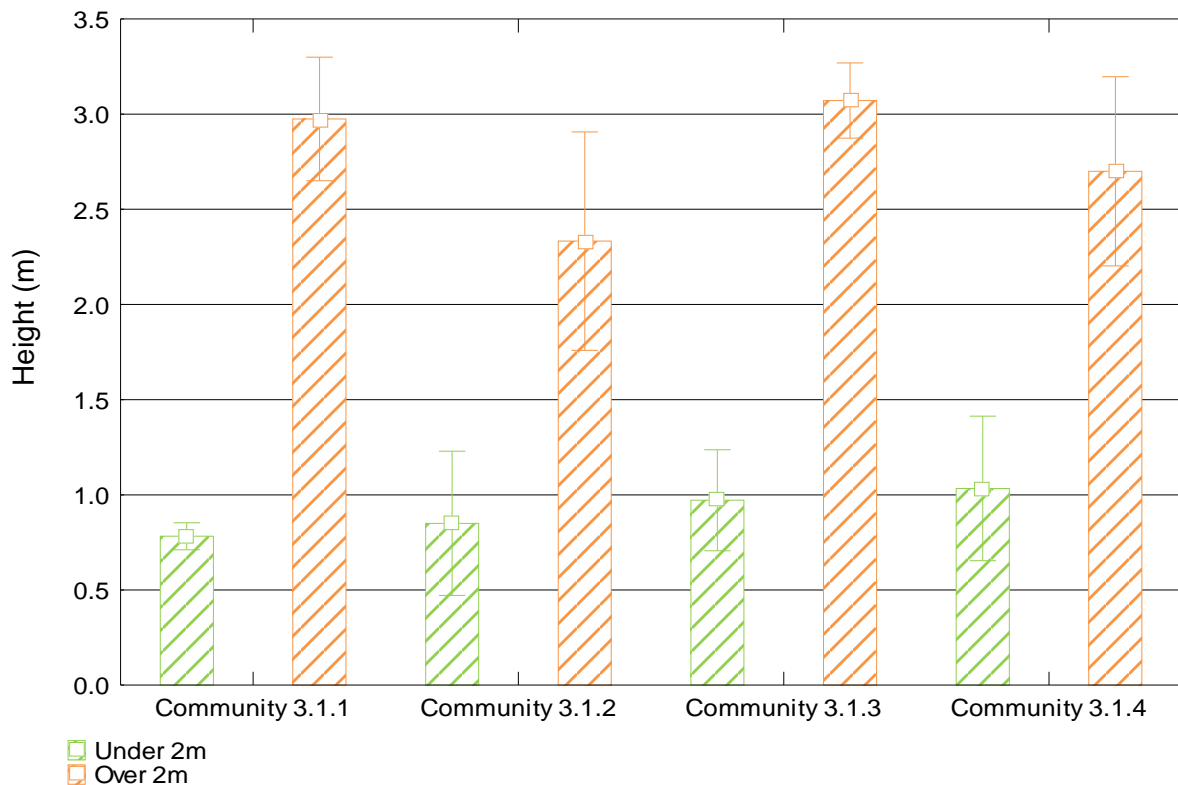
The average woody densities for the stratum above 2 m in height were the highest in the *Acacia caffra-Bothriochloa insculpta* (3.1.4) and *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) Communities (111.4 plants/ha & 106 plants/ha respectively) and did not indicate any statistically significant difference (Figure 4.12 & Tables 4.3 & A21). The leaf biomass of the woody stratum above 2 m of the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) (861.2 kg/ha) was, however, considerably higher than the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (230.4 kg/ha) which was not expected from the similar woody densities (Figure 4.13 & Table 4.3). Although the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had a slightly lower woody density, its leaf biomass for the stratum above 2 m was more than three times higher than the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (Figures 4.12 & 4.13 & Table 4.3). The first reason for the large difference in leaf biomass above 2 m in height between these two communities (3.1.3 & 3.1.4), despite the similar densities, is that larger woody individuals with more leaf material were present in the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3). This argument is supported by the canopy spread (673.6 m<sup>2</sup>/ha) and average height (3.1 m) of the woody stratum above 2 m of the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) which is considerably higher than that of the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (447.1 m<sup>2</sup>/ha & 2.7 m) (Figures 4.14 & 4.15 & Table 4.3) although the difference is not statistically significant (Table A23). The reason for the occurrence of smaller woody individuals in the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) could be attributed to the shallowness of the soil in this community which leads to less water being available for plants. Both these communities (3.1.3 & 3.1.4) are found on the Shortlands soil type. The Shortlands soil found in the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) are, however, considerably shallower than in the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) (see Chapter 3). Therefore, although the woody density of the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) is high, the lack of adequate available underground water and space for root development because of shallow bedrock likely inhibits the height development of the woody layer. This assumption needs to be confirmed in follow-up studies. The second reason for the higher leaf biomass in the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) is due to the high frequencies of broad-leaved woody species in this community in contrast to the dominance of *Acacia* species in the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4). Such broad-leaved species carry more leaf biomass per volume and therefore produce a higher biomass with the same density of woody individuals as an *Acacia* dominated community.



**Figure 4.13** Leaf biomass (kg/ha) of the woody component of the four plant communities in the strata under and above 2 m.



**Figure 4.14** Canopy spread (m²/ha) of the woody component of the four plant communities in the strata under and above 2 m.



**Figure 4.15** Average height of the woody component of the four plant communities in the strata under and above 2 m.

The *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) had the highest percentage of unpalatable woody species of the four plant communities (7.5%) (Tables 4.3 & 4.4). This value was, however, not considerably higher than the other communities and, because of the higher leaf biomass in the stratum above 2 m as discussed above, the browsing capacity of the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) was also considerably higher than the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) (4.2 ha/BU & 15.8 ha/BU respectively) (Figure 4.13 & Tables 4.3 & 4.4). This resulted in the *Eragrostis rigidior-Ziziphus mucronata* Community (3.1.3) being the most adequate for maintaining large amounts of game in the Impala Platinum mining area. The lower browsing capacity of the *Acacia caffra-Bothriochloa insculpta* Community (3.1.4) is, however, still the second highest of the four communities and will be adequate to successfully sustain relative amounts of browsing animals. This land-use potential can be considered for these two plant communities during the development of a management strategy.

The *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities showed the highest standard deviations in all measured attributes of the woody layer (Figures 4.12-4.14) which could explain why the considerable difference between the woody layers of these two communities did not prove to be statistically

significant (Tables A21-A24). The reasons for the variance between plots as discussed earlier under 4.3.1.3 and 4.3.1.4 were the large differences between plots close to residential settlements and plots further away.

**Table 4.4 Frequencies of the woody species of the four plant communities**

Species	Palatability	Com 3.1.1	Com 3.1.2	Com 3.1.3	Com 3.1.4
<i>Acacia caffra</i>	Palatable	0	0.3	5.4	44.5
<i>Acacia galpinii</i>	Palatable	0	0.5	0	0
<i>Acacia hereroensis</i>	Palatable	0	0	0.6	0
<i>Acacia karroo</i>	Palatable	12.7	4.3	1.5	1.6
<i>Acacia mellifera</i>	Palatable	0.5	4.8	4.9	0
<i>Acacia nilotica</i>	Palatable	10.4	2.4	8.7	5.3
<i>Acacia robusta</i>	Unpalatable	0.1	0	0	0
<i>Acacia tortilis</i>	Palatable	13.1	12.5	14.9	8
<i>Aloe marlothii</i>	Unpalatable	0.1	0	0.3	0
<i>Boscia albitrunca</i>	Palatable	0.1	0	0	0
<i>Dichrostachys cinerea</i>	Palatable	6.8	1.4	8	4.5
<i>Diospyros lycioides</i>	Palatable	0.3	0.6	0.9	0
<i>Dombeya rotundifolia</i>	Palatable	0	0	0	0.3
<i>Ehretia rigida</i>	Palatable	0.1	0	1.1	1.1
<i>Euclea undulata</i>	Palatable	0	0	0.1	0
<i>Grewia flava</i>	Palatable	0.1	0	7.7	4.5
<i>Opuntia ficus-indica</i>	Palatable	0.1	0	0	0
<i>Searsia lancea</i>	Palatable	0	0	0.3	0.3
<i>Searsia leptodictya</i>	Palatable	0.1	0	0	0
<i>Searsia pyroides</i>	Unpalatable	0.2	0.3	5.1	2.7
<i>Tarchonanthus camphoratus</i>	Palatable	0	0	0.8	0
<i>Tipuana tipu</i>	Palatable	0	1	0	0
<i>Ziziphus mucronata</i>	Palatable	0.4	2.4	12.3	1.9
<i>Ziziphus zeyheriana</i>	Palatable	0.2	0	0	0

The woody densities of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) in the stratum under 2 m and especially above 2 m in height are considerably lower than the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities (Figure 4.12 & Table 4.3). This difference is also reflected in the leaf biomass and canopy spread of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) which are significantly lower than the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities (Figures 4.13 & 4.14 & Table 4.3). Only the differences between the woody layers of the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Indigofera heterotricha-Aristida bipartita* (3.1.1) Communities are statistically significant (Tables A21-A23). The browsing capacity in the above 2 m height stratum of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) is only 76.7 ha/BU which is considerably lower than the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities (Table 4.3). The *Indigofera*

*heterotricha-Aristida bipartita* Community (3.1.1) will, therefore, not be able to sustain large amounts of game and this potential land-use can not be considered (Table 4.3).

### **Comparative summary of the quantitative results of the four plant communities.**

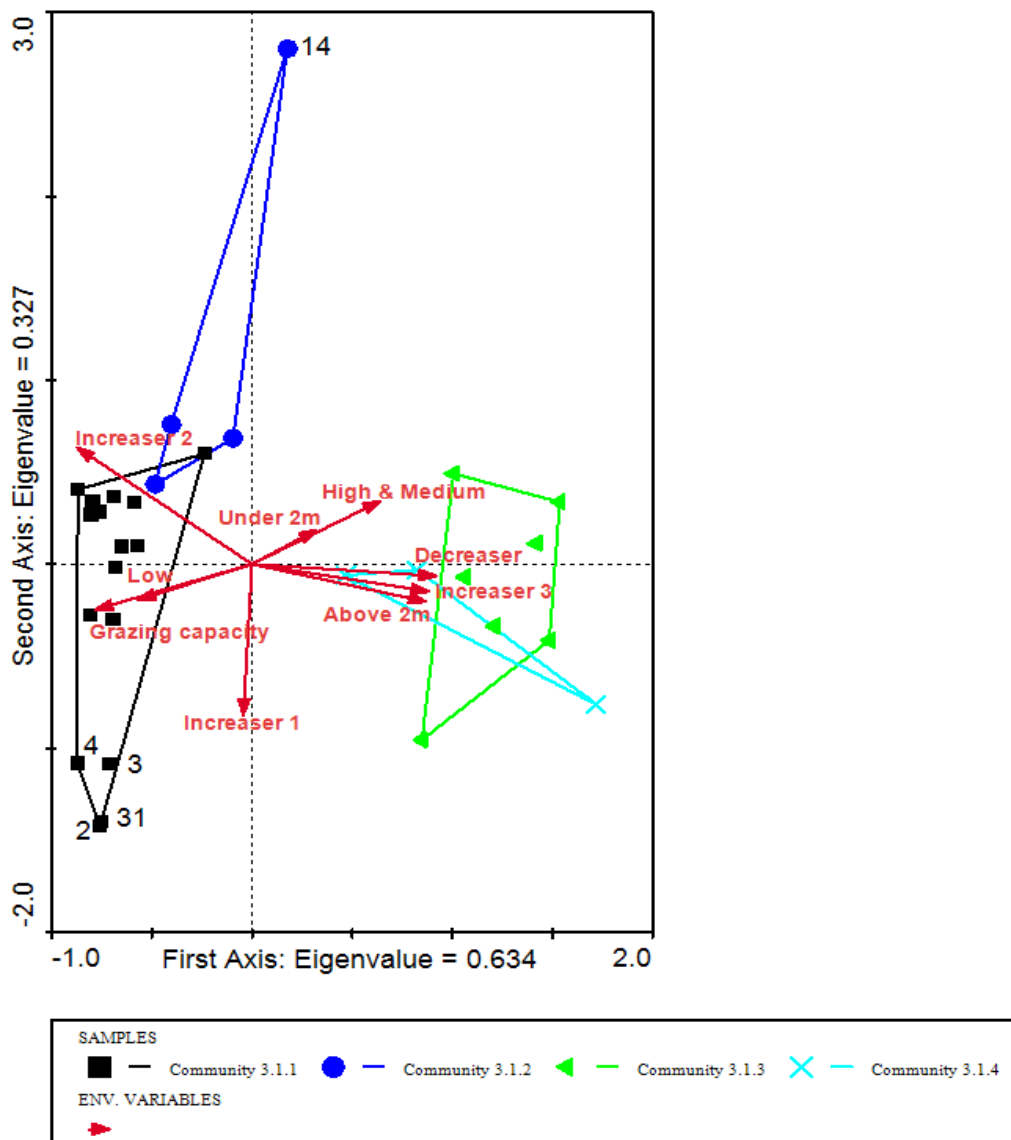
Correspondence Analysis (CA) ordinations were carried out in order to conclude the results of this chapter by comparing the herbaceous and woody layers of all four plant communities in the Impala Platinum mining area in a single figure (Figure 4.16).

Environmental variables are positively correlated in the directions of the arrows with the exception of the grazing capacity which is negatively correlated in the direction of the arrow. The high eigenvalue of the first axis of Figure 4.16 (0.634) indicates that changes in composition, ecological status and grazing value of species, grazing capacity and woody density between the various plots of the four plant communities are strongly correlated to the first axis. The frequencies of Increaser 2 species increase to the left while the frequencies of Increaser 1, 3 and Decreaser species increase to the right hand side of the first axis. The frequencies of grass species with high and medium grazing value (see arrow labelled: High & Medium – Figure 4.16) also increase to the right while the frequencies of grass species with low grazing value (see arrow labelled: Low – Figure 4.16) increase to the left. The grazing capacity, therefore, also decreases to the left hand side of the first axis. The first axis of this ordination bi-plot indicates a degradation gradient similar to Figure 4.7, which improves from high levels on the left to low levels on the right.

With the exceptions of plots 2, 3, 4 & 31, which have more Increaser 1 species and are, therefore, in a less disturbed state as was discussed under 4.3.1.1, the rest of the sampling plots of the *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) form a grouping which indicates a correlation in species composition (Figure 4.16). The *Indigofera heterotricha-Aristida bipartita* Community (3.1.1) has the lowest grazing capacity relative to the other plant communities. Species with low grazing values are abundant in this community which, together with a low grass biomass, are the main reasons for the low grazing capacity (Figure 4.16).

The sampling plots of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) are also grouped as one community with the exception of plot number 14 (Figure 4.16). The reason for plot number 14 not correlating with the rest of the sampling plots of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) is that the species *Cynodon dactylon* (grass) and *Acacia mellifera* (woody) are present in significantly higher abundances than in

the rest of the community (Tables A8 & A10). The Increaser 2 species category exhibits the highest frequencies in the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) but most of these species have medium rather than low grazing values (Figure 4.16). For this reason together with high grass biomass, the grazing capacity of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) is high (1.9 ha/LSU).



**Figure 4.16** Correspondence Analysis (CA) ordination bi-plot indicating correlations in species composition, veld condition, grazing capacities and woody densities between the four plant communities. Certain plots are numbered in the ordination and will be referred to in the text.

The soil type present in the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) is classified as Witbank (mostly Arcadia soil used as top soil to cover the mine spoil). The

*Indigofera heterotricha-Aristida bipartita* Community (3.1.1), which is found on deep Arcadia soils, can therefore be viewed as the natural, less disturbed form of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2). The composition and ecological status of the species in these two communities (3.1.1 & 3.1.2) can also be compared and used in order to determine the success of the rehabilitation processes to date. The *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) has the higher grazing capacity of the two communities as more species with high and medium grazing value occur in this community but as is evident from Figure 4.16, the sampling plots of these two communities are not clustered separately but are more grouped as one identity. The single cluster formed by the sampling plots of the two communities indicates a high similarity in composition and also ecological status of species. This ordination, therefore, concludes that the attempts of the rehabilitation processes to restore the opencast mining areas to a more natural form have been relatively successful in terms of species composition at the time that the study was carried out. The densities of the woody component for the strata under 2 m and especially above 2 m in height (see arrows labelled: Under 2 m and Over 2 m – Figure 4.16) of the *Aristida bipartita-Bothriochloa insculpta* Community (3.1.2) are, however, still very low relative to the other communities. It is expected that the densities will increase over time.

The sampling plots of the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities are also closely grouped and some overlap is even visible. This indicates large similarity in species composition between these two plant communities. The reasons for the distinct characterization between the two communities are discussed in Chapter 3. The *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities have high grazing capacities (2.5 ha/LSU & 1.8 ha/LSU) according to Figure 4.16. The frequencies of Increaser 3 and Decreaser species, which mostly have high and medium grazing values, are also high in these two communities (Figure 4.16). This, together with high grass biomass, is responsible for the high grazing capacities. The densities of the woody stratum under and above 2 m in height for the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities are also higher than those of the *Indigofera heterotricha-Aristida bipartita* (3.1.1) and *Aristida bipartita-Bothriochloa insculpta* (3.1.2) Communities (Figure 4.16). This results in higher browsing capacities (Table 4.4) for the *Eragrostis rigidior-Ziziphus mucronata* (3.1.3) and *Acacia caffra-Bothriochloa insculpta* (3.1.4) Communities and higher numbers of browsing animals can, therefore, be sustained over the long term.

#### 4.4. Conclusions

The specific objectives of this chapter included the determining of veld conditions, grazing and browsing capacities and landscape functionality of selected plant communities in order to reach the study's main objective of providing potential land-use and management recommendations for the Impala Platinum mining area. The Fixed Point Monitoring of Vegetation Methodology- FIXMOVE was successfully used to survey the herbaceous and woody layers of the four identified plant communities. Veld conditions were assessed together with ecological status of grass species and grazing and browsing capacities of the four communities. The objectives of this chapter were thus successfully reached. The data were then compared between the communities in order to determine land-use potential and to aid in making recommendations towards future management strategies (discussed in Chapter 5). The additional results included from the Landscape Function Analysis surveys complimented the quantitative data and supported the conclusions drawn about the plant communities.

Sufficient, relevant data were collected inside the allocated timeframe and budget using the FIXMOVE methodology and the comparisons and interpretations of the results are used in combination with the results of Chapter 3 to successfully reach the objectives of the study (Chapter 5). FIXMOVE can therefore be regarded as a useful tool to gather quantitative herbaceous and woody data and gain a more holistic view of the vegetation of an area in a relatively short amount of time.

#### 4.5. References

- Begon, M., Townsend, C.R., Harper, J.L. 2006.** Ecology: From Individuals to Ecosystems. 4<sup>th</sup> Ed. Blackwell Publishing.
- Bodenstein, V., Meissner, H.H. & Van Hoven, W. 2000.** Food selection by Burchell's zebra and blue wildebeest in the Timbavati area of the Northern Province Lowveld. *South African Journal of Wildlife Reserves*, 30(2): 63-72.
- Cadenasso, M.L., Pickett, S.T.A., Weathers, K.C. & Jones, C.G. 2003.** A Framework for Theory of Ecological Boundaries. *Bioscience*, 53(8): 750-758, August.
- Driver, A., Cowling, R.M. & Maze, K. 2003.** Planning for living landscapes: Perspectives and lessons from South Africa. Botanical Society of South Africa, Cape Town.
- Ludwig, J.A. & Tongway, D.J. 1997.** A Landscape Approach to Rangeland Ecology. (*In* Ludwig, J.A. *et. al. eds.* Landscape Ecology, Function & Management: Principles from Australia's Rangelands. CSIRO Publishing, Melbourne, Australia. p. 4-7)

- McGarical, K. & Marks, B.J. 1995.** FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. p. 11.
- Meeske, R, Botha, P.R., Van der Merwe, G.D., Greyling, J.F., Hopkins, C. & Marias, J.P. 2009.** Milk production of two ryegrass cultivars with different total non-structural carbohydrate contents. *South African Journal of Animal Science*, 69(1): 15-21.
- Morgenthal, T.L. & Kellner, K. 2008.** FIXMOVE Fixed Point Monitoring of Vegetation Methodology. 1<sup>st</sup>Ed. Department of Agriculture.
- Moussa, A.S., Mokau, E.M., Kellner, K., Dames, C.J., Jordaan, F. & Coetzee, M. 2009.** Local Level Monitoring: Land-user's monitoring field guide for improved management decisions. DMP/GEF, South Africa.
- Rezaei, S.A., Arzani, H. & Tongway, D.J. 2005.** Assessing rangeland capability in Iran using landscape function indices based on soil surface attributes. *Journal of Arid Environments*, 65: 460-473.
- Smit, G.N. 2008.** Field Guide to the Acacias of South Africa. 1<sup>st</sup> Ed. Briza Publications.
- Smit, G.N. 2006.** Calculation of grazing capacity and browse capacity for game species. (In Schutte, F., ed. Game Ranching in Central South Africa. Charmainé Alberts Design & Marketing, Brandfort, South Africa. p. 18-28.)
- Smit, G.N. 1989.** Quantitative description of woody plant communities: Part II. Computerized calculation procedures. *Tydskrif vir die Weidingsvereniging van Suid Afrika*, 6(4):192-194.
- Smyth, A.K. & James, C.D. 2004.** Characteristics of Australia's rangelands and key design issues for monitoring biodiversity. *Journal of Australian Ecology*, 29: 3-15.
- STATSOFT, Inc. 2009.** STATISTICA (data analysis software system), version 9.0. [www.statsoft.com](http://www.statsoft.com).
- Tainton, N.M., Aucamp, A.J. & Danckwerts, J.E. 1999.** Principles of managing veld. (In Tainton, N., ed. Veld management in South Africa. 1<sup>st</sup> Ed. University of Natal Press, Pietermaritzburg. p. 169-193.)
- Ter Braak, C.J.F. 1986.** Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 65 (5).
- Tongway, D.J. & Hindley, N. 2004.** Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes. With special reference to Minesites and Rangelands. CSIRO Sustainable Ecosystems, Canberra Australia.
- Trollope, W.S.W. & Potgieter, A.L.F. 1986.** Estimating grass fuel loads with a disc pasture meter in the Kruger National Park. *Journal of the Grassland Society of South Africa*, 3,4: 148-152.

- Trollope, W.S.W., Van den Broeck, D., Brown, D., Webber, L.N. & Nibe, S. 2004.** Assessment of veld condition in the Thicket communities of the Great Fish River Reserve in the Eastern Cape Province of South Africa.
- Van der Walt, L. 2010.** Landscape functionality of plant communities in the Impala Platinum mining area, Rustenburg. North-West University, Potchefstroom. (Unpublished report – Honors in Environmental Science).
- Van Niekerk, W.A., Abubeker Hassen, N.H., Coertze, C. & Coertze, R.J. 2006.** Effect of different grazing pressure by lambs grazing *Lolium perenne* and *Dactylis glomerata* pastures during spring on: 1. Diet quality. *South African Journal of Animal Science*, 36: 46-49.
- Van Oudtshoorn, F. 2004.** Gids tot Grasse van SuidAfrika. 2<sup>nd</sup> Ed. Briza Publikasies.
- Van Wyk, B., Van Wyk, P. 2010.** Field Guide to Trees of Southern Africa. 13<sup>th</sup> Ed. Struik Publishers.
- Van Wyk, B., Van Wyk, P. & Van Wyk, B. 2008.** Fotogids tot Bome van Suider-Afrika. 1<sup>st</sup> Ed. BrizaPublikasies.
- Vetter, S. 2003.** What are the costs of land degradation to communal livestock farmers in South Africa? The case of the Herschel district, Eastern Cape. University of Cape Town, Cape Town. (Thesis - Ph.D.).

## CHAPTER 5

### Recommendations and Conclusions

#### 5.1. Recommendations

Recommendations towards the conservation of the norite koppies in the Impala Platinum mining area will be provided. This will be followed by recommendations on the conservation and management of the four plant communities present in the thornveld and finally recommendations on the management of the communities of the rehabilitated areas.

##### 5.1.1. Norite koppies

The plant communities found on the norite koppies in the south-eastern parts of the Impala Platinum mining area only cover a small area relative to the other landscape categories. They are, however, high in biodiversity and unique in the study area. The *Pappea capensis-Heteropogon contortus*-, *Setaria lindenbergiana-Dombeya rotundifolia*- and the *Ficus abutilifolia-Croton gratissimus* Communities also contain the species *Solanum supinum* which is vulnerable according to the Red Data List of South Africa (SANBI, 2009a). The protected tree species (SANBI, 2009b) *Boscia albitrunca* is also present in the *Microchloa caffra-Sporobolus stapfianus* Community. These norite koppies represent a part of the Norite Koppies Bushveld vegetation type according to Mucina & Rutherford (2006) which also only covers a small surface area in South Africa and although having a least threatened conservation status, ground truthing suggests that this vegetation type is rather susceptible to transformation. Its conservation status therefore needs to be revised. The continuous mining of such areas, especially for the granite industry, poses serious threats to the biodiversity of these ecosystems (North West Department of Agriculture, Conservation and Environment, 2010). Granite mining in the North West Province contributes 46% of the national mining of granite (North West Department of Agriculture, Conservation and Environment, 2010). The general style of opencast mining applied in this industry is responsible for the pollution and large scale consumption of environmental resources. Dolomite and norite koppies are, therefore, proposed to be protected according to the North West Spatial Development Framework and Zoning Plan and it is further proposed that no development should occur on ridges with a slope of more than 5° in the North West Province (Maxim Planning Solutions, 2004). The additional anthropogenic disturbances such as habitat fragmentation and degradation caused around the edges of norite koppies in the Impala Platinum mining area by the local communities developing informal settlements poses

another problem to the successful maintenance of the biodiversity and ecology of the plant communities of the norite koppies.

Any form of development on and inside a buffer area surrounding certain predetermined norite koppies in the Impala Platinum mining area should therefore be prohibited in order to guarantee the successful and continued existence of the ecology of these koppies. Adequate sizes for the buffer areas need to be determined in further studies. A specified number of prominent norite koppies that contain representative self sufficient examples of all the identified plant communities and species listed for conservation should be identified. Individuals from local communities owning houses that are present inside the identified buffer zones of these specific koppies could be relocated and supplied with alternative housing and compensation.

## **5.1.2. Thornveld**

### **5.1.2.1. *Eragrostis rigidior-Ziziphus mucronata* Community**

The deep Shortlands and Oakleaf soils on which this plant community is found is favourable for development of infrastructure and for this reason most of the residential settlements are situated on these soils. The *Eragrostis rigidior-Ziziphus mucronata* Community is therefore highly fragmented and large parts have been completely destroyed and replaced by urban infrastructure. At present, it only covers a small representative area of the Impala Platinum mining area and the continuous expansion of the local residential settlements is systematically degrading and decreasing the size of this plant community. The anthropogenic disturbance around the urban fringes is also evident in this plant community. The veld condition as well as grazing and browsing potential are lower in the fringe areas than in the more natural parts of this plant community (see Chapter 4). The *Eragrostis rigidior-Ziziphus mucronata* Community has the highest potential for commercial farming of livestock and game of all the plant communities present in the Impala Platinum mining area. The area covered by this plant community is however not adequate in size for the establishment of a nature reserve and because of the large threat posed to its existence by anthropogenic activities, it is recommended that the remaining parts of this plant community be viewed and actively managed as high priority conservation areas. Two tree species namely *Boscia albitrunca* and *Combretum imberbe* which are included in the Protected Species List of South Africa (SANBI, 2009b) and two forb species that are categorized as vulnerable on the Red Data List of South Africa (SANBI, 2009a) (*Lotononis globulosa* and *Solanum supinum*) occur

in this plant community and thus further increase its status as a conservation unit. This plant community also forms part of the Zeerust and Marikana Thornveld vegetation types of which less than 4% and 1% are respectively conserved (Mucina & Rutherford, 2006). The Marikana Thornveld is also regarded as an endangered vegetation type (Mucina & Rutherford, 2006). The conservation of this plant community in the Impala Platinum mining area can therefore make a considerable contribution to the conservation efforts of these two vegetation types. The small part of the *Eragrostis rigidior-Ziziphus mucronata* Community present in the north easterly corner of the Impala Platinum mining area forms part of the Central Sandy Bushveld vegetation type which is categorized as vulnerable according to Mucina & Rutherford (2006). It however covers a very small surface area and is situated on a privately owned farm. It is, therefore, not viable to attempt any form of formal conservation.

Buffer zones must be established around this plant community in order to decrease the negative effect caused by residential areas. The expansion of local urban settlements must also be monitored and more effective options for the utilization of space for infrastructure development have to be considered in order to supply to the needs and demands of growing local communities as well as aiding in the conservation of this plant community.

#### **5.1.2.2. *Acacia caffra-Bothriochloa insculpta* Community**

This plant community covers less than 2% of the Impala Platinum mining area. Continuous anthropogenic development taking place in the surrounding areas have profound negative impacts on this plant community especially because of its small surface area. The *Acacia caffra-Bothriochloa insculpta* Community has high species diversity and also contains the plant species *Cyphostemma hardyi* which is categorized as vulnerable according to the Red Data List of South Africa (SANBI, 2009a). Similar to the *Eragrostis rigidior-Ziziphus mucronata* Community, this plant community forms part of the Zeerust Thornveld vegetation type which is not adequately conserved in South Africa according to Mucina & Rutherford (2006). Conservation of the *Acacia caffra-Bothriochloa insculpta* Community will therefore contribute to the conservation of the ecological variation found in the Zeerust Thornveld vegetation type because of the uniqueness of this plant community in the Impala Platinum mining area.

This plant community must be declared a conservation area as soon as possible in order to prevent more damage and decrease in size. Further development in the areas surrounding this plant community should be managed in a way that will cause the least possible disturbance and degradation.

### 5.1.2.3. *Indigofera heterotricha-Aristida bipartita* Community

The *Indigofera heterotricha-Aristida bipartita* Community covers the largest part of the Impala Platinum mining area and for this reason the plant community is mainly being utilized by local communities as grazing for their livestock. Because the local farmers are subsistence farmers rather than commercial farmers, they often lack sufficient knowledge about which grazing practices to follow in order to decrease the damage caused to the veld and also to gain more financial advantage from farming. This plant community is therefore currently intensely being degraded by over-utilization mainly in the form of grazing and for acquiring firewood and building materials. This is taking place especially in areas surrounding residential settlements (Chapter 4).

Although the two Red Data List plant species (SANBI, 2009a) *Boophone disticha* (Declining) and *Cyphostemma hardyi* (Vulnerable) are present in this plant community, the natural species diversity is low and still declining due to anthropogenic effects. According to Mucina & Rutherford (2006), this plant community also forms part of the Zeerust and Marikana Thornveld vegetation types of which the percentage area conserved in South Africa is inadequate. By establishing conservation units inside the *Indigofera heterotricha-Aristida bipartita* Community, a contribution can be made towards the conservation of the Zeerust- and Marikana Thornveld vegetation types.

A large representative part of the *Indigofera heterotricha-Aristida bipartita* Community must be identified for conservational purposes and for the protection of Red Data List species. One conservation unit must be situated in the less disturbed, natural northern part of the Impala Platinum mining area because it forms part of the Zeerust Thornveld vegetation type which needs to be conserved (Mucina & Rutherford, 2006) and another unit in the central or southern parts of the leased area in order to aid in the conservation of the Marikana Thornveld vegetation type. These central and southern parts of the Impala Platinum mining area, are highly degraded and transformed and because of the endangered conservation status of the Marikana Thornveld vegetation type (Mucina & Rutherford, 2006), this conservation unit must receive high priority. Controlled rotational grazing practices need to be implemented in the remaining parts of this plant community. Local farmers will also have to be educated and supplied with the right agricultural information, skills and resources in order to successfully continue farming in these areas but in more ecologically sustainable ways. As a result they will be able to farm in more financially profitable ways in future. Fencing will have to be provided for the implementation of rotational grazing practices and to ensure that grazing capacities are not exceeded. Local community projects can also be launched to decrease the density of the woody species *Dichrostachys cinerea* (sickle bush)

which is intensely encroached in the area south of the Bospoort dam and is responsible for the decrease in veld condition and grazing potential. The wood of this species provides good burning fuel and can be sold for local financial gain.

#### **5.1.2.4. *Cyperus sexangularis-Cynodon dactylon* Riparian community**

The riparian community which is present in and around all water sources in the Impala Platinum mining area is widely disturbed due to the utilization of these water sources for various anthropogenic requirements such as washing of clothes and drinking water for livestock. Constant anthropogenic activities therefore take place in this plant community and because of the disturbance, large numbers of declared weeds and invaders, especially Category 1 species, have established and flourish in this plant community (see Chapter 3). The low species richness can also be attributed to these anthropogenic effects.

Community projects for the active removal of such undesired species in heavily affected areas must be launched and management strategies will have to be implemented in order to monitor and prevent re-establishment over time. The Working for Water (WfW) programme functions on a national level and deals with these above mentioned aspects ([www.dwaf.gov.za](http://www.dwaf.gov.za)). The WfW programme has provided jobs for more than 20 000 people countrywide of which 52% are women ([www.dwaf.gov.za](http://www.dwaf.gov.za)). Its introduction into the local communities of the Impala Platinum mining area should therefore be considered. The dependency of local communities on these natural water sources can also be decreased by providing alternative sources of clean water in the residential areas.

#### **5.1.3. Rehabilitated areas**

The *Aristida bipartita-Bothriochloa insculpta* Community, which characterizes the rehabilitated opencast mining areas, has high herbaceous biomass and therefore high grazing potential. The community is, however, not being utilized because it is located around mining infrastructure. Large amounts of organic litter material tend to build up on the soil surface of this plant community, especially during winter months, because of the lack in removal of herbaceous biomass in the form of grazing. This poses a large fire hazard which could cause major damage to the surrounding infrastructure.

Controlled grazing practices should be implemented in the *Aristida bipartita-Bothriochloa insculpta* Community to ensure adequate utilization of its grazing potential and sufficient removal of biomass for winter months. Continuous monitoring and management of the

grazing activities taking place in this plant community is however essential to prevent any form of degradation.

Large numbers of exotic species as well as declared weeds and invaders are present in the plant communities of the old and new tailings dams (see Chapter 3). Several of these species however serve purposes in the rehabilitation processes of the tailings dams. The grass species *Arundo donax* and the woody species *Tamarix ramosissima* are often used in rehabilitation because of their fast growth rates and tolerance. They also aid in stabilizing soils on tailings dams. For the sake of the success of the rehabilitation, their presences are, therefore, acceptable provided they do not spread into the natural surrounding areas. Spreading and establishment of these species is however occurring in the surrounding natural environment which could cause major problems for the ecology of the natural areas. This issue needs to be combated and prevented. The indigenous species *Seriphium plumosum* and the invader *Tamarix ramosissima*, which both have high densities and cover abundances in the *Imperata cylindrica-Tamarix ramosissima* Sub-community, cause intense decreases in grazing potential of this community. They will therefore have to be actively removed if the plateaus of the tailings dams are considered for future grazing. If this potential land-use is however not considered it will be best to leave these species as part of the plant community as they aid in soil stabilization and, therefore, the rehabilitation processes on the tailings dams because of their vigorous, underground root systems.

## 5.2. Conclusions

The first specific objectives of the study were to identify, describe and spatially illustrate all the plant communities in the Impala Platinum mining area as well as to determine possible environmental factors that influence the plant community structure and species composition. Eleven plant communities with seven sub-communities were identified and described by following a phytosociological approach and verification of the classification was done in 2010. Environmental variables which influence plant community structure and species composition could be identified by using the multivariate analysis programme, CANOCO (Ter Braak, 1986). These findings prove the first hypothesis. Although the topography did not play a role in plant community structure and species composition as initially hypothesised, the aspect and percentage soil surface rockiness in the norite koppies and the soil type in the thornveld were the main influencing environmental factors. With the exception of the norite koppies, there were no large variations in topography in the mining area, which explains why this variable had no influencing role. The plant communities could be captured on a vegetation

map of the Impala Platinum mining area by means of ArcView 9.2 (ESRI, 2006). Similar plant communities, which also form part of the various vegetation types present in the Impala Platinum mining area according to Mucina & Rutherford (2006), have previously been described in the literature by Van der Meulen (1979) and Panagos (1996). The initial objectives were successfully reached and spatially explicit plant diversity information could be obtained.

Further objectives of the study included veld condition assessments as well as determining grazing and browsing capacities and landscape functionality of certain plant communities. The Fixed Point Monitoring of Vegetation Methodology- FIXMOVE (Morgenthal & Kellner, 2008) was used to conduct these assessments and additional landscape function analysis (Tongway & Hindley, 2004) results obtained from Van der Walt (2010) were used to support the data. Although the veld condition in terms of erosion risk of the *Eragrostis rigidior-Ziziphus mucronata* and the *Acacia caffra-Bothriochloa insculpta* Communities are low, these two communities exhibited the highest ecological status of herbaceous species and were identified as the two plant communities with the best potential for grazing and browsing practices. The landscape function analysis, however, indicated that the *Acacia caffra-Bothriochloa insculpta* Community has the lowest functionality of the four plant communities. The *Aristida bipartita-Bothriochloa insculpta* Community has a high grazing capacity but does not provide good potential for browsing practices because of the lack of a well established woody component. The woody layer is however expected to increase as the rehabilitated areas progressively become more naturalized. The veld condition, landscape functionality and species composition of the *Aristida bipartita-Bothriochloa insculpta* Community indicated that the attempts to rehabilitate the opencast mining areas had been relatively successful at the time of surveying. The *Indigofera heterotricha-Aristida bipartita* Community exhibits poor ecological status regarding the herbaceous species and does not provide good potential for grazing or browsing practices. Anthropogenic exploitation such as the removal of trees for fire wood and building material as well as over-grazing by livestock is responsible for the decline in condition of this community.

The veld condition assessment, together with the determining of grazing and browsing capacities, therefore, produced sufficient results. The second hypothesis was, however, rejected. The *Aristida bipartita-Bothriochloa insculpta* Community, found in the rehabilitated opencast mining areas, exhibits a better veld condition, landscape functionality and grazing capacity relative to the *Indigofera heterotricha-Aristida bipartita* Community, which is viewed as its natural representative form in the Impala Platinum mining area. The rehabilitation

processes prove to have been effective in contrast with the intensive disturbance experienced in the *Indigofera heterotricha-Aristida bipartita* Community. The *Indigofera heterotricha-Aristida bipartita* Community does however have a higher browsing capacity which was expected due to the disturbance caused by the rehabilitation processes on the woody layer of the *Aristida bipartita-Bothriochloa insculpta* Community.

By combining the results obtained from the specific objectives, the main objective of the study could successfully be reached: Recommendations regarding spatially explicit conservation and management of anthropogenically threatened or ecologically important areas with high plant diversity or containing Red Data List (SANBI, 2009a) or Protected plant (SANBI, 2009b) species could be made. Further recommendations towards future land-use specifically for grazing or browsing purposes could also be made in a spatially explicit manner. These results and recommendations concluded from the vegetation study can be further combined with the results obtained from other biodiversity studies conducted during 2009 and 2010 on birds, reptiles, amphibians, small mammals and butterflies to aid in the establishment of an official conservation plan for the Impala Platinum mining area.

The current study contributed to increase the little knowledge available on the Norite Koppies Bushveld vegetation type (Mucina & Rutherford, 2006), which is threatened especially by the granite mining industry. The vegetation type has a small representative cover area in South Africa which was only broadly described by Van der Meulen (1979) and Panagos (1996). It can, therefore, be regarded as relatively unique. Transformation of this vegetation type is however continuously contributing to a decrease in its size. The detailed, spatially explicit information acquired during the current study about the specific plant communities of this vegetation type, together with additional koppies not previously indicated on the vegetation map of South Africa (Mucina & Rutherford, 2006), could therefore aid in more efficient conservation of the Norite Koppies Bushveld vegetation type. It could also shed more light on the ecological importance or value of this vegetation type. A paper on the norite koppies of the Impala Platinum mining area, submitted to the journal *Bothalia*, is currently being reviewed (Paper title: The phytosociological description of norite koppies in the Rustenburg area, North West Province and refinement of the Norite koppies bushveld on the national vegetation classification map of South Africa).

The plant communities identified in the thornveld landscape category of the current study and the recommendations made towards the conservation of parts of these communities can play an important role towards more effective conservation of the Zeerust and Marikana

Thornveld vegetation types in general (Mucina & Rutherford, 2006). These two vegetation types are not being adequately conserved in South Africa and because the Marikana Thornveld is classified as an endangered vegetation type, the role of Impala Platinum as an active contributor to its conservation should prove very important. The current study also served as a trial for the Fixed Point Monitoring of Vegetation- FIXMOVE methodology (Morgenthal & Kellner, 2008). This is a relatively new combination of sampling techniques for conducting field surveys which has not been adequately applied in practice to compare its effectiveness to other methodologies. The results obtained from the current study therefore served as a basis for determining the success of the methodology.

The success of the rehabilitation processes used in the old opencast mining areas of Impala Platinum, was determined in terms of veld condition and landscape functionality assessments. Although veld condition assessments were not conducted in the plant communities of the rehabilitated tailings dams, landscape functionality of these communities were determined by Van der Walt (2010) in order to determine the success of the rehabilitation. These results can be compared with other studies of rehabilitated mined areas and can potentially be used as a form of reference in similar future studies.

### 5.3. References

- ESRI (Environmental Systems Research Institute). 2006.** ArcView 9.2. www.esri.com Redlands, CA: USA.
- Maxim Planning Solutions. 2004.** North West Spatial Development Framework and Zoning Plan. Vol 4.p. 93.
- Morgenthal, T.L. & Kellner, K. 2008.** FIXMOVE Fixed Point Monitoring of Vegetation Methodology. 1<sup>st</sup> Ed. Department of Agriculture.
- Mucina, L. & Rutherford, M.C. (eds.) 2006.** The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.
- North West Department of Agriculture, Conservation and Environment. 2010.** North West Province, Environmental Outlook: A report on the state of the environment 2008.[Web:] [http://www.nwpg.gov.za/Agriculture/NW\\_ENVIRONMENTAL\\_OUTLOOK/index.asp](http://www.nwpg.gov.za/Agriculture/NW_ENVIRONMENTAL_OUTLOOK/index.asp). [Date of use: 11 February 2010.]
- Panagos, M.D. 1996.** The natural plant communities of the Onderstepoort Nature Reserve. Unpublished Report, ARC Onderstepoort Veterinary Research Institute, Pretoria.

- South African National Biodiversity Institute (SANBI). 2009a.** Interim Red Data List of South African Plant Taxa. [Web:] <http://www.sanbi.org/biodeiversity/Red%20List%2003-02-2009.xls>. [Date of use: 19 October 2009.]
- South African National Biodiversity Institute (SANBI). 2009b.** Protected Plants and Plant Permits in South Africa. [Web:] <http://www.sanbi.org/frames/tspfram.htm>. [Date of use: 19 October 2009.]
- Ter Braak, C.J.F. 1986.** Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 65 (5).
- Tongway, D.J. & Hindley, N. 2004.** Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes. With special reference to Mine sites and Rangelands. CSIRO Sustainable Ecosystems, Canberra Australia.
- Van der Meulen, F. 1979.** Plant sociology of the western Transvaal bushveld, South Africa: A syntaxonomic and synecological study. A. Gantner, Vaduz.
- Van der Walt, L. 2010.** Landscape functionality of plant communities in the Impala Platinum mining area, Rustenburg. North-West University, Potchefstroom. (Unpublished report – Honors in Environmental Science).

## **APPENDIX**

**Phytosociological table containing species with low constancy and cover for the Norite Koppies (Table A1).**

**Phytosociological table containing species with low constancy and cover for the Thornveld (Table A2).**

**Phytosociological table containing species with low constancy and cover for the Rehabilitates areas (Table A3).**

**Species and Quantitative data tables of the *Indigofera heterotricha-Aristida bipartita* Community (Tables A4-A7).**

**Species and Quantitative data tables of the *Aristida bipartita-Bothriochloa insculpta* Community (Tables A8-A11).**

**Species and Quantitative data tables of the *Eragrostis rigidior-Ziziphus mucronata* Community (Tables A12-A15).**

**Species and Quantitative data tables of the *Acacia caffra-Bothriochloa insculpta* Community (Tables A16-A19).**

**Tables indicating statistically significant differences in quantitative data of the four plant communities (Tables A20-A23).**

**An example of the data sheet used during the phytosociological surveys (Data Sheet A1).**

**An example of the data sheet used during the quantitative surveys (Data Sheet A2).**

Table A1 Species with low constancy and cover for the Norite koppies

RELEVÉ NUMBERS	1		2		3		4			
	3.1		3.2		4					
	1		2		3		4			
PLANT COMMUNITIES	1		2		3.1		3.2		4	
SPECIES										
<i>Melhania prostrata</i>	.	.	.	.	.	.	.	.	.	.
<i>Raphionacme galpinii</i>	.	.	.	.	.	.	.	.	.	.
<i>Leucas glabrata v. glabrata</i>	.	.	.	.	.	.	.	.	.	.
<i>Hypoestes aristata</i>	.	.	.	.	.	.	.	.	.	.
<i>Bonatea speciosa</i>	.	.	.	.	.	.	.	.	.	.
<i>Cynodon dactylon</i>	.	.	.	.	.	.	.	.	.	.
<i>Panicum coloratum</i>	.	.	.	.	.	.	.	.	.	.
<i>Phyllanthus maderaspatensis</i>	.	.	.	.	.	.	.	.	.	.
<i>Sida dregei</i>	.	.	.	.	.	.	.	.	.	.
<i>Cheilanthes eckloniana</i>	.	.	.	.	.	.	.	.	.	.
<i>Portulaca quadrifida</i>	.	.	.	.	.	.	.	.	.	.
<i>Brachiaria eruciformis</i>	.	.	.	.	.	.	.	.	.	.
<i>Aristida adscensionis</i>	.	.	.	.	.	.	.	.	.	.
<i>Aristida bipartita</i>	.	.	.	.	.	.	.	.	.	.
<i>Pavetta zeyheri</i>	.	.	.	.	.	.	.	.	.	.
<i>Diheteropogon amplectens</i>	.	.	.	.	.	.	.	.	.	.
<i>Commiphora schimperi</i>	.	.	.	.	.	.	.	.	.	.
<i>Grewia monticola</i>	.	.	.	.	.	.	.	.	.	.
<i>Melhania acuminata</i>	.	.	.	.	.	.	.	.	.	.
<i>Ximenia caffra</i>	.	.	.	.	.	.	.	.	.	.
<i>Stylosanthes fruticosa</i>	.	.	.	.	.	.	.	.	.	.
<i>Diospyros lycioides s. guerkei</i>	.	.	.	.	.	.	.	.	.	.
<i>Commelina subulata</i>	.	.	.	.	.	.	.	.	.	.
<i>Sida spinosa</i>	.	.	.	.	.	.	.	.	.	.
<i>Eragrostis rigidior</i>	.	.	.	.	.	.	.	.	.	.
<i>Indigofera oxytropis</i>	.	.	.	.	.	.	.	.	.	.
<i>Brachiaria deflexa</i>	.	.	.	.	.	.	.	.	.	.
* <i>Plumbago zeylanica</i>	.	.	.	.	.	.	.	.	.	.
<i>Withania somnifera</i>	.	.	.	.	.	.	.	.	.	.
<i>Rhynchosia densiflora</i>	.	.	.	.	.	.	.	.	.	.



Table A1 Species with low constancy and cover for the Norite koppies

RELEVÉ NUMBERS																																												
	3	6	7	3	1	2	3	1	2	4	1	1	1	1	2	2	2	2	3	3	3	4	4	2	3	6	2	3	4	4	4	2	1	3	2	4								
PLANT COMMUNITIES	1										2										3																							
	1										2										3.1					3.2					4													
	1										2										3.1					3.2					4													
<i>Corchorus schimperi</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Brachylaena rotundata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Mimusops zeyheri</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Neonotonia wightii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Pseudognaphalium luteo-album</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Euclea undulata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cleome rubella</i>	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Ocimum gratissimum</i>	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Aristida stipitata</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Eragrostis biflora</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Harpagophytum zeyheri</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Jasminum fluminense</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Striga asiatica</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Aristida congesta s. congesta</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Indigofera daleoides</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Kyllinga alba</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Waltheria indica</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Eragrostis heteromera</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
* <i>Bidens pilosa</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Chamaecrista mimosoides</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Chloris virgata</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Crinum graminicola</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Echinochloa holubii</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Geigeria elongata</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Orbeopsis lutea s. lutea</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Talinum cafrum</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Heliotropium lineare</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Ipomoea sinensis</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Kalanchoe paniculata</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Vahlia capensis</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Craterostigma plantagineum</i>	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.



**Table A1 Species with low constancy and cover for the Norite koppies**

RELEVÉ NUMBERS																																																				
	3	6	7	3	1	2	3	1	2	4	1	1	1	1	2	2	2	2	3	3	3	4	4	2	3	6	2	3	4	4	4	2	1	3	2	4																
PLANT COMMUNITIES	1										2										3										4																					
																					3.1					3.2																										
<i>Anthospermum rigidum s. pumilum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Jamesbrittenia atropurpurea</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
* <i>Chenopodium album</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Enneapogon cenchroides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
* <i>Boerhavia erecta</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
* <i>Ipomoea purpurea</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Convolvulus sagittatus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Salvia runcinata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Teucrium trifidum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
* <i>Cestrum laevigatum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Cheilanthes multifida</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Cucumis anguria</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Cyperus marlothii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Eragrostis congesta</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Hirpicium bechuanense</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Leonotis ocymifolia v. schinzii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Aptosimum procumbens</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Fingerhuthia africana</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Thesium utile</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Triraphis andropogonoides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Urelytrum agropyroides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Ziziphus zeyheriana</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Tragia okanyua</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
<i>Digitaria ternata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		
* indicates an alien species																																																				









Table A2 Species with low constancy and cover for the Thornveld

RELEVÉ NUMBERS	1										2										3										4																	
	1										2										3										4.1					4.2												
<i>Hyperthelia dissoluta</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Veronica anagallis-aquatica</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Rhoicissus tridentata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
* <i>Plumbago zeylanica</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Asparagus virgatus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Alternanthera sessilis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Agrostis lachnantha</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cynodon transvaalensis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Urochloa panicoides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Hemarthria altissima</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Amaranthus hypochondriacus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Ranunculus multifidus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Eleusine coracana</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cyperus marginatus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Pulicaria scabra</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Conyza scabrida</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Waltheria indica</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
* indicates an alien species																																																

Table A3 Species with low constancy and cover for the Rehabilitated areas

RELEVÉ NUMBERS	5	4	4	4	5	5	5	5	6	5	5	4	5	5	6	6	7	7	6	6	9	9	
	4	6	7	9	0	2	3	7	8	1	5	6	8	9	1	0	7	1	2	8	9	1	3
PLANT COMMUNITIES	1				2									3									
	1				2.1			2.2			2.3			3									
<b>SPECIES</b>																							
<i>Chloris virgata</i>	.	.	.	3	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.
* <i>Nicotiana glauca</i>	.	.	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
* <i>Cirsium vulgare</i>	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	+	.	.	.	.	.
<i>Pollichia campestris</i>	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Achyranthes aspera</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
<i>Eleusine coracana</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
<i>Amaranthus thunbergii</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
<i>Solanum retroflexum</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
* <i>Salvia reflexa</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+
<i>Acalypha indica</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+
* <i>Physalis viscosa</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+
* <i>Eucalyptus camaldulensis</i>	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.
<i>Acacia sieberiana</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.
* <i>Dichanthium aristatum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.
<i>Searsia pendulina</i>	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Senecio pleistocephalus</i>	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Helichrysum splendidum</i>	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Ehretia rigida</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Portulaca quadrifida</i>	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Diospyros lycioides</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Taphinanthus deifolius</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
* <i>Jacaranda mimosifolia</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
* <i>Schinus molle</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Setaria verticillata</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
* <i>Sonchus oleraceus</i>	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Eragrostis biflora</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Hyperthelia dissoluta</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Sporobolus fimbriatus</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Guilleminea densa</i>	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Hirpicium bechuanense</i>	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Aristida adscensionis</i>	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Monsonia angustifolia</i>	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
* <i>Malvastrum coromandelianum</i>	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
<i>Tribulus terrestris</i>	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
* <i>Dactyloctenium aegyptium</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
<i>Hypochaeris radicata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
<i>Kalanchoe rotundifolia</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
<i>Wahlenbergia undulata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
<i>Bulbostylis hispidula</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
<i>Senecio harveianus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
<i>Geigeria burkei</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
<i>Indigofera holubii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
<i>Dicoma anomala</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
<i>Helichrysum argyrosphaerum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
<i>Sorghum bicolor</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Hemizygia pretoriae</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Urelytrum agropyroides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
* <i>Tipuana tipu</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Heliotropium strigosum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Sida spinosa</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Merremia palmata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Lactuca inermis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

**Table A3 Species with low constancy and cover for the Rehabilitated areas**

RELEVÉ NUMBERS	5	4	4	4	5	5	5	5	6	5	5	4	5	5	6	6	7	7	6	6	9	9		
	4	6	7	9	0	2	3	7	8	1	5	6	8	9	1	0	7	1	2	8	9	1	3	
PLANT COMMUNITIES	1					2					3													
	1					2.1			2.2		2.3		3											
<i>Commelina africana</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	
<i>Kohautia amatymbica</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
<i>Striga forbesii</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
<i>Rhynchosia nitens</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
* <i>Ricinus communis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
<i>Elephantorrhiza elephantina</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Setaria sphacelata v. sericea</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Thesium utile</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Talinum cafferum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Commelina benghalensis</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Sesamum triphyllum</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Striga gesnerioides</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
* <i>Euphorbia heterophylla</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
* indicates an alien species																								

**Table A4 Quantitative species data of the herbaceous layer of the *Indigofera heterotricha*-*Aristida bipartita* Community**

Site numbers	Ecological status	1	2	3	4	5	6	10	11	13	21	22	25	26	27	30	31	32	Average	
<b>Species</b>		<b>Frequency</b>																		
<i>Aristida bipartita</i>	Increaser 2	76	20.8	25.6	26.4	72.8	76.8	26.4	0.8	56.8	36.8	41.6	48.8	33.6	88.8	40.8	22.4	9.6	41.5	
<i>Aristida canescens</i>	Increaser 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0.1
<i>Bidens bipinnata</i>	Forb	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Bothriochloa insculpta</i>	Increaser 2	11.2	3.2	0	0	0	1.6	6.4	11.2	0	0	4.8	0	4.8	2.4	0	2.4	0.8	2.9	
<i>Brachiaria eruciformis</i>	Increaser 2	1.6	4.8	5.6	2.4	2.4	0	0	0	0	0.8	0	0	0	0	2.4	4	4	1.6	
<i>Chamaecrista mimosoides</i>	Forb	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0.1
<i>Convolvulus sagittatis</i>	Forb	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0.1
<i>Corchorus asplenifolius</i>	Forb	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0.1
<i>Crabbea hirsuta</i>	Forb	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	0.8	0	0	0	0.1
<i>Cymbopogon pospischilii</i>	Increaser1/ Increaser 3	0	0	0.8	1.6	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0.3
<i>Cynodon dactylon</i>	Increaser 2	0	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0	0	0	0	0.2
<i>Dichanthium annulatum</i>	Decreaser	0	0	0	0	0	0.8	2.4	1.6	0	0	0.8	13.6	3.2	0	0	0	0	0	1.3
<i>Digitaria eriantha</i>	Decreaser	0	0	12.8	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
<i>Echinochloa holubii</i>	Increaser 2	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0.1
<i>Enneapogon cenchroides</i>	Increaser 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0.1
<i>Eragrostis chloromelas</i>	Increaser 2	2.4	4.8	12	2.4	8.8	1.6	7.2	16.8	0.8	14.4	0	8	2.4	6.4	8	8.8	11.2	6.8	
<i>Euphorbia inaequilatera</i>	Forb	0.8	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Felicia muricata</i>	Forb	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0.8	0.1

**Table A4 Quantitative species data of the herbaceous layer of the *Indigofera heterotricha*-*Aristida bipartita* Community**

Site numbers	Ecological status	1	2	3	4	5	6	10	11	13	21	22	25	26	27	30	31	32	Average
<b>Species</b>		<b>Frequency</b>																	
<i>Fingerhuthia africana</i>	Decreaser	0	1.6	0	1.6	0	0	0	0	0	0	5.6	0	0	0	0	0	0	0.5
<i>Hemizygia pretoriae</i>	Forb	0	0	0	8	0	0	0	0	0	2.4	0	0	0.8	0	0	0	0	0.7
<i>Heteropogon contortus</i>	Increaser 2	1.6	0	0	0	0	0	1.6	2.4	0	0	0	0	0	0	0	0	0	0.3
<i>Hyparrhenia hirta</i>	Increaser 1	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0.1
<i>Indigofera heterotricha</i>	Forb	0.8	5.6	0	0.8	0	0.8	0	0	0.8	0	0	0	0	0	0	0	0	0.5
<i>Ipomoea magnosiana</i>	Forb	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0.1
<i>Ischaemum afrum</i>	Increaser 2	4	8.8	8	12.8	7.2	12	46.4	16	28	33.6	33.6	25.6	39.2	0	39.2	9.6	60.8	22.6
<i>Kohautia caespitosa</i>	Forb	0	0	0	0	0	3.2	1.6	0	1.6	1.6	0	0.8	0.8	1.6	0	1.6	2.4	0.9
<i>Kohautia sp.</i>	Forb	0.8	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Panicum schinzii</i>	Increaser 2	0	0.8	4	11.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
<i>Panicum volutans</i>	Increaser 2	0.8	0	0	0.8	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Rhynchosia minima</i>	Forb	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Salvia repens</i>	Forb	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Salvia runcinata</i>	Forb	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0.1
<i>Schkuhria pinnata</i>	Forb	0	0.8	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
<i>Seddera suffruticosa</i>	Forb	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0.1
<i>Sesbania transvaalensis</i>	Forb	0	0	0	0.8	0	0	0	0	2.4	0	0	0	0	0	0	0	0.8	0.2
<i>Setaria incrassata</i>	Decreaser	0	0	0	0	0	0	0.8	11.2	0.8	1.6	3.2	0	4	0	0	1.6	3.2	1.6

**Table A4 Quantitative species data of the herbaceous layer of the *Indigofera heterotricha*-*Aristida bipartita* Community**

Site numbers	Ecological status	1	2	3	4	5	6	10	11	13	21	22	25	26	27	30	31	32	Average
<b>Species</b>		<b>Frequency</b>																	
<i>Sorghum versicolor</i>	Increaser 2	0	0.8	0.8	0.8	4.8	2.4	0	1.6	3.2	0	5.6	0	0	0.8	0	0	0	1.2
<i>Tephrosia purpurea</i>	Forb	0	3.2	0.8	1.6	3.2	0.8	0	0.8	4	0	0.8	0.8	0.8	0	0	0.8	0	1
<i>Themeda triandra</i>	Decreaser	0	0	1.6	0	0	0	5.6	32.8	0	4	0	0	8.8	0	0	0	0	3.1
<i>Tragia sp.</i>	Forb	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0.1
<i>Urelytrum agropyroides</i>	Increaser 1	0	43.2	26.4	25.6	0	0	0	0	0	0	0	0	0	0	8.8	47.2	6.4	9.3
<i>Vernonia oligocephala</i>	Forb	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0.1

**Table A5 Quantitative ecological data of the herbaceous layer of the *Indigofera heterotricha*-*Aristida bipartita* Community**

Site numbers		1	2	3	4	5	6	10	11	13	21	22	25	26	27	30	31	32	Average
<b>Ecological status (Frequency)</b>	Increaser 1	0	43.2	26.4	25.6	0	0	0	0.8	0	0	0	0	0	0	8.8	47.2	6.4	9.3
	Increaser 2	96	44	56	56.8	96.8	94.4	88	52.8	88.8	85.6	85.6	82.4	80	98.4	90.4	48.8	86.4	78.3
	Increaser 3	0	0	0.8	1.6	0	0	0	0	0	0	3.2	0	0	0	0	0	0	0.3
	Decreaser	0	1.6	14.4	2.4	0	0.8	8.8	45.6	0.8	5.6	9.6	13.6	16	0	0	1.6	3.2	7.3
<b>Grazing potential (Frequency)</b>	High	0	0.8	18.4	12	0	0.8	8.8	48.8	0.8	5.6	4	13.6	16	0	0	1.6	3.2	7.9
	Medium	20.8	24	26.4	20	23.3	17.6	61.6	49.6	32	48.8	49.6	33.6	46.4	9.6	49.6	25.6	76.8	36.2
	Low	76.8	64	52.8	54.4	73.6	76.8	26.4	0.8	56.8	36.8	44.8	48.8	33.6	88.8	49.6	70.4	16	51.2
<b>Grass biomass</b>	(kg/ha)	2563	2329	2233	3045	2918	2471	2563	1932	2608	1209	4199	2085	3045	2471	1722	2035	2184	2447.8
<b>Grazing capacity</b>	(ha/LSU)	6.9	6.5	3.7	3.8	5.4	8	2	1.9	4.3	5.6	1.6	3.7	1.9	15.4	4.3	6.6	2.1	4.9
<b>Basal cover</b>	(%)	18.4	20	17.6	11.2	16.8	16.8	9.6	14.4	16	17.6	20.8	15.2	17.6	21.6	17.6	21.6	16.8	17
<b>Physical parameters (Frequency)</b>	Bare patches	21.6	30.4	28	21.6	17.6	40.8	26.4	23.2	31.2	36.8	27.2	31.2	29.6	32	39.2	30.4	20	28.7
	Litter patches	3.2	0.8	2.4	7.2	0.8	0.8	0	0.8	0.8	0	0	2.4	0.8	0.8	4.8	2.4	4.8	1.9
	Rock patches	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0.1
<b>Erosion factor</b>	Point to tuft distance (cm)	2.6	3.8	3	3.4	2.9	2.8	3.1	1.9	2.8	3	3.9	4.6	3.8	3	3.6	4.3	2.9	3.3
	Erosion risk	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

**Table A6 Quantitative species data of the woody layer of the *Indigofera heterotricha-Aristida bipartita* Community**

Site numbers		1	2	3	4	5	6	10	11	13	21	22	25	26	27	30	31	32	Average
Species	Palatability	Frequency																	
<i>Acacia karroo</i>	Palatable	0.8	0.8	6.4	12.8	0	0	44	23.2	0	35.2	7.2	37.6	33.6	4.8	2.4	0	7.2	12.7
<i>Acacia mellifera</i>	Palatable	2.4	0	0	0	0.8	3.2	0	0	0	0	0	0	0	0.8	0.8	0.8	0	0.5
<i>Acacia nilotica</i>	Palatable	0.8	22.4	16	7.2	10.4	8.8	4	1.6	12.8	1.6	16	0.8	3.2	29.6	20.8	12.8	7.2	10.4
<i>Acacia robusta</i>	Unpalatable	0	0	0.8	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0.1
<i>Acacia tortilis</i>	Palatable	27.2	16.8	15.2	9.6	31.2	15.2	0.8	3.2	18.4	1.6	13.6	0.8	0.8	13.6	13.6	24	17.6	13.1
<i>Aloe marlothii</i>	Unpalatable	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0.1
<i>Boscia albitrunca</i>	Palatable	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0.1
<i>Dichrostachys cinerea</i>	Palatable	2.4	4.8	4	4	3.2	7.2	6.4	2.4	12	4.8	20	14.4	12	6.4	6.4	4.8	0.8	6.8
<i>Diospyros lycioides</i>	Palatable	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0	0	0	0.3
<i>Ehretia rigida</i>	Palatable	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0.1
<i>Grewia flava</i>	Palatable	0	0	0.8	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0.1
<i>Opuntia ficus-indica</i>	Palatable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.1
<i>Searsia leptodictya</i>	Palatable	0	0	0	0	0	0	0	0	0	0	0	0	2.4	0	0	0	0	0.1
<i>Searsia pyroides</i>	Unpalatable	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0.8	1.6	0	0	0.2
<i>Ziziphus mucronata</i>	Palatable	0	1.6	0	0	0	0	0	0	0	3.2	0	0	0	0	1.6	0	0	0.4
<i>Ziziphus zeyheriana</i>	Palatable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0.2

**Table A7 Quantitative ecological data of the woody layer of the *Indigofera heterotricha-Aristida bipartita* Community**

Site numbers		1	2	3	4	5	6	10	11	13	21	22	25	26	27	30	31	32	Average
<b>Palatability (%)</b>	Palatable	100	100	98.1	100	98.3	100	98.6	100	100	100	100	100	98.6	98.6	96.6	100	100	99.3
	Unpalatable	0	0	1.9	0	1.7	0	1.4	0	0	0	0	0	1.4	1.4	3.4	0	0	0.7
<b>Density (Plants/ha)</b>	Under 2m	54.2	180.2	105.5	167	64.9	125.2	961.8	220.4	418.2	569.6	205.4	1134	2475	301.9	319.9	411.1	172.4	463.9
	Above 2m	15.1	15.6	21.6	0	37.8	5.8	21.9	1	0.6	1.5	21.9	9.3	17	15.2	5.8	7.3	0.2	11.6
<b>Leaf biomass (kg/ha)</b>	Under 2m	8.9	41.9	45.8	91.8	13.5	43.6	429	16.2	222.3	250.6	84.1	346.4	559.6	123.6	88	77.9	91.7	149.1
	Above 2m	126.7	51.9	81.5	0	126.1	14.4	43.6	1.7	5	3.7	110.1	22.2	42	75.6	30.7	72.7	1.2	47.6
<b>Browsing capacity (ha/BU)</b>	Under 2m	408.8	87.2	79.7	39.7	270.1	83.7	8.5	225.3	16.4	14.6	43.4	10.5	6.5	29.5	41.5	46.9	39.8	24.5
	Above 2m	28.2	70.3	44.8	0	28.9	253	83.7	2202	727.3	993.4	33.2	164.5	86.9	48.3	118.7	50.2	2967	76.7
<b>Canopy spread (m<sup>2</sup>/ha)</b>	Under 2m	35.8	167.6	170.9	364.1	71.4	180.3	1635	147.7	869.9	996.8	320.4	1270	2500	504.2	403.1	378.2	355.1	610
	Above 2m	180	84.2	168	0	260.8	36.7	85.8	2.8	7.6	7.4	210.5	44.5	84.5	179.8	57.9	80.5	1.6	87.8
<b>Average individual height (m)</b>	Under 2m	0.6	0.8	0.8	0.8	0.7	0.8	0.8	0.4	0.9	0.9	0.9	0.8	0.7	1	0.8	0.7	0.9	0.8
	Above 2m	3.8	3	2.8	0	3.3	2.8	2.4	3.2	4	2.2	2.8	2.3	2.5	2.9	2.6	4.3	2.7	3

**Table A8 Quantitative species data of the herbaceous layer of the *Aristida bipartita-Bothriochloa insculpta* Community**

Site numbers	Ecological status	14	15	18	19	Average	23
<b>Species</b>	<b>Frequency</b>						
<i>Aristida bipartita</i>	Increaser 2	30.4	53.6	48	24.8	39.2	1.6
<i>Bothriochloa insculpta</i>	Increaser 2	23.2	36	18.4	48	31.4	0
<i>Brachiaria eruciformis</i>	Increaser 2	0	0	5.6	2.4	2	0.8
<i>Chamaecrista mimosoides</i>	Forb	0	0	0	0	0	0.8
<i>Cirsium vulgare</i>	Forb	0	0	0	0	0	0.8
<i>Corchorus asplenifolius</i>	Forb	0	0.8	0	0	0.2	0
<i>Cymbopogon pospischilii</i>	Increaser 1/ Increaser 3	4	1.6	0	0	1.4	0
<i>Cynodon dactylon</i>	Increaser 2	30.4	2.4	3.2	0	9	0.8
<i>Eragrostis chloromelas</i>	Increaser 2	0.8	0.8	15.2	15.2	8	2.4
<i>Felicia muricata</i>	Forb	0	0	0	0	0	0.8
<i>Fingerhuthia africana</i>	Decreaser	1.6	0.8	0	3.2	1.4	0
<i>Heteropogon contortus</i>	Increaser 2	0	0	0	0.8	0.2	0
<i>Ischaemum afrum</i>	Increaser 2	0	0	2.4	0	0.6	0.8
<i>Panicum schinzii</i>	Increaser 2	0.8	0	0	0	0.2	0
<i>Panicum volutans</i>	Increaser 2	0	0	0.8	0	0.2	74.4
<i>Rhynchosia minima</i>	Forb	2.4	0	0	0.8	0.8	1.6
<i>Sesbania transvaalensis</i>	Forb	0	0	0	0	0	0.8
<i>Setaria incrassata</i>	Decreaser	1.6	0	0	0	0.4	5.6
<i>Sorghum versicolor</i>	Increaser 2	4	3.2	5.6	0.8	3.4	0
<i>Tagetes minuta</i>	Forb	0	0	0	0	0	0.8
<i>Tephrosia purpurea</i>	Forb	0	0.8	0.8	2.4	1	8
<i>Themeda triandra</i>	Decreaser	0.8	0	0	0	0.2	0
<i>Urochloa mosambicensis</i>	Increaser 2	0	0	0	1.6	0.4	0

**Table A9 Quantitative ecological data of the herbaceous layer of the *Aristida bipartita-Bothriochloa insculpta* Community**

Site numbers		14	15	18	19	Average	23
<b>Ecological status (Frequency)</b>	Increaser 1	4	1.6	0	0	1.4	0
	Increaser 2	89.6	96	99.2	93.6	94.6	80.8
	Increaser 3	0	0	0	0	0	0
	Decreaser	4	0.8	0	3.2	2	5.6
<b>Grazing potential (Frequency)</b>	High	33.6	2.4	3.2	1.6	10	6.4
	Medium	29.6	40.8	47.2	70.4	47.2	4
	Low	34.4	55.2	48.8	24.8	40.8	76
<b>Grass biomass</b>	(kg/ha)	2698	3983	3211	4678	3643	2424
<b>Grazing capacity</b>	(ha/LSU)	2.1	2.1	2.3	1	1.9	14.5
<b>Basal cover</b>	(%)	12.8	15.2	16	16.8	15.2	1.6
<b>Physical parameters (Frequency)</b>	Bare patches	48	34.4	17.6	20.8	30.2	4
	Litter patches	0	1.6	25.6	10.4	9.4	28.8
	Rock patches	0	0	0	0	0	0
<b>Erosion factor</b>	Point to tuft distance (cm)	3.9	3.4	3.9	4.1	3.8	5.6
	Erosion risk	Low	Low	Low	Low	Low	Med

**Table A10 Quantitative species data of the woody layer of the *Aristida bipartita-Bothriochloa insculpta* Community**

Site numbers		14	15	18	19	Average	23
<b>Species</b>	<b>Palatability</b>	<b>Frequency</b>					
<i>Acacia caffra</i>	Palatable	0	0	1.6	0	0.4	0
<i>Acacia galpinii</i>	Palatable	2.4	0	0	0	0.6	0
<i>Acacia karroo</i>	Palatable	0.8	12.8	2.4	4	5	1.6
<i>Acacia mellifera</i>	Palatable	23.2	0	0	0.8	6	0
<i>Acacia nilotica</i>	Palatable	0	1.6	4	4	2.4	2.4
<i>Acacia tortilis</i>	Palatable	3.2	20	20.8	12.8	14.2	5.6
<i>Dichrostachys cinerea</i>	Palatable	0	0.8	2.4	0	0.8	4
<i>Diospyros lycioides</i>	Palatable	0	0	0	3.2	0.8	0
<i>Searsia pyroides</i>	Unpalatable	0.8	0	0	0	0.2	0.8
<i>Tipuana tipu</i>	Palatable	4.8	0	0	0	1.2	0
<i>Ziziphus mucronata</i>	Palatable	1.6	0	1.6	8.8	3	0

**Table A11 Quantitative ecological data of the woody layer of the *Aristida bipartita-Bothriochloa insculpta* Community**

Site numbers		14	15	18	19	Average	23
<b>Palatability (%)</b>	Palatable	97.8	100	100	97.6	99	94.5
	Unpalatable	2.2	0	0	2.4	1	5.6
<b>Density (Plants/ha)</b>	Under 2m	301.3	488.9	260.4	125.4	294	23
	Above 2m	0.1	0	0.4	1.8	0.6	0
<b>Leaf biomass (kg/ha)</b>	Under 2m	66.3	71.7	159.1	72	151	5.1
	Above 2m	0.4	0	0.5	4.8	2.4	0
<b>Browsing capacity (ha/BU)</b>	Under 2m	55.1	50.9	22.9	50.7	39.6	718.6
	Above 2m	8373	0	7343	754.9	2475.2	0
<b>Canopy spread (m<sup>2</sup>/ha)</b>	Under 2m	412.8	405.8	541.6	288.4	412	23.46
	Above 2m	1	0	1.1	6.4	2.1	0
<b>Average individual height (m)</b>	Under 2m	0.6	0.7	1	1.1	0.9	0.7
	Above 2m	2.2	0	2.2	2.6	2.3	0

**Table A12 Quantitative species data of the herbaceous layer of the *Eragrostis rigidior-Ziziphus mucronata* Community**

Site numbers	Ecological status	7	8	9	12	24	28	29	Average
Species	Frequency								
<i>Aloe greatheadii</i>	Forb	2.4	5.6	1.6	2.4	4	0	2.4	2.6
<i>Aristida bipartita</i>	Increaser 2	0	0	0	0	0	1.6	0	0.2
<i>Aristida canescens</i>	Increaser 2	0	0	0	16	8	0	3.2	3.9
<i>Aristida congesta</i>	Increaser 2	6.4	20.8	0.8	2.4	3.2	7.2	8.8	7.1
<i>Aristida stipitata</i>	Increaser 2	0.8	4	0.8	0	0	0	0	0.8
<i>Asparagus suaveolens</i>	Forb	0	0	0	0	0.8	0	0	0.1
<i>Barleria macrocephala</i>	Forb	0	0	0	0	0.8	0	0	0.1
<i>Blepharis integrifolia</i>	Forb	0	0	0.8	0	0	0	0	0.1
<i>Bothriochloa insculpta</i>	Increaser 2	24.8	5.6	4.8	0	1.6	7.2	6.4	7.2
<i>Brachiaria nigropedata</i>	Decreaser	0	1.6	0	0	0	0	0	0.2
<i>Chascanum hederaceum</i>	Forb	0	0	0	0	1.6	0	0	0.2
<i>Chloris virgata</i>	Increaser 2	0	0	0	0	0	0.8	0	0.1
<i>Commelina africana</i>	Forb	2.4	0	0	0	0.8	0	0	0.5
<i>Corchorus asplenifolius</i>	Forb	0.8	0	0.8	0	0.8	0	0.8	0.5
<i>Crabbea hirsuta</i>	Forb	0	0	0.8	0	0	0	0	0.1
<i>Cymbopogon nardus</i>	Increaser 1	3.2	4	0	0	0	20	16.8	6.3
<i>Cymbopogon pospischilii</i>	Increaser 1/ Increaser 3	17.6	8	10.4	5.6	4	0.8	0	6.6
<i>Cynodon dactylon</i>	Increaser 2	6.4	0.8	3.2	0	0	1.6	0	1.7
<i>Digitaria argyrograpta</i>	Decreaser	0	0	0	1.6	0	0	0	0.2
<i>Digitaria eriantha</i>	Decreaser	0	0	0	0	0	1.6	0	0.2
<i>Elionurus muticus</i>	Increaser 3	0	0	0	21.6	1.6	0	1.6	3.5
<i>Enneapogon scoparius</i>	Increaser 3	0	0	0	0	3.2	0	0	0.5
<i>Eragrostis pseudosclerantha</i>	Increaser 2	0	0	0.8	0	0	0	0	0.1
<i>Eragrostis rigidior</i>	Increaser 2	3.2	7.2	0.8	4	8	5.6	15.2	6.3
<i>Eragrostis superba</i>	Increaser 2	0	0	0	4.8	0	0	0	0.7

**Table A12 Quantitative species data of the herbaceous layer of the *Eragrostis rigidior-Ziziphus mucronata* Community**

Site numbers	Ecological status	7	8	9	12	24	28	29	Average
Species	Frequency								
<i>Evolvulus alsinoides</i>	Forb	0	0	0	0	0	0	0.8	0.1
<i>Felicia muricata</i>	Forb	0	7.2	2.4	2.4	0	0	0	1.7
<i>Fingerhuthia africana</i>	Decreaser	0	0	0	0	1.6	0	0	0.2
<i>Hermannia depressa</i>	Forb	0	0	0	0	0.8	0	0	0.1
<i>Heteropogon contortus</i>	Increaser 2	4	3.2	34.4	5.6	23.2	4	14.4	12.7
<i>Hibiscus pusillus</i>	Forb	0	0	0	0	0.8	0	0	0.1
<i>Hibiscus trionum</i>	Forb	0	0	0	0	0.8	0	0	0.1
<i>Hyperthelia dissoluta</i>	Increaser 1	0	0	0	0	0	1.6	0	0.2
<i>Hyparrhenia hirta</i>	Increaser 1	4	0	11.2	4	1.6	3.2	0	3.4
<i>Indigofera circinnata</i>	Forb	0	0	0	0	0	0	0.8	0.1
<i>Indigofera comosa</i>	Forb	0	2.4	0	0	0	0	0	0.3
<i>Ledebouria cooperi</i>	Forb	0	0.8	0	0	0	0	0	0.1
<i>Ledebouria sp.</i>	Forb	0	0	0	0.8	0	0	0	0.1
<i>Lippia scaberrima</i>	Forb	0	1.6	0	0	0	0	0	0.2
<i>Lotononis listii</i>	Forb	0	0	0	0.8	0	0	0	0.1
<i>Melinis repens</i>	Increaser 2	1.6	0.8	7.2	0.8	3.2	1.6	2.4	2.5
<i>Panicum coloratum</i>	Decreaser	2.4	13.6	8	4	11.2	7.2	4.8	7.3
<i>Panicum maximum</i>	Decreaser	0	4	4.8	0	3.2	6.4	8.8	3.9
<i>Ruellia cordata</i>	Forb	0	0	0.8	0	0	0	0	0.1
<i>Senna italica</i>	Forb	0	0	0.8	0	0	0	0	0.1
<i>Talinum sp.</i>	Forb	0	0	0	0	0	0	0.8	0.1
<i>Tephrosia purpurea</i>	Forb	0	0.8	0	0.8	0	0	0	0.2
<i>Themeda triandra</i>	Decreaser	20	0.8	0.8	20.8	9.6	16.8	4	10.4
<i>Tragus berteronianus</i>	Increaser 2	0	0	0.8	0	0.8	0.8	0.8	0.5
<i>Urochloa mosambicensis</i>	Increaser 2	0	6.4	0.8	0	4	7.2	3.2	3.1

**Table A13 Quantitative ecological data of the herbaceous layer of the *Eragrostis rigidior-Ziziphus mucronata* Community**

Site numbers		7	8	9	12	24	28	29	Average
<b>Ecological status (Frequency)</b>	Increaser 1	7.2	4	11.2	9.6	1.6	25.6	16.8	10.9
	Increaser 2	47.2	48.8	54.4	33.6	52	37.6	54.4	46.9
	Increaser 3	17.6	8	10.4	21.6	8.8	0	1.6	9.7
	Decreaser	22.4	20	13.6	26.4	25.6	32	17.6	22.5
<b>Grazing potential (Frequency)</b>	High	28.8	27.2	17.6	26.4	28	40.8	20.8	27.1
	Medium	36	16	51.2	18.4	36	22.4	36	30.9
	Low	29.6	37.6	20.8	46.4	24	32	33.6	32
<b>Grass biomass</b>	(kg/ha)	2698	2471	1444	4056	2424	3647	3293	2861.9
<b>Grazing capacity</b>	(ha/LSU)	2.1	3.4	3.7	2	2.4	1.6	2	2.5
<b>Basal cover</b>	(%)	11.2	12.8	8	19.2	19.2	8.8	12.8	13.1
<b>Physical parameters (Frequency)</b>	Bare patches	35.2	36.8	48	28	32.8	27.2	20.8	32.7
	Litter patches	2.4	4	0.8	2.4	0.8	12.8	14.4	5.4
	Rock patches	4	0	4.8	0	11.2	0	0	2.9
<b>Erosion factor</b>	Point to tuft distance (cm)	4	5.1	5.8	5.3	4.7	7.8	7.8	5.8
	Erosion risk	Low	Med	Med	Med	Low	Med	Med	Med

**Table A14 Quantitative species data of the woody layer of the *Eragrostis rigidior-Ziziphus mucronata* Community**

Site numbers		7	8	9	12	24	28	29	Average
<b>Species</b>	<b>Palatability</b>	<b>Frequency</b>							
<i>Acacia caffra</i>	Palatable	2.4	0	6.4	0.8	0	0.8	27.2	5.4
<i>Acacia hereroensis</i>	Palatable	0	0	0	0	0	4	0	0.6
<i>Acacia karroo</i>	Palatable	4.8	0.8	1.6	0	0	3.2	0	1.5
<i>Acacia mellifera</i>	Palatable	0	0	8	0	26.4	0	0	4.9
<i>Acacia nilotica</i>	Palatable	4.8	11.2	7.2	33.6	1.6	0.8	1.6	8.7
<i>Acacia tortilis</i>	Palatable	4	18.4	6.4	12.8	12.8	29.6	20	14.9
<i>Aloe marlothii</i>	Unpalatable	0	2.4	0	0	0	0	0	0.3
<i>Dichrostachys cinerea</i>	Palatable	8.8	12.8	9.6	16.8	0	4.8	3.2	8
<i>Diospyros lycioides</i>	Palatable	3.2	0	1.6	0	0	0	1.6	0.9
<i>Ehretia rigida</i>	Palatable	0.8	0	4	0	0.8	0	2.4	1.1
<i>Euclea undulata</i>	Palatable	0	0	0.8	0	0	0	0	0.1
<i>Grewia flava</i>	Palatable	4.8	4	3.2	0	8	15.2	18.4	7.7
<i>Searsia lancea</i>	Palatable	0	0	1.6	0	0	0.8	0	0.3

**Table A14 Quantitative species data of the woody layer of the *Eragrostis rigidior-Ziziphus mucronata* Community**

Site numbers		7	8	9	12	24	28	29	Average
Species	Palatability	Frequency							
<i>Searsia pyroides</i>	Unpalatable	18.4	1.6	7.2	4	0.8	1.6	2.4	5.1
<i>Tarchonanthus camphoratus</i>	Palatable	0	0	1.6	0	4	0	0	0.8
<i>Ziziphus mucronata</i>	Palatable	25.6	16.8	14.4	0	1.6	13.6	14.4	12.3

**Table A15 Quantitative ecological data of the woody layer of the *Eragrostis rigidior-Ziziphus mucronata* Community**

Site numbers		7	8	9	12	24	28	29	Average
Palatability (%)	Palatable	76.3	94.1	89.1	94.1	98.6	97.8	97.4	92.5
	Unpalatable	23.7	5.9	10.9	5.9	1.4	2.2	2.6	7.5
Density (Plants/ha)	Under 2m	1165	754.7	1722	597.3	589.1	577	364.3	824.2
	Above 2m	85.1	41.6	68.2	55.6	13.2	120.4	358.2	106
Leaf biomass (kg/ha)	Under 2m	620.4	855.1	682.9	270.7	200.2	490.4	396.2	502.3
	Above 2m	861	322.3	265.8	1010	108.3	795.3	2666	861.2
Browsing capacity (ha/BU)	Under 2m	5.9	4.3	5.3	13.5	18.2	7.4	9.2	7.3
	Above 2m	4.2	11.3	13.7	3.6	33.7	4.6	1.4	4.2
Canopy cover (m <sup>2</sup> /ha)	Under 2m	1491	1675	1739	698.8	453.6	1039	739.5	1119
	Above 2m	571	221.3	252.3	752.3	115.8	792.2	2010	673.6
Average individual height (m)	Under 2m	0.9	1	0.8	0.8	0.6	1.3	1.4	1
	Above 2m	3.3	2.9	3.1	3.1	3.3	2.7	3.1	3.1

**Table A16 Quantitative species data of the herbaceous layer of the *Acacia caffra*-*Bothriochloa insculpta* Community**

Site numbers	Ecological status	16	17	20	Average
Species	Frequency				
<i>Aloe greatheadii</i>	Forb	1.6	0.8	0.8	1.1
<i>Aptosimum procumbens</i>	Forb	1.6	0	0	0.5
<i>Aristida bipartita</i>	Increaser 2	0	4.8	20	8.3
<i>Aristida canescens</i>	Increaser 2	4.8	0	0	1.6
<i>Aristida congesta</i>	Increaser 2	2.4	2.4	0	1.6
<i>Bothriochloa insculpta</i>	Increaser 2	1.6	32.8	20.8	18.4
<i>Commelina africana</i>	Forb	2.4	0	0	0.8
<i>Cymbopogon pospischilii</i>	Increaser 1/ Increaser 3	2.4	8	12.8	7.7
<i>Digitaria argyrograpta</i>	Decreaser	2.4	0	0	0.8
<i>Digitaria eriantha</i>	Decreaser	0	2.4	0.8	1.1
<i>Diheteropogon amplexans</i>	Decreaser	0	0.8	0	0.3
<i>Enneapogon scoparius</i>	Increaser 3	0	1.6	1.6	1.1
<i>Eragrostis chloromelas</i>	Increaser 2	0	3.2	15.2	6.1
<i>Eragrostis rigidior</i>	Increaser 2	2.4	0	0	0.8
<i>Eragrostis superba</i>	Increaser 2	0.8	0	0	0.3
<i>Felicia muricata</i>	Forb	3.2	0	0	1.1
<i>Fingerhuthia africana</i>	Decreaser	2.4	3.2	1.6	2.4
<i>Hemizygia pretoriae</i>	Forb	0	0.8	0	0.3
<i>Heteropogon contortus</i>	Increaser 2	44.4	20.8	0.8	22
<i>Ischaemum afrum</i>	Increaser 2	0	1.6	21.6	7.7
<i>Kohautia caespitosa</i>	Forb	0	0	0.8	0.3
<i>Ledebouria revoluta</i>	Forb	0	0	0.8	0.3
<i>Panicum coloratum</i>	Decreaser	4.8	3.2	0	2.7
<i>Panicum maximum</i>	Decreaser	0	0.8	0	0.3
<i>Schizachyrium sanguineum</i>	Increaser 1	0	0.8	0	0.3
<i>Themeda triandra</i>	Decreaser	21.6	4	1.6	9.1
<i>Tragus berteronianus</i>	Increaser 2	0	0.8	0	0.3
<i>Urelytrum agropyroides</i>	Increaser 1	0	7.2	0.8	2.7

**Table A17 Quantitative ecological data of the herbaceous layer of the *Acacia caffra-Bothriochloa insculpta* Community**

Site numbers		16	17	20	Average
<b>Ecological status (Frequency)</b>	Increaser 1	0	8	0.8	2.9
	Increaser 2	56.8	66.4	78.4	67.2
	Increaser 3	2.4	9.6	14.4	8.8
	Decreaser	31.2	14.4	4	16.5
<b>Grazing potential (Frequency)</b>	High	28.8	10.4	2.4	13.9
	Medium	52	62.4	59.2	57.9
	Low	9.6	25.6	35.2	23.5
<b>Grass biomass</b>	(kg/ha)	2743	2654	3453	2950
<b>Grazing capacity</b>	(ha/LSU)	1.7	1.9	1.7	1.8
<b>Basal cover</b>	(%)	11.2	11.2	16	12.8
<b>Physical parameters (Frequency)</b>	Bare patches	52.8	44.8	32.8	43.5
	Litter patches	0	2.4	0	0.8
	Rock patches	3.2	0	0	1.1
<b>Erosion factor</b>	Point to tuft distance (cm)	5.4	4.3	3.7	4.5
	Erosion factor	Med	Low	Low	Low

**Table A18 Quantitative species data of the woody layer of the *Acacia caffra-Bothriochloa insculpta* Community**

Site numbers		16	17	20	Average
<b>Species</b>	<b>Palatability</b>	<b>Frequency</b>			
<i>Acacia caffra</i>	Palatable	50.4	26.4	56.8	44.5
<i>Acacia karroo</i>	Palatable	0	0.8	4	1.6
<i>Acacia nilotica</i>	Palatable	4.8	6.4	4.8	5.3
<i>Acacia tortilis</i>	Palatable	3.2	19.2	1.6	8
<i>Dichrostachys cinerea</i>	Palatable	2.4	7.2	4	4.5
<i>Dombeya rotundifolia</i>	Palatable	0.8	0	0	0.3
<i>Ehretia rigida</i>	Palatable	0	0	3.2	1.1
<i>Grewia flava</i>	Palatable	8	4	1.6	4.5
<i>Searsia lancea</i>	Palatable	0	0.8	0	0.3
<i>Searsia pyroides</i>	Unpalatable	0.8	5.6	1.6	2.7
<i>Ziziphus mucronata</i>	Palatable	0	1.6	4	1.9

**Table A19 Quantitative ecological data of the woody layer of the *Acacia caffra*-*Bothriochloa insculpta* Community**

Site numbers		16	17	20	Average
<b>Palatability (%)</b>	Palatable	98.9	92.2	98	96.4
	Unpalatable	1.1	7.8	2	3.6
<b>Density (Plants/ha)</b>	Under 2m	342.7	870.2	431.3	548.1
	Above 2m	90.7	63.8	179.6	111.4
<b>Leaf biomass (kg/ha)</b>	Under 2m	119.3	228.6	174	174
	Above 2m	226.1	170	295.2	230.4
<b>Browsing capacity (ha/BU)</b>	Under 2m	30.6	16	21	21
	Above 2m	16.1	21.5	12.4	15.8
<b>Canopy spread (m<sup>2</sup>/ha)</b>	Under 2m	435.2	965.9	625.4	675.5
	Above 2m	403.6	301.8	635.8	447.1
<b>Average individual height (m)</b>	Under 2m	1	0.9	1.2	1
	Above 2m	2.9	2.7	2.5	2.7

**Table A20 Statistically significant differences between the grazing capacity and grass biomass of the four plant communities**

	Unequal N HSD variable: Grazing capacity				Unequal N HSD variable: Grass biomass			
<b>Differences are significant at p &lt; 0.05</b>								
	{1}	{2}	{3}	{4}	{1}	{2}	{3}	{4}
<b>Com 3.1.1</b>		0.37	0.31	0.46		0.11	0.71	0.83
<b>Com 3.1.2</b>	0.37		0.99	1	0.11		0.43	0.65
<b>Com 3.1.3</b>	0.31	0.99		0.99	0.71	0.43		1
<b>Com 3.1.4</b>	0.46	1	0.99		0.83	0.65	1	

**Table A21 Statistically significant differences between the woody density of the four plant communities**

	Unequal N HSD variable: Woody density under 2 m				Unequal N HSD variable: Woody density over 2 m			
<b>Differences are significant at p &lt; 0.05</b>								
	{1}	{2}	{3}	{4}	{1}	{2}	{3}	{4}
<b>Com 3.1.1</b>		0.97	0.57	1		0.99	<b>0.02</b>	0.17
<b>Com 3.1.2</b>	0.97		0.48	0.93	0.99		0.07	0.11
<b>Com 3.1.3</b>	0.57	0.48		0.91	<b>0.02</b>	0.07		1
<b>Com 3.1.4</b>	1	0.93	0.91		0.17	0.11	1	

**Table A22 Statistically significant differences between the leaf biomass of the woody component of the four plant communities**

	Unequal N HSD variable: Leaf biomass under 2 m				Unequal N HSD variable: Leaf biomass over 2 m			
Differences are significant at p < 0.05								
	{1}	{2}	{3}	{4}	{1}	{2}	{3}	{4}
<b>Com 3.1.1</b>		0.96	<b>0.002</b>	1		1	<b>0.005</b>	0.95
<b>Com 3.1.2</b>	0.96		<b>0.01</b>	0.93	1		<b>0.03</b>	0.9
<b>Com 3.1.3</b>	<b>0.002</b>	<b>0.01</b>		0.1	<b>0.005</b>	<b>0.03</b>		0.26
<b>Com 3.1.4</b>	1	0.93	0.1		0.95	0.9	0.26	

**Table A23 Statistically significant differences between the canopy spread of the woody component of the four plant communities**

	Unequal N HSD variable: Canopy spread under 2 m				Unequal N HSD variable: Canopy spread over 2 m			
Differences are significant at p < 0.05								
	{1}	{2}	{3}	{4}	{1}	{2}	{3}	{4}
<b>Com 3.1.1</b>		0.96	0.36	1		0.98	<b>0.01</b>	0.51
<b>Com 3.1.2</b>	0.96		0.32	0.94	0.98		<b>0.03</b>	0.33
<b>Com 3.1.3</b>	0.36	0.32		0.78	<b>0.01</b>	<b>0.03</b>		0.81
<b>Com 3.1.4</b>	1	0.94	0.78		0.51	0.33	0.81	

**Table A24 Statistically significant differences between the average height of the woody component of the four plant communities**

	Unequal N HSD variable: Avg. woody height under 2m				Unequal N HSD variable: Avg. woody height over 2m			
Differences are significant at $p < 0.05$								
	{1}	{2}	{3}	{4}	{1}	{2}	{3}	{4}
<b>Com 3.1.1</b>		0.96	0.28	0.4		0.4	0.98	0.9
<b>Com 3.1.2</b>	0.96		0.81	0.66	0.4		0.28	0.8
<b>Com 3.1.3</b>	0.28	0.81		0.98	0.98	0.28		0.79
<b>Com 3.1.4</b>	0.4	0.66	0.98		0.9	0.8	0.79	





**Data Sheet A2: An example of the data sheet used during the quantitative surveys.**

FIXMOVE Datasheet: Grassland/Savanna										21	
Fix site ID		GPS		S		E		Date	200_		
Nearest Town						KM		Time	__:	__	
Observer						Institution					
Photo nr	S		E		N		W		Other:		
<b>Herbaceous Survey (2 m interval over 250 m transect)</b>											
Point to Tuft Distance (DIST) & Disk Pasture Meter (DPM)											
m	Species	Dist	DPM	m	Species	Dist	DPM				
2				52							
4				54							
6				56							
8				58							
10				60							
12				62							
14				64							
16				66							
18				68							
20				70							
22				72							
24				74							
26				76							
28				78							
30				80							
32				82							
34				84							
36				86							
38				88							
40				90							
42				92							
44				94							
46				96							
48				98							
50				100							
<b>Ecosystem Integrity</b>											
Parameter	Observations (presence/absence)									Total	
Sheet Erosion patch											
Rill/Gully Erosion patch											
Rock patch											
Litter patch											
Bare patch											

**SHEET 1A**

FIXMOVE Datasheet: Grassland/Savanna

22

Herbaceous Survey (2m interval over 250 transect)

Fix site ID	GPS	S	E	Date	200		
Point to Tuft Distance (DIST) & Disk Pasture Meter (DPM)							
m	Species	Dist	DPM	m	Species	Dist	DPM
102				152			
104				154			
106				156			
108				158			
110				160			
112				162			
114				164			
116				166			
118				168			
120				170			
122				172			
124				174			
126				176			
128				178			
130				180			
132				182			
134				184			
136				186			
138				188			
140				190			
142				192			
144				194			
146				196			
148				198			
150				200			

Ecosystem Integrity

Parameter	Observations (presence/absence)	Total
Sheet Erosion patch		
Rill/Gully Erosion patch		
Rock patch		
Litter patch		
Bare patch		

SHEET 1B

Herbaceous Survey (2m interval over 250 transect)

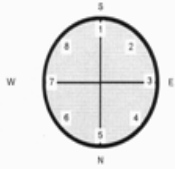
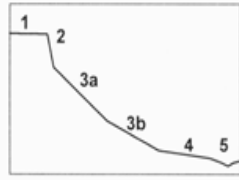
Fix site ID	GPS	S	E	Date	200		
<b>Point to Tuft Distance (DIST) &amp; Disk Pasture Meter (DPM)</b>							
m	Species	Dist	DPM	m	Species	Dist	DPM
202				226			
204				228			
206				230			
208				232			
210				234			
212				236			
214				238			
216				240			
218				242			
220				244			
222				246			
224				248			
				250			

Ecosystem Integrity

Parameter	Observations (presence/absence)	Total
Sheet Erosion patch		
Rill/Gully Erosion patch		
Rock patch		
Litter patch		
Bare patch		

SHEET 1C

Habitat information

Fix site ID	_____	GPS	_____	S	_____	E	_____	Date	200_	__	__
Aspect					Slope (%)						
					_____ %						
Phenology	Green-up	Flowering	Fruiting	Senescence	Dormant						
Impacts	Oldfield	Grazing	Fire	Aliens	Encroachment	Urban	Insects	Rodents	Drought		

Management

Erosion				Present Grazing regime			
Type	Extent	Severity	Stability	Type	Intensity		
Wind	High 3	High 3	Unstable 3	Continuous – selective	4	High	3
Water: Sheet	Mod 2	Mod 2	Part Stabilized 2	Continuous - non-selective	3	Mod	2
Water: Rill	Low 1	Low 1	Stabilized 1	Rotational – selective	2	Low	1
Water: Gully	None 0	None 0		Rotational – non-selective	1	Rested	0

CARA assessment

Class	Alien Woody	Alien Weeds	Encroachment	Over Grazing	Fire
None	0	0	0	0	0
Low	1	1	1	1	1
Moderate	2	2	2	2	2
High	3	3	3	3	3
Very High	4	4	4	4	4
Species	1.	1.	1.		
	2.	2.	2.		
	3.	3.	3.		
Comments					

Dominant Species

	Trees	Shrubs	Graminoids	Perennial Forbs
1				
2				
3				
4				
5				

Bare Patch Organization

	Patch Size	Number of Patches					
		1-5			6-10	>10	
1	1-2 m Patches						
2	2-5m Patches	1	2	3	4	5	>5
3	>5m Patches	1	2	3	4	5	>5
4	Erosion Patches	1	2	3	4	5	>5

FIXMOVE Datasheet: Grassland/Savanna

25

Transect Datasheet: Woody Survey (Shrubs and Trees)

Fix site ID	QUADRAT		SPECIES	DIST	H_TREE	H_CAN	H_LEAVE	CANOP	CANOP	BASAL	Stems
			Acac kar					DIAM1	DIAM2	DIAM	S/M
1	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
2	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
3	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
4	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
5	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
6	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
7	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
8	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
9	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
10	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									
11	1	<2m									
	2	<2m									
	3	>2m									
	4	>2m									
	4	Tallest									

SHEET 2A

FIXMOVE Datasheet: Grassland/Savanna

26

Fix site ID	QUADRAT	SPECIES Acac kar	GPS DIST	H_TREE	H_CAN	S H_LEAVE	E CANOP DIAM1	Date CANOP DIAM2	200 BASAL DIAM	Stems S/M
12	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
13	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
14	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
15	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
16	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
17	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
18	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
19	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
20	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
21	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								
22	1	<2m								
	2	<2m								
	3	>2m								
	4	>2m								
	4	Tallest								

SHEET 3B

FIXMOVE Datasheet: Grassland/Savanna

27

Fix site ID			GPS	S			E		Date	200		
	QUADRAT	SPECIES Acac kar	DIST	H_TREE	H_CAN	H_LEAVE	CANOP DIAM1	CANOP DIAM2	BASAL DIAM	Stems S/M		
23	1	<2m										
	2	<2m										
	3	>2m										
	4	>2m										
	4	Tallest										
24	1	<2m										
	2	<2m										
	3	>2m										
	4	>2m										
	4	Tallest										
25	1	<2m										
	2	<2m										
	3	>2m										
	4	>2m										
	4	Tallest										

SHEET 3C