

# **A multidisciplinary approach for the assessment of rehabilitation at asbestos mines in South Africa**

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# TABLE OF CONTENTS

Acknowledgements.....	v
Preface.....	vi
Summary.....	vii
List of Abbreviations.....	viii
List of Figures.....	x
List of Tables.....	xiii

## CHAPTER 1: INTRODUCTION

1. BACKGROUND.....	1
1.1. Asbestos and its history in South Africa.....	1
1.2. Health related risks associated with asbestos.....	3
1.3. Legislation related to asbestos mining.....	5
1.4. Rehabilitation of asbestos tailings.....	6
2. PERSPECTIVE AND OUTLINE OF DISSERTATION.....	13
2.1. Problem statement.....	13
2.2. Aim and objectives.....	14
2.3. Outline of dissertation.....	14

## CHAPTER 2: MATERIALS AND METHODS

1. SITE DESCRIPTION.....	15
1.1. Limpopo Province.....	16
1.2. North-West Province.....	18
1.3. Northern Cape Province.....	20
2. QUANTITATIVE DATA.....	22
2.1. Cover depth.....	22
2.2. Physical and chemical soil properties.....	22
2.3. Analysis of microbial activity.....	23
2.4. Vegetation properties.....	24
2.5. Small mammal abundance.....	25
3. QUALITATIVE DATA.....	26
3.1. Footprint area.....	26
3.2. Land use.....	26
3.3. Erosion or flood damage.....	26
3.4. Secondary pollution.....	27
3.5. Water control structures.....	28
3.6. Atmospheric sampling.....	29
4. STATISTICAL ANALYSIS.....	29

## **CHAPTER 3: RESULTS AND DISCUSSION**

1. MONITORING FRAMEWORK .....	30
2. RESULTS FOR THE LIMPOPO PROVINCE.....	32
2.1. Quantitative results for the Limpopo Province .....	32
2.2. Qualitative results for the Limpopo Province .....	34
3. RESULTS FOR THE NORTH-WEST PROVINCE.....	36
3.1. Quantitative results for the North-West Province .....	36
3.2. Qualitative results for the North-West Province .....	38
4. RESULTS FOR THE NORTHERN CAPE PROVINCE .....	39
4.1. Quantitative results for the Northern Cape Province.....	39
4.2. Qualitative results for the Northern Cape Province.....	41

## **CHAPTER 4: GENERAL DISCUSSION AND CONCLUSIONS**

1. DISCUSSION OF QUANTITATIVE RESULTS .....	43
2. DISCUSSION OF QUALITATIVE RESULTS.....	49
3. SITE SCORING AND CALCULATION OF THE RMI .....	51
4. CONCLUSIONS AND RECOMMENDATIONS.....	57

<b>REFERENCES .....</b>	<b>59</b>
-------------------------	-----------

<b>APPENDIX A: RECORD OF MINES.....</b>	<b>64</b>
---	-----------

<b>APPENDIX B: QUANTITATIVE RESULTS.....</b>	<b>67</b>
--	-----------

APPENDIX B.1. VEGETATION SURVEY RESULTS.....	67
--	----

B.1.1. Limpopo Province.....	67
B.1.2. North-West Province .....	79
B.1.3. Northern Cape Province .....	82
B.1.4. List of species abbreviations.....	92

APPENDIX B.2. OTHER QUANTITATIVE RESULTS .....	96
--	----

B.2.1. Limpopo Province.....	96
B.2.2. North-West Province .....	100
B.2.3. Northern Cape Province .....	104

**APPENDIX C: QUALITATIVE RESULTS** ..... 108

APPENDIX C.1. LIMPOPO PROVINCE ..... 108

    C.1.1. Erosion ..... 108

    C.1.2. Secondary pollution..... 110

    C.1.3. Water control structures ..... 115

APPENDIX C.2. NORTH-WEST PROVINCE ..... 118

    C.2.1. Erosion ..... 118

    C.2.2. Secondary pollution..... 120

    C.2.3. Water control structures ..... 123

APPENDIX C.3. NORTHERN CAPE PROVINCE ..... 125

    C.3.1. Erosion ..... 125

    C.3.2. Secondary pollution..... 127

    C.3.3. Water control structures ..... 130

*“There is no spot of ground, however arid, bare or ugly, that cannot be tamed into such a state, as may give an impression of beauty and delight.” Gertrude Jekyll*

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*"If the only prayer you ever say in your whole life is "thank you" that would suffice." Meister Eckhart*

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## **PREFACE**

The research discussed in this dissertation was conducted from February 2009 to May 2010 in the School of Environmental Sciences and Development, North-West University, Potchefstroom Campus, Potchefstroom, South Africa.

The research conducted and presented in this dissertation represents original work undertaken by the author and has not been previously submitted for degree purposes to any university. Where use has been made of the work of other researchers, it is duly acknowledged in the text.

The reference style used in this dissertation is according to the specifications given by the Council of Biology Editors (CBE) Scientific Style using the name-year system

(<http://writing.colostate.edu/references/sources/cbe/index.cfm>).

Any opinion, findings, and conclusions or recommendations expressed in this material are those of the author and therefore the NRF does not accept any liability in regard thereto.

## SUMMARY

The asbestos mining industry has left a legacy of pollution that continues to poison former mining areas and surrounding land – posing a significant health risk to local communities. The rehabilitation of sites disturbed by mining activities, aims to negate the adverse effects associated with these post-mining landscapes and to achieve the return of a disturbed site to a degree of its former state or to a sustainable usable condition. In order to assist the effective rehabilitation of derelict and ownerless asbestos mines it was critical to develop a scientific database to indicate the status of rehabilitation at specific sites. The Rehabilitation Prioritisation Index (RPI) was developed in 2007 to indicate the sequence for rehabilitation of asbestos pollution by quantifying the risk associated with a specific pollution site. The use of the RPI has been implemented by the South African Department of Minerals and Energy as part of an integrated approach towards the rehabilitation of the asbestos legacies of the past. In this study, a multidisciplinary approach was applied to sites in three provinces as identified in the RPI, to facilitate the development of the Rehabilitation Monitoring Index (RMI). It is envisioned that this index, as part of a larger monitoring database, would assist in the successful monitoring and long-term rehabilitation of asbestos mines. During the monitoring process, the most prominent aspects governing the rehabilitation process were identified from comprehensive assessments of quantitative and qualitative data. Quantitative parameters included cover depth, physical and chemical soil properties, soil microbial activity, vegetation properties and small mammal surveys. Qualitative data included the footprint area, land use, erosion or flood damage, secondary pollution and water control structure damage. From the quantitative data, those parameters which had the greatest influence on the rehabilitation process were identified. In order of most to least important these groups were analysed by multivariate statistical ordination and classified into four groups: success parameters > essentials to be addressed > reasons for failure > non-distinguishable entities. The qualitative data indicated that the Limpopo Province was in the highest state of degradation after rehabilitation and that site history plays an important role in rehabilitation planning. Quantitative and qualitative parameters were assessed for all sites and applied in the RMI as weighted factors from which the rehabilitation status of a specific site can be calculated. Qualitative data was given a weight of 25% and quantitative data a weight of 75%. RMI values were calculated for each parameter and sites were distributed across a range which classifies the sites according to their rehabilitation status. Once again the Limpopo Province was identified as the province with the least successful rehabilitation. The results from this investigation show that a multidisciplinary approach is a step in the right direction for the successful monitoring of rehabilitated post-mining sites such as asbestos mines. It is however necessary that the RMI must be validated and the weights allocated to qualitative parameters must be reconsidered for the future development of this tool. While the RPI and RMI cannot be compared directly, it might be of great revelation to reassess the RPI values of all the sites after rehabilitation and compare this data to the RMI values.

## LIST OF ABBREVIATIONS

Al	aluminium
B	boron
BC	basal cover
C	carbon
Ca	calcium
CEC	cation exchange capacity
Cl	chlorine
Cu	copper
DEAT	Department of Environmental Affairs and Tourism
DHA	dehydrogenase activity
DME	Department of Minerals and Energy
DTEC	Departments of Tourism, Environment and Conservation
EC	electrical conductivity
Fe	iron
Gefco	Griqualand Exploration and Finance Company
GPS	global positioning system
HCC	herbaceous crown cover
HCH	herbaceous crown height
IDP	integrated development plans
INF	iodonitrotetrazolium violet-formazan
INT	iodonitrotetrazolium chloride
K	potassium
Mg	magnesium
Mo	molybdenum
Mn	manganese
MPRDA	Mineral and Petroleum Resources Development Act (Act 28 of 2002)
N	nitrogen
Na	sodium
NCOH	National Centre for Occupational Health
NEMA	National Environmental Management Act (Act 107 of 1998)
NH <sub>4</sub>	ammonia
NO <sub>3</sub>	nitrate
P	phosphorus
PLFA	phospholipid fatty acid
RDA	redundancy analysis
RMI	rehabilitation monitoring index
RPI	rehabilitation prioritisation index

SER	Society for Ecological Restoration
SO <sub>4</sub>	sulphate
THAM	tris (hydroxymethyl)-aminomethane
WCC	woody crown cover
WCH	woody crown height
WCS	water control structures
Zn	zinc

## LIST OF FIGURES

- Figure 2-1:** Map of the distribution of asbestos mines in the Limpopo Province. Previously rehabilitated dumps are indicated in green, partially rehabilitated dumps in yellow and asbestos dumps where no rehabilitation has been carried out in red points..... 17
- Figure 2-2:** Map of the distribution of asbestos mines in the Northern Cape and North-West Provinces. Previously rehabilitated dumps are indicated in green, partially rehabilitated dumps in yellow and asbestos dumps where no rehabilitation has been carried out in red points (Map 1 of 2). ..... 19
- Figure 2-3:** Map of the distribution of asbestos mines in the Northern Cape and North-West Provinces. Previously rehabilitated dumps are indicated in green, partially rehabilitated dumps in yellow and asbestos dumps where no rehabilitation has been carried out in red points (Map 2 of 2). ..... 21
- Figure 3-1:** Monitoring project framework for the monitoring of previously rehabilitated asbestos mines in South Africa. The project was divided into different categories, of which this study forms part of the first 4 categories where the quantitative and qualitative data was evaluated..... 31
- Figure 3-2:** Framework for the classification of results into quantitative and qualitative factors. .... 31
- Figure 3-3:** RDA diagram of quantitative factors for the Limpopo Province. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.498 and 0.255 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height; EGN: Egnep; KROM: Kromellenboog; ZEEL: Zeelig; KL3: Kloof 3; KL2: Kloof2; MSRM: M&S Riverdump; RABES: Rabeskloof; KEMP: Kempville; PYLK: Pylkop; LA/PIE: Lagers/Piesangdraai; VOC: Voorspoed Complex..... 32
- Figure 3-4:** Bar graphs for (a) percentage organic carbon, (b) dehydrogenase activity and (c) woody crown cover for sites monitored in the Limpopo province. .... 33
- Figure 3-5:** Gully erosion at Egnep dump in the Limpopo Province. .... 34
- Figure 3-6:** Secondary pollution in the river at M & S Riverdump..... 35
- Figure 3-7:** Loose asbestos fibres at Zeelig dump indicating secondary pollution on the dump after rehabilitation. .... 35

**Figure 3-8:** RDA diagram of quantitative factors for the North-West Province. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.429 and 0.315 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height; POMF: Pomfret; NCW: Ncweng; CORE: Coretsi; WHIR: Whiterock; GAM: Ga-Mopedi; SADR: Sardinia. .... 36

**Figure 3-9:** Bar graphs for (a) percentage organic carbon, (b) dehydrogenase activity, (c) herbaceous crown cover and (d) basal cover for sites monitored in the North-West Province..... 37

**Figure 3-10:** Soil sampling for secondary pollution in the North-West Province at the Pomfret dump..... 38

**Figure 3-11:** RDA diagram of quantitative results for the Northern Cape Province. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.498 and 0.242 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height; MEREN; Merencor; ENGL: Engeland; WANC: Wandrag Complex; RIRIE: Riries; WHBC: Whitebank Complex; MTVE: Mt Vera. .... 39

**Figure 3-12:** Bar graphs for (a) percentage organic carbon, (b) dehydrogenase activity, (c) herbaceous crown cover and (d) basal cover for sites monitored in the Northern Cape Province..... 40

**Figure 3-13:** Damaged waterway in the Northern Cape Province..... 42

**Figure 3-14:** Damaged retaining weir 1 in the Northern Cape Province at the Kuruman-East asbestos mine. .... 42

**Figure 3-15:** Damaged retaining weir 2 in the Northern Cape Province, where the gabion structure was damaged by floods..... 42

**Figure 4-1:** RDA diagram illustrating the quantitative results for all three provinces. A co-variable descriptor to specify the province of origin was included. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.052 and 0.021 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height..... 43

**Figure 4-2:** Framework for the development of the RMI values for asbestos rehabilitation, indicating the weights allocated to the different criteria of qualitative and quantitative parameters. .... 53

## LIST OF TABLES

<b>Table 2-1:</b> Status of rehabilitation for asbestos mines in the different provinces in South Africa. ....	15
<b>Table 2-2:</b> Total asbestos mine-areas monitored in three provinces. ....	15
<b>Table 4-1:</b> Table of quantitative weights assigned to the different quantitative parameters. Parameters with the highest weight (expressed as a percentage) had the greatest impact on the rehabilitation process. ....	44
<b>Table 4-2:</b> Description of different parameters influencing rehabilitation. ....	45
<b>Table 4-3:</b> Weights assigned to qualitative parameters to evaluate rehabilitation practices. ....	49
<b>Table 4-4:</b> Example of how the RMI values were calculated for erosion type in the Northern Cape Province. ....	52
<b>Table 4-5:</b> Distribution range list of mines according to RMI values. Sites with the highest values are in the most need of rehabilitation. ....	54
<b>Table 4-6:</b> Distribution range list according to RPI values. Sites with the highest value had the highest risk in terms of pollution to humans and the environment. ....	56

# CHAPTER 1: INTRODUCTION

## 1. BACKGROUND

### 1.1. Asbestos and its history in South Africa

Asbestos is one of the oldest and most widely used minerals known to mankind. The name asbestos is derived from the Greek for *inextinguishable flame* and the Greeks termed this mineral as the miracle mineral. The use of asbestos however, turned out to be one of the most controversial issues surrounding the industrial mineral industry (Hart, 1988; Virta, 2003). Its carcinogenic nature, an overall lack of knowledge of minimum safe exposure levels, its widespread use for more than 100 years and the long latency for the development of lung cancer and mesothelioma are the main contributing factors to these controversies (Virta, 2003). Mining of asbestos generates vast amounts of residue material, which is chemically not that different from the original rock. An important difference is its fineness, making it more susceptible to weathering. The residue dumps are unsightly and subject to wind erosion. Revegetation of the dumps is not only aesthetically desirable but is also a means of stabilising material, which, if airborne, is a potentially serious health hazard (Meyer, 1980). The main problems associated with vegetation establishment on asbestos tailings are extremely alkaline conditions, low nutrient concentrations such as P, K and Ca, and surface crusting (Hossner and Hons, 1992).

Asbestos is a generic term for six naturally occurring fibrous minerals from the amphibole and serpentine group of rocks that have been used in commercial products such as asbestos cement. It is a commercial description for mineral products that possess high tensile strength, flexibility, resistance to chemical and thermal degradation and high electrical resistance that can be woven. The most common asbestos types are chrysotile  $Mg_6[(OH)_4Si_2O_5]_2$  (white asbestos) which is a fibrous form of serpentine and the most abundant form; crocidolite  $Na_2Fe_5[(OH)Si_4O_{11}]_2$  (blue asbestos); and amosite  $MgFe_6[(OH)Si_4O_{11}]_2$  (brown asbestos). Crocidolite and amosite are asbestiform minerals belonging to the amphibole group (Hart, 1988). Asbestos was one of the most useful non-metallic minerals and its applications varied from household appliances to the building industry. The greatest amount of asbestos was used for asbestos-cement products such as tiles and sheets of flat and corrugated asbestos (Howling, 1937).

Asbestos fields occur in several provinces throughout South Africa. Crocidolite occurs mainly in the North-West Province and the Northern Cape Province. The crocidolite fields of the Northern Cape stretch over 450km from just south of Prieska on the Orange River to the Botswana border (Hart, 1988). Crocidolite occurs in cross-fibre seams in the banded ironstones of the Asbestos Hills Formation of the Griquatown Group that range in thickness from less than 1mm to about 50mm. The maximum fibre length is about 150mm (Howling, 1937; Hart, 1988). Amosite is found almost exclusively in the Mpumalanga and Limpopo Provinces. The amosite field occupies portions of the Polokwane (Pietersburg) and Letaba district, and extends from Chuniespoort in the west to the Steelpoort River in the east, a distance of some 90km. In this

region, the asbestos is confined to the banded ironstone of the Penge Formation of the Chuniespoort Group (Hart, 1988). There are many deposits of chrysotile in the Limpopo and Kwa-Zulu Natal Provinces. The most important chrysotile deposits are those located in the Barberton area, where the chrysotile bodies are hosted in ultramafic intrusions within the Swartkoppies Formation, which forms part of the Onverwacht Group of rocks (Hart, 1988; McCulloch, 2003).

Asbestos mining in South Africa began in earnest in the 1930's, and through the subsequent decades attracted a multitude of companies. South Africa is in the unique position that it is the only country in the world that has reserves of and produced all three principal varieties of asbestos (Hart, 1988). Together with Canada and Zimbabwe, South Africa was one of the most important asbestos producing countries in the former British Empire. Canada was the largest producer of asbestos in the world, but South Africa possessed the only commercial deposits of amosite and crocidolite (Howling, 1937). From 1950 through the mid-1980's South Africa was the second most important market-economy producer of asbestos. After World War II, production increased dramatically, aided by worldwide rebuilding efforts and growing economies. The number of mills in South Africa increased rapidly, allowing for increased fibre production. Mining increased from 41 500t per annum in 1948 to its peak of 380 000t per annum in 1977 (Virta, 2003). At its height in the 1970's, the South African asbestos mining industry employed 20 000 asbestos mine workers (Coombes, 2002). By 1981, the foreign companies had withdrawn from active mining in South Africa and a long series of mergers and acquisitions had reduced the major producers to only two: The Griqualand Exploration and Finance Company (Gefco) and Msauli Asbes, which was later called Hanova (Hart, 1988). As the awareness of the asbestos health issue increased, sales declined, indicating that production was outpacing demand. South African producers as well as the then Department of Mines dismissed medical evidence about the dangers of asbestos and blamed Canadian and Russian interests for seeking to have their chrysotile take over the markets vacated by amosite and crocidolite (Virta, 2003; McCulloch, 2003). After peaking in 1977, production declined rapidly to 135 000t per annum in 1987, 50 000t in 1997, and 6 220t in 2003 (Virta, 2003).

As a result of declining international demand, South African asbestos mines began closing towards the end of the 1970's. Amosite production and mining stopped in 1992, while crocidolite mining stopped in 1989. The last chrysotile mines, Kaapsehoop and Msauli, ceased mining operations in 2001. There was a stockpile of chrysotile asbestos fibre at the Msauli mine near Baberton. These stockpiles were calculated to be sold off by September 2003. During this time Hanova employed 20 people who worked on closing down and rehabilitating the mine. It was estimated that these people remained employed at the mine until the end of June 2003 (NEDLAC, 2002).

## 1.2. Health related risks associated with asbestos

Asbestos causes three major diseases namely asbestosis, lung cancer and mesothelioma. All types of asbestos are known to cause asbestosis, other pleural disorders and cancer. Asbestosis is an occupational disease confined to the workplace caused by the inhalation of asbestos fibres. It is a non-malignant lung disease associated with exposure to amphiboles. As the disease develops it may produce a crippling fibrosis of lung tissue. As the lung loses elasticity its capacity to function is reduced (McCulloch, 2002). This disease comprises a mixture of symptoms which are associated with the scarring of lungs and general fibrosis, which will cause the victim to suffer from progressive shortness of breath. The disease can be fatal and will not be diminished by removing the individual from the hazardous environment in which the disorder was contracted. In contrast, mesothelioma can result from trivial exposure, which means the risk of injury crosses the boundary that usually distinguishes occupational from environmental hazards (McCulloch, 2006). It is mainly associated with crocidolite exposure, with amosite regarded as being less potent. Mesothelioma is usually fatal and is a primary cancer of the lining of the lung or the abdominal cavity. This inoperable malignancy of the lung lining, has progressive pain and shortness of breath as two of the major symptoms that occur. Pleural effusion is another disease caused by asbestos. It is the accumulation of fluid between the layers of the membrane lining the lung and the chest cavity (Nel, 2006).

The methods used in the mining of asbestos depend on the type of ore body to be mined. During the early or tributer period of asbestos mining, asbestos lay close to the surface and the basic labour unit was the family. A tributer is a mine worker, working by a system of payment based on the value of ore mined. Men dug the fibre from surface deposits, which was then hand-processed or cobbled by women, while the children helped by sorting the fibre and putting it into bags. The fibre was then sold to company stores. The tributer system offered mining companies the advantage that miners were paid piece rates and therefore the cost of “dead mining” was borne by the labour force. The informality of this system meant that mine workers and their families fell outside the provisions of the Mines and Works Act of 1911. Consequently, the companies avoided the cost of providing compounds, rations or medical care for their workers. While the conditions were harsh, it offered the advantage over employment offered by gold mines of allowing families to stay together (CSMI, 2008).

According to McCulloch (2003), while asbestos mining was ‘safer’ than gold mining in terms of the rate of rock-falls and fatalities, the long-term environmental and health costs were unacknowledged by the companies or by the workers themselves. In 1949, as part of the first survey of the North-East Transvaal, Gert Schepers of the Silicosis Medical Bureau visited Penge mine and found the labour conditions appalling, with women and children working in clouds of fibre. Schepers wrote a report to inform the British owned company Casap (a subsidiary of Cape asbestos), about the dangers of asbestos, but it had no effect.

Dr. Chris Wagner from the National Centre for Occupational Health (NCOH) began to uncover the link between mesothelioma and asbestos in the 1950's, but state authorities failed to reduce the dust levels. Wagner's discovery threatened the market for South African fibre at the very moment when the industry had invested heavily in new mines and mills. Having decided to continue mining, the industry needed to control the knowledge of the risk (McCulloch, 2005). A mixture of politics and the isolation of the mines allowed the British-owned companies and their subsidiaries to escape the strictures of the various mines acts. When threatened with regulation, the companies threatened to close the mines. They said that if they were forced to invest in decent conditions for workers, the mines would not be profitable and they would have to be closed. As there was no alternative employment in the area, the Department of Minerals simply turned a blind eye, the life of the mines was too limited to justify major investment. The companies and their competitors argued that although the conditions were poor, the benefits in term of employment, taxation, and export earnings far outweighed the costs. When the risks of asbestosis and mesothelioma were identified, the same rationale was used to justify dirty mills and hazardous waste dumps (McCulloch, 2003). Dr J.C. Sleggs who visited Kuruman in the Northern Cape after World War II wrote: "When I first saw it the land was blue for miles around the asbestos settlements. The mills indiscriminately spewed blue dust clouds over the countryside. And whenever the wind rose, a blue haze hovered over the dumps. Dust concentrations in some houses near the mills were so high that konimeter samples could not be analysed because the fibres were too dense to count" (McCulloch, 2003).

The incidence of asbestos related diseases in South Africa was masked by a number of factors: mines were infrequently visited by health officers and few records were kept of employees. The state inspectorate also had little interest in protecting the employees from occupational injury due to political aspects. South Africa reportedly has the highest incidence of mesothelioma in the world with data suggesting that 400 to 500 patients are diagnosed with mesothelioma each year (Naidoo, 2008). According to Naidoo (2008), "Asbestos has left its death verdict on miners, workers and mining communities in South Africa – without any 'miracle' to date to cure the related illnesses of this mineral." In 2001, a turning point was reached in the history of occupational health and safety when an historic out-of-court settlement was reached between Cape plc (formerly the UK's second largest asbestos group), and the residents of the Northern Cape and Northern Province. In terms of the agreement, South Africa will provide a modicum of financial recompense to thousands of injured workers and residents (Kazan-Allen, 2002). As well as bringing relief to the plaintiffs, the settlement raises the possibility that in the future multi-national companies may be held responsible for the behaviour of their subsidiaries in the developing world (McCulloch, 2003).

### 1.3. Legislation related to asbestos mining

Before 1956, companies that mined asbestos in South Africa were not bound by law to conserve the environment. The first legislation applicable to asbestos in South Africa was introduced in 1976 under the Atmospheric Pollution Prevention Act (Act no. 45 of 1965) when asbestos-producing areas were declared as dust pollution sites. The first Act indicating the rehabilitation responsibilities of mine operations were the Minerals Act (Act no. 50 of 1991). This Act stated in section 12 that the holder of mining authorisation remains liable for complying with the relevant provisions of the Act until a certificate has been issued to the effect that the said provisions have been complied with (Nel, 2006).

Today, South African legislation imposes a clear obligation on mining companies to prevent environmental damage and defines clear responsibilities associated with mine rehabilitation and closure. Rehabilitation activities should be controlled by legal requirements contained in many South African Acts and Regulations. However, the essence of these requirements is contained in three key pieces of legislation namely:

- The Constitution (Act 108 of 1996);
- The National Environmental Management Act [(NEMA) (Act 107 of 1998)];
- The Mineral and Petroleum Resources Development Act [(MPRDA) (Act 28 of 2002)].

According to the Constitution of the Republic of South Africa (Act 108 of 1996) section 24, “everyone has the right to an environment that is not harmful to their health or well-being”. It also states that “everyone has the right to have the environment protected, through reasonable and other legislative measures that prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development”. NEMA, (Act 107 of 1998) states that pollution and degradation of the environment must be rehabilitated. According to the MPRDA (Act 28 of 2002) section 38 (1) (d) any person who is a holder of a reconnaissance permission, prospecting right, mining right, mining permit or retention permit must as far as it is reasonably practicable, rehabilitate the environment affected by the prospecting or mining operations to its natural or predetermined state or to a land use which conforms to the generally accepted principle of sustainable development. The national Departments of Tourism, Environment and Conservation (DTEC) and Minerals and Energy (DME) budget for funds on an annual basis for the rehabilitation of derelict and ownerless mines and the DME is responsible for the rehabilitation of these dumps (Nel, 2006).

In 2001, South Africa banned asbestos mining and regulations were put in place to prohibit the use, manufacture, importation and exportation of asbestos and asbestos-containing materials (Naidoo, 2008). In 2004, the South African Government announced its intention to phase-out the use of asbestos by 2009. This announcement caused turmoil in neighbouring Zimbabwe, which at this time still was a major exporter of chrysotile. From 2004 to 2006, Zimbabwe lobbied for a change of heart on the ban asbestos proposals, by indicating that chrysotile fibre has a different structure and chemical composition, and that it is not a health or environmental risk (Kazan-Allen, 2006). The leading asbestos manufacturer in Zimbabwe, Turnall Fibre

Cement, believed that the ban would have unpredictable effects on its export earnings, with exports to South Africa having earned the company R22-million in 2007 (Naidoo, 2008).

The Department of Environmental Affairs and Tourism (DEAT) gazetted the asbestos banning regulations on March 28, 2008. The legislation prohibits the import or export of asbestos or asbestos containing materials, excluding material in transit through the country, and prohibits the acquisition, processing or repackaging of asbestos and the manufacturing or distribution of asbestos (Holman, 2008). It is focused on the effort to stop the use of asbestos, but it did not resolve the enormous environmental contamination or the problem of existing asbestos still found all over South Africa (Holman, 2008). As part of the Cape plc case in 2001, certain conditions had to be met before any money would be distributed one of these conditions was that the South African Government should agree not to hold Cape plc liable for the clean-up of former sites. Together with the implementation of the MPRDA (Act 28 of 2002), the South African Government (specifically the DME) became responsible for the clean-up of ownerless asbestos mines.

#### **1.4. Rehabilitation of asbestos tailings**

Mining waste usually includes waste rock and tailings on land surfaces which often pose highly stressful conditions for rehabilitation (Li, 2006). Abandoned mine tailings have highly diverse physical, chemical and ecological conditions. The tailings are normally variable in physical composition with depth and low in organic matter and essential plant nutrients which complicate the establishment of vegetation (Hossner and Hons, 1992).

The rehabilitation of sites disturbed by mining activities, aims to achieve the return of a disturbed site to a degree of its former state or to a sustainable usable condition; it emphasizes the reparation of ecosystem processes, productivity and services (SER, 2004). It recognises that this rehabilitated condition will most probably not achieve the original condition and land use of the impacted area (Mulligan, 1997). Section 38 (1) of the MPRDA (Act no 28 of 2002) refers to having the mine area restored to its natural or predetermined state but this is tempered by the qualification that rehabilitation must be practicable and also provides for the Public Participation Process to define 'end use'. Internationally, there are three schools of thought to the objectives of rehabilitation. These are as follows (Coaltech, 2007):

- "What the affected community wants, the affected community gets" – the key focus is on providing the end product requested by the affected communities, rather than on the previous status quo;
- "Restoration of previous land use capability" – the original thought process in the South African context, because mining often occurs on land with high agricultural potential; and.
- "No net loss of biodiversity" – there must be no loss of biodiversity - rehabilitation must restore the biodiversity of the site to its natural state.

In the South African context, rehabilitation objectives usually contain elements of all three approaches. Rehabilitation objectives should align with the national and regional Integrated Development Plans (IDPs), which may or may not match the local community wishes (Coaltech, 2007).

### 1.4.1. Factors influencing rehabilitation

Possible post-mining land uses for land disturbed by mining are influenced by characteristics of the environment in which the mine is sited, the nature of the mining process and social considerations (Mulligan, 1997). The central question facing land managers attempting to remediate or restore degraded land, is how to measure the success or failure of rehabilitation efforts on a particular site or landscape (Harris, 2003). One of the main objectives for rehabilitation of any mine is the establishment of vegetation which appears to be the answer to achieving rehabilitation success on mine discard sites. However, re-establishment of ecosystem function in post mining landscapes calls for a holistic approach to rehabilitation (Claassens, 2007). There are several potential soil limitations to plant establishment and growth on tailings. Each site must be evaluated separately to identify adverse substrate characteristics prior to preparation for revegetation. At many sites there is evidence of two or more adverse factors and it is often the interaction of these factors that determines the successful rehabilitation as measured by plant establishment and vegetative growth (Hossner and Hons, 1992).

The interaction of revegetated plants with the physical, chemical and biological components of the soil environment, determine whether vegetation will persist on rehabilitated areas (Van Rensburg *et al.*, 2004). Therefore, it is important when characterising soil quality, to use a selection of all types of soil properties constituting soil quality as a whole. These should include properties that are relevant to the chemical, physical and biological aspects of soil that are most sensitive to management practices and environmental stress (Hill *et al.*, 2000). Physical and chemical soil analyses forms the foundation for the majority of management decisions but does not allow insight into the biological structures within the soil. Traditionally, criteria for judging the success of rehabilitation have focused on visual aboveground indicators, such as soil erosion, vegetation cover and diversity of vegetation. The occurrence of certain morphological phenomena, such as loss of organic matter, water and wind erosion, salinisation, acidification, poor drainage and structural deterioration are important signs of degradation in soil quality (Doran and Parkin, 1994). During this study, related criteria were used to assess the success of the rehabilitation on the asbestos tailings sites.

#### **1.4.1.1. Soil depth**

In most cases of rehabilitation, as in asbestos rehabilitation, the rehabilitation process involves the establishment of self-sustaining vegetation. It is therefore necessary to ensure that the surface zone of the rehabilitated landscape, whether this is replaced soil, excavated overburden or mineral-processing waste, is capable of supporting plant growth (Mulligan, 1997). The depth of soil replaced on excavated overburden or tailings will be governed by factors such as the desired post-mining land use, the quantity and quality of the surface and subsoil available and the nature of the underlying waste material. Due to the health risks associated with asbestos, the dumps have to be sufficiently covered by topsoil to prevent secondary pollution. If the underlying material does not have major limitations to root growth such as salinity, sodicity or acidity, a layer of soil as thin as 50mm will aid in vegetative establishment by providing a suitable environment for seed germination, by allowing infiltration of water and by supplying nutrients and microorganisms (Mulligan, 1997).

#### **1.4.1.2. Chemical properties of tailings**

The major chemical properties affecting rehabilitation of asbestos tailings include: adequate nutrient supply; a favourable pH; the absence of toxic elements and a low salinity.

For satisfactory plant growth, the root zone must be characterised by the following -

- An adequate nutrient supply:  
Lack of one or more of the essential nutrients is the most limiting factor to plant growth on mine wastes. Deficiencies of nutrients in overburden waste or tailings are easily rectified with the addition of fertiliser (Mulligan, 1997). N is a limiting factor in most tailings. Many tailings are deficient in P and are commonly deficient in K (Hossner and Hons, 1992). Moisture stress, excess or deficiencies in Mo, Ca, P, and N, have all been cited as key factors responsible for poor plant growth in asbestos tailings (Van Rensburg and Pistorius, 1998). Application of gypsum can be made to asbestos tailings to balance the Ca:Mg ratio and to increase the long-term success of revegetation.
- A favourable pH:  
The optimum pH range for vegetation establishment varies, but little growth occurs at pH values less than 4.0 due to Al and/or Mn toxicity, and above 9.0 as a result of immobilisation of P and micronutrients such as Fe, Cu, Zn and Mn (Mulligan, 1997).
- An absence of toxic elements:  
Asbestos tailings usually have high pH values and available heavy metal concentrations in the tailings are greater than the limits normally tolerated by plants (Ellerly and Walker, 1986; Mulligan, 1997). Metal toxicities can occur in waste rock and tailings under different pH conditions. When metal toxicity occurs, the solubility can be reduced by liming to raise the pH or by adding P fertiliser or by incorporating organic matter to complex the metals (Mulligan, 1997). Heavy metals decrease root respiration, water and nutrient uptake, and inhibit cell mitosis in root meristematic regions. The presence of heavy metals may also reduce the microbial and microfaunal populations in the soils

(Hossner and Hons, 1992). Soil properties which affect the proportion of metal which is either in solution or exchangeable and which therefore may determine the degree of toxicity of a soil for plant growth include clay and organic matter contents, cation exchange capacity (CEC), pH, and the concentrations of Ca and P.

- Low salinity:

Excess concentrations of soluble salts are present in many tailings materials. High levels of Na result in clay dispersion and a reduction in electrolyte content through leaching. Salinity causes surface crusting, which is one of the main limitations of vegetation establishment on open-cast mines and asbestos tailings (Mulligan, 1997).

#### **1.4.1.3. Physical properties of tailings**

The major physical properties affecting rehabilitation of asbestos tailings include: a suitable root zone; solar radiation; texture of the tailings; erosion, water runoff and secondary pollution.

- A suitable root zone:

A suitable root zone for plants should have a good available water capacity and be sufficiently drained. The growth medium should not cause mechanical impedance to the expanding root system. These conditions are functions of the pore size distribution in the medium and its stability. Bulk densities of mine tailings are sometimes elevated due to compaction. Root penetration and moisture stress due to limited rooting volumes generally become a problem (Hossner and Hons, 1992).

- Solar radiation:

Tailings exposed to direct solar radiation can have extremely high temperatures of up to 65°C. High potential evapotranspiration and low water-holding capacity suggest that water deficit limit revegetation of coarser tailings, especially in arid regions (Hossner and Hons, 1992).

- Texture:

The texture of tailings ranges from sand to clay depending on the composition of the original material, stratification, and the method of slurry entry into the tailings pond. Fine-textured, non-aggregating materials tend to pack to a high bulk density resulting in low infiltration and permeability and restricted root penetration due to poor structural characteristics. Coarse textured materials are generally poorly buffered, devoid of organic matter, deficient in nutrients, without structure, prone to crusting, and have a low water-holding capacity (Hossner and Hons, 1992; Mulligan, 1997). Crusting, cracking, and a general lack of structure are common characteristics of mine tailings brought about by differences in texture, lack of organic matter and variable mineralogy (Hossner and Hons, 1992).

#### 1.4.1.4. Microbiological properties of tailings

The significance of microbial communities in sustainable soil ecosystems has been acknowledged for some time and an essential element for evaluating impacts of management practices is the accurate assessment of microbial community function and structure (Tate and Rogers, 2002). According to Jenkinson (1977) the microbial biomass accounts for only 1-3% of soil organic carbon, but it is the eye of the needle through which all organic material that enters soil must pass (Morris *et al.*, 2003). Analysis of soil microbial properties are needed to promote long-term sustainability of ecosystems by adding to the collection of information on soil status that will serve as an indication of soil quality (Ibekwe *et al.*, 2002). Analysis of the soil microbial community meets all five criteria against which the potential of a particular ecosystem metric could be judged. These include:

- It should be relevant to the ecosystems under study and to the objectives of the assessment programmes.
- It should be sensitive to anthropogenic changes.
- It should provide a response that can be differentiated from natural variation.
- It should be environmentally benign.
- It should be cost effective to measure (Harris, 2003).

Some of the methods used to investigate soil microorganisms include cultivation-dependent techniques and cultivation-independent community profiling methods. The latter can be divided into biochemical, physiological, and molecular approaches. According to Hill *et al.*, (2000) it has been estimated that less than 0.1% of the microorganisms found in typical soil environments are cultivable using modern culture media formulations.

In recent years, a range of methods with distinct advantages over previously used culture-based methods have emerged to characterise soil microbial communities. These include analysis of enzymatic activities, phospholipids fatty acid (PLFA) analysis, community level physiological profiling and nucleic acid based techniques, such as polymerase chain reaction amplification. Microbial activity is fundamental to the functioning of soil ecosystems and the assay of a variety of soil enzymes gives an indication of the diversity of functions that can be assumed by the microbial community (Claassens *et al.*, 2008). Results obtained from analyses of microbial community function may be a valuable indication of the status of the system and the effectiveness of management interventions (Harris, 2009). Enzyme assays are performed under optimised reaction conditions that give an indication of the potential enzymatic activity in a soil sample (Tate and Rogers, 2002). Rather than assaying actual enzymatic activity the use of buffered and optimised methods have the advantage of standardising environmental factors, which allows for comparison from different geographical locations and environmental conditions (Claassens *et al.*, 2008).

Dehydrogenase is present in all microorganisms and is regarded as an accurate measure of the microbial oxidative capacity of soil and therefore of viable microorganisms. According to Smith and Pugh (1979), the dehydrogenase assay can provide a valid indication of soil microbial activity because it depends on the metabolic state of soil microorganisms and could be valuable in ecological investigations. Measures of dehydrogenase activity have been applied to estimate the degree of recovery of tailings and mine discard in semi-arid regions (Claassens, 2007).

#### **1.4.1.5. Flora and Fauna**

The main objective of rehabilitation is to establish early vegetation on the tailings in order to reduce the risk of degradation of the artificial system created. The primary objective of revegetation is therefore to reduce soil movement to a minimum. The aims of revegetation are:

- to stabilise the soil and minimise erosion;
- to prevent pollution of streams and air by particulate matter;
- to re-establish nutrient cycles;
- to ameliorate soil physical properties; and
- in the longer term, to re-establish naturally sustaining native plant ecosystems (Coaltech, 2007).

Revegetation is considered a key indicator of rehabilitation success, as it can reflect critical stages of ecosystem development and functionality. The determination of optimum vegetation cover thresholds that ensure the biological control of hydrological processes has been stressed as an important goal for the rehabilitation of both natural and man-made landscapes (Moreno-de las Heras *et al.*, 2009). This is particularly important in areas where climatic restrictions severely constrain the development of continuous vegetation cover as is the case in South Africa.

The elevated topography of tailings and mine stockpiles accompanied by difficult climatic conditions characteristic to the arid and semi-arid areas of southern Africa, also deter the establishment of permanent self-sustaining vegetation cover (Milton, 2001). Vegetation cover is effective in reducing surface erosion because the roots bind the substrate; it reduces the energy of runoff and stimulates the stabilisation of soil by forming soil aggregates (Moreno-de las Heras *et al.*, 2009). It reduces the visual scars of the mining operations and can return a large proportion of percolating water to the atmosphere through transpiration, thus reducing the concentrations of heavy metals entering watercourses (Tordoff *et al.*, 2000). Revegetation objectives should be set to meet the post-closure land uses that have been agreed on by the landscape planner for each site.

The end land use and the vegetation and faunal requirements, will have been set during the Public Participation Process in association with the end-user communities concerned. This could entail the re-establishment of the native vegetation, erosion control for the protection of water resources, establishment of high quality grazing or the preparation of lands for arable use. Species selected for rehabilitation

establishment should provide protection from erosion and meet the biodiversity objectives. Rehabilitation success is recorded on the basis of vegetation establishment and its composition (Coaltech, 2007). It is critically important to use species that are locally adapted to the area (Morgental *et al.*, 2004).

Another useful indicator for monitoring mine site rehabilitation is habitat complexity, which is the mix of plant life forms and other structural features that provide suitable habitats for animals. The habitat complexity index is a simple landscape structure metric based on the ecological principle that more habitats for animals will develop as vegetation complexity and landscape integrity increase. Studies in Australia have demonstrated a strong correlation between habitat complexity and the abundance of different ground-dwelling mammals (Ludwig *et al.*, 2003). Fauna are important components of native ecosystems and in the post-mining environment provide an indication of whether the ecosystem development processes are heading in the right direction (Mulligan, 1997). A small mammal survey can be conducted by setting traps in grids across the sites, and checking the traps at regular intervals.

## 2. PERSPECTIVE AND OUTLINE OF DISSERTATION

### 2.1. Problem statement

The asbestos mining industry has left a legacy of pollution that continues to poison former mining areas and surrounding land. This poses a significant and continuous health risk to local communities. According to the MPRDA (Act 28 of 2002), it is the responsibility of the South African Government to ensure that abandoned and ownerless asbestos mines have a similar or better land usage capacity than its pre-land use capability and to monitor and improve the disturbed environment using the best available technology. The Department of Minerals and Energy (DME) commissioned Viridus Technologies (Pty) Ltd t/a Eko Rehab (African Gabions, 2002) for the rehabilitation of asbestos mines as part of the agreement reached during the Cape plc case. Subsequently, as part of an ongoing effort to negate the problem of asbestos pollution, a Rehabilitation Prioritisation Index (RPI) was developed in 2007.

The RPI provides a scientifically based method to indicate the sequence for rehabilitation of asbestos pollution by quantifying the risk associated with a specific pollution site. The success of rehabilitation depends on the sustainability of the rehabilitation measures applied, which is also applicable to the RPI and explains the importance of frequently revisiting the information used in the database to ensure relevant and accurate risk assessments (Van Rensburg *et al.*, 2008). With the application of the RPI, asbestos mines in South Africa were prioritised to determine which of the mines were in the most need of rehabilitation. The rehabilitation of sites disturbed by mining activities, aims to achieve the return of a disturbed site to a degree of its former state or to a sustainable usable condition. The use of the RPI has been implemented by the South African Department of Minerals and Energy as part of the integrated approach towards the rehabilitation of the asbestos legacies of the past (Van Rensburg *et al.*, 2008). In accordance with this index, 144 derelict and ownerless asbestos mines have been identified, of which 84 still needed to be rehabilitated. To ensure the long-term success of rehabilitation practices, it is critical that a comprehensive database of quantitative and qualitative data is established by means of continuous monitoring of rehabilitated sites. Rehabilitation of asbestos dumps is made difficult by problems such as poor soil quality, toxicity and textural and structural problems and monitoring is required to ensure that resources are not lost or degraded unnecessarily, and that a sustainable end product has been achieved.

In this study, a multidisciplinary approach was applied to facilitate the development of a Rehabilitation Monitoring Index (RMI) as part of an asbestos rehabilitation database. This index would assist in the successful long-term rehabilitation and monitoring of asbestos mines. During the investigation various rehabilitated mines in three provinces of South Africa were characterised in terms of a variety of quantitative and qualitative parameters. Furthermore, those parameters which are critical in the successful rehabilitation of asbestos mines were identified. Based on these findings, it will be possible to refine rehabilitation practices and thus negate the negative social and environmental impacts associated with asbestos.

## **2.2. Aim and objectives**

The aim of this study was to apply a selection of multidisciplinary criteria to already rehabilitated, or partially rehabilitated asbestos mining sites in three provinces in South Africa as identified in the RPI, in order to characterise the rehabilitation progress at these sites in terms of quantitative and qualitative parameters.

Specific objectives of the investigation include the following:

- An assessment of quantitative data, including cover depth, physical and chemical soil properties, soil microbial activity, vegetation properties and small mammal abundance.
- An assessment of qualitative data including the footprint area, land use, erosion or flood damage, secondary pollution and water control structure damage in three provinces
- An investigation of the relationship among the respective sites in the three provinces in terms of quantitative and qualitative parameters using multivariate statistical analysis.
- Determining the most prominent quantitative and qualitative parameters influencing the progress of rehabilitation at the various sites in the three provinces.
- Development of a Rehabilitation Monitoring Index (RMI) from which the rehabilitation status of a specific site can be calculated and determined according to a range distribution (well rehabilitated to poorly rehabilitated).

## **2.3. Outline of dissertation**

Chapter 1 is the introduction to the study, which includes the background to the study. It describes the history of asbestos in South Africa, legislation related to asbestos mining, and health related risks associated with asbestos. Parameters influencing rehabilitation such as: soil depth; chemical, physical and microbiological properties of tailings; flora and fauna are also discussed. This chapter also includes the perspective and outline of the dissertation.

Chapter 2 contains a description of the sites located in the Limpopo, North-West and Northern Cape Provinces, respectively; sampling procedures; and materials and methods used.

Chapter 3 includes the results obtained for the three provinces respectively, in terms of qualitative and quantitative data. Comparisons are made between different provinces and their rehabilitation procedures.

Chapter 4 contains a general discussion of all the results. The most prominent parameters influencing the rehabilitation process are identified. Conclusions and recommendations for future research are also discussed.

Appendix A is a record of all the mines monitored in the three provinces, Appendix B contains the quantitative results and Appendix C the qualitative results of all of the mines monitored in the three provinces.

## CHAPTER 2: MATERIALS AND METHODS

### 1. SITE DESCRIPTION

The Department of Minerals and Energy (DME) commissioned Viridus Technologies (Pty) Ltd t/a Eko Rehab (African Gabions, 2002) for the rehabilitation of asbestos mines. The study was conducted on selected asbestos mines from the Limpopo, North-West and Northern Cape Provinces, respectively. The status of the asbestos mines in South Africa can be divided into three classes (Table 2-1):

- rehabilitated asbestos dumps,
- partially rehabilitated asbestos dumps, and
- asbestos dumps where no rehabilitation has been carried out.

**Table 2-1:** Status of rehabilitation for asbestos mines in the different provinces in South Africa.

Provinces	Northern Cape	North-West	Mpumalanga	Limpopo	Gauteng	Total
Rehabilitated	16	11	3	36	0	66
Partially rehabilitated	9	2	0	1	0	12
Not rehabilitated	39	6	13	7	1	66
<b>Total</b>	64	19	16	44	1	144

The total number of mine areas monitored in each of the three provinces is presented in Table 2-2. In the Limpopo Province, 12 mines which included 52 dumps were monitored. In the Northern Cape Province, seven mines were monitored which included 34 dumps. Seven mines were monitored in the North-West Province, which included 30 dumps. A record of the mines monitored is presented in Appendix A.

**Table 2-2:** Total asbestos mine-areas monitored in three provinces.

Provinces	Total dumps rehabilitated	Total dumps monitored	Percentage of dumps monitored (%)
Northern Cape	40 + 34 = 74	34	46
North-West	9 + 30 = 39	30	77
Limpopo	36 + 52 + 88	52	59
<b>Total</b>			<b>61</b>

## 1.1. Limpopo Province

The sites located in the Limpopo province are mostly situated in the Savanna biome with mixed bushveldt as the vegetation type. Asbestos mines in this area consist mainly of amosite and were found in the Polokwane (Pietersburg) and Letaba districts which stretches from Chuniespoort in the west to the Steelpoort River in the east, a distance of about 90 km. In this region, the asbestos is confined to the banded ironstone of the Penge Formation of the Chuniespoort Group (Hart, 1988). There are many deposits of chrysotile in the Limpopo and Kwa-Zulu Natal Provinces. In Figure 2-1 the mines that were monitored in the Limpopo Province are illustrated. Mines in the Bewaarkloof area are situated within the mountains and this made fieldwork challenging. Mines were also located within the Bewaarkloof Nature Reserve area which are being utilised by local farmers for grazing and living. Penge and Kromellenboog sites are located near the small towns of Penge and Kromellenboog and access was therefore significantly easier (Redco, 2008).

The rainfall in the mixed bushveld veldt type varies between 450 – 560 mm, occurring in the summer months. Temperatures vary from -8°C to 40°C with an average of 21°C. The soil is mostly coarse, sandy and shallow with overlying granite, quartzite, sandstone or shale. The vegetation varies from a dense, short bushveldt to an open tree savanna. On shallow soils, Red Bushwillow *Combretum apiculatum* dominates the vegetation. Other trees and shrubs include Common Hook-thorn *Acacia caffra*, Sicklebush *Dichrostachys cinerea*, Live-long *Lannea discolor*, *Sclerocarya birrea* and various *Grewia* species. The herbaceous layer is dominated by grasses such as *Digitaria eriantha*, *Schmidtia pappophoroides*, *Antheophora pubescens*, *Stipagrostis uniplumis*, and various *Aristida* and *Eragrostis* species. In deeper and sandier soils, *Terminalia sericea* becomes dominant, with *Ochna pulchra*, *Grewia flava*, *Peltophorum africanum* and *Burkea africana* as prominent woody species, while *Eragrostis pallens* and *Perotis patens* are characteristically present in the sparse grassland (Bredenkamp *et al.*, 1996).

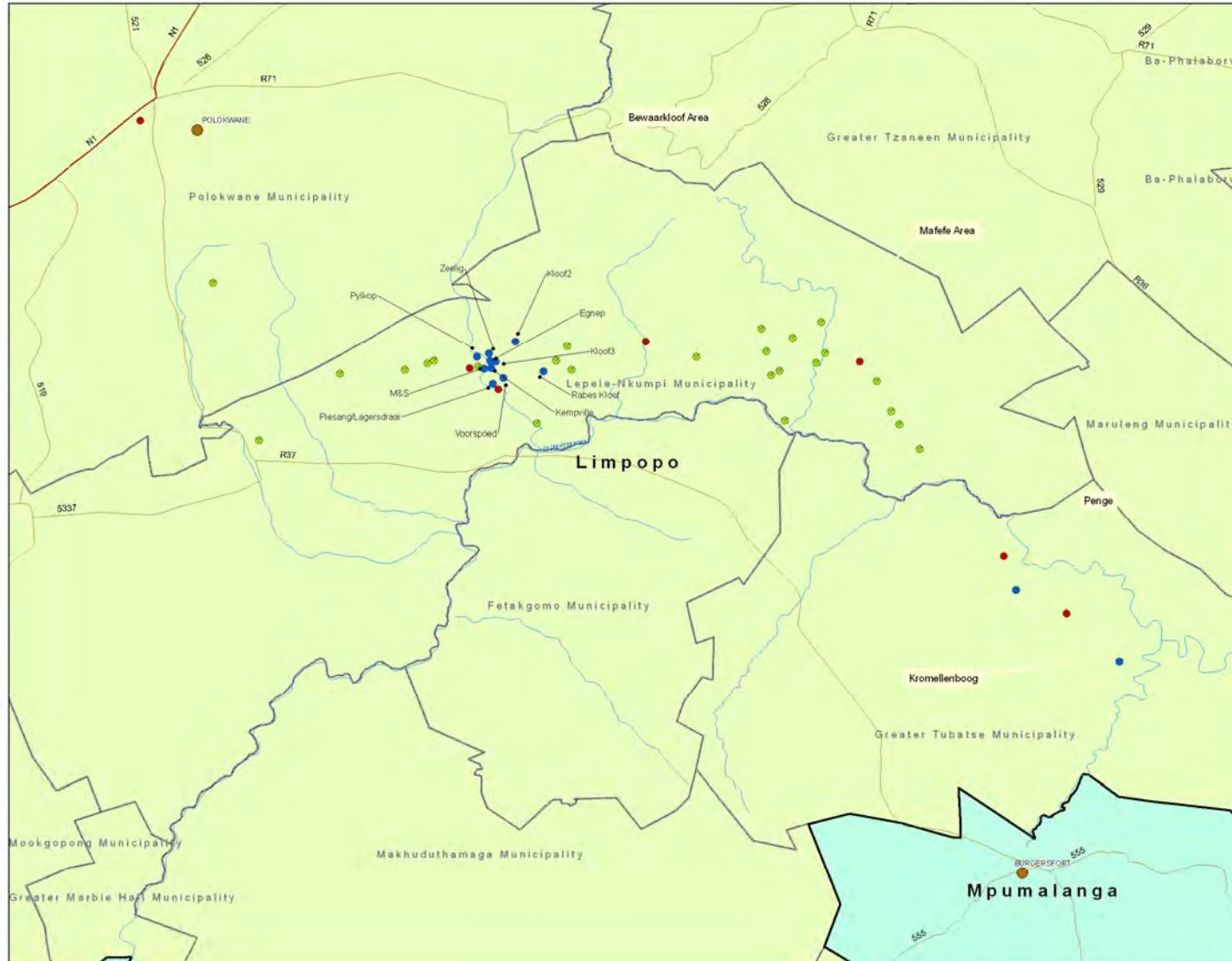
The objectives for the rehabilitation of the asbestos dumps in the Limpopo Province were mainly focused on the community's requirements. The rationale was to keep the local community away from the rehabilitated sites for health and safety purposes and to encourage this, succulent woody species such as *Euphorbia tirucalli* were planted (Van Rensburg *et al.*, 2004). The latex of *Euphorbia* species is highly toxic and can cause blindness and blisters on the skin and may even be fatal if swallowed (Voigt, 2007). Sites were treated with a layer of topsoil and organic material to act as a sustainable growth medium for vegetation. Species selection for revegetation was focused on the vegetation native to the environment. The natural vegetation in the area consists of trees and thus *Acacia* species were incorporated into the rehabilitation plan. *Acacia* species are fast growing leguminous trees with high nitrogen litter content and they are able to develop nodules with nitrogen fixing bacteria and mycorrhizae that improves the nutrient status of the soil. This symbiotic relationship is a key component of natural systems, since soil microorganisms are involved in governing the cycles of major plant nutrients and in sustaining vegetation cover (Remigi *et al.*, 2008). Due to the difficulty in establishing trees on rehabilitated sites, goats were used as seed processors. Goats from the local community were fed *Acacia* seeds and leaves, and their manure was used on the sites as organic matter (Van Rensburg *et al.*, 2004).

# Asbestos Dumps in the Limpopo Province



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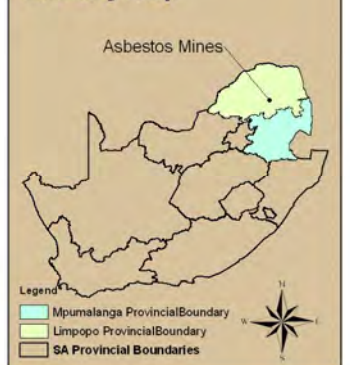
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Minerals and Energy  
REPUBLIC OF SOUTH AFRICA



## Legend

- CensusData Placenames
- Monitored Asbestos Mines
- Rehabilitation Status of Asbestos Mines**
- No
- Partial
- Yes
- DWAF Rivers selection
- National Roads
- Mainroads
- ▭ Municipal Boundaries
- ▭ Limpopo Province
- ▭ Mpumalanga Province

## Locality Map



April 2008

**Figure 2-1:** Map of the distribution of asbestos mines in the Limpopo Province. Previously rehabilitated dumps are indicated in green, partially rehabilitated dumps in yellow and asbestos dumps where no rehabilitation has been carried out in red points.

## 1.2. North-West Province

Sites in the North-West Province were mainly situated within the Savanna biome in the Kalahari plains thorn bushveldt vegetation type. Crocidolite was mostly mined in this region. The average annual rainfall is 481 mm which falls in summer and early autumn. Temperatures vary between -9°C and 42°C with an average of 18°C. The low rainfall and grazing by livestock influence the structure of this vegetation type. Vegetation is characterised by *Acacia erioloba* and *Boscia albitrunca* as the dominant trees. The shrub layer is dominated by *Acacia* species. Grass cover depends on the amount of rainfall. Grasses such as *Eragrostis lehmanniana*, *Schmidtia kalahariensis* and *Stipagrostis uniplumis* are prominent (Bredenkamp *et al.*, 1996). The mines monitored in the North-West and Northern Cape Provinces in the Kalahari plains thorn bushveldt vegetation type is illustrated in Figure 2-2. Mines are located on the border of the provincial boundary and therefore maps were created of groups of asbestos mines which were situated close to one another (Redco, 2008).

The rationale for the rehabilitation in this region was mostly to restore grazing for animals. The dominant growth forms occurring in the North-West Province are a mixture of trees, shrubs and grasses which are a close representation of the natural vegetation found in the area.

# Asbestos Dumps in the Northern Cape & North-West Province Map 1 of 2



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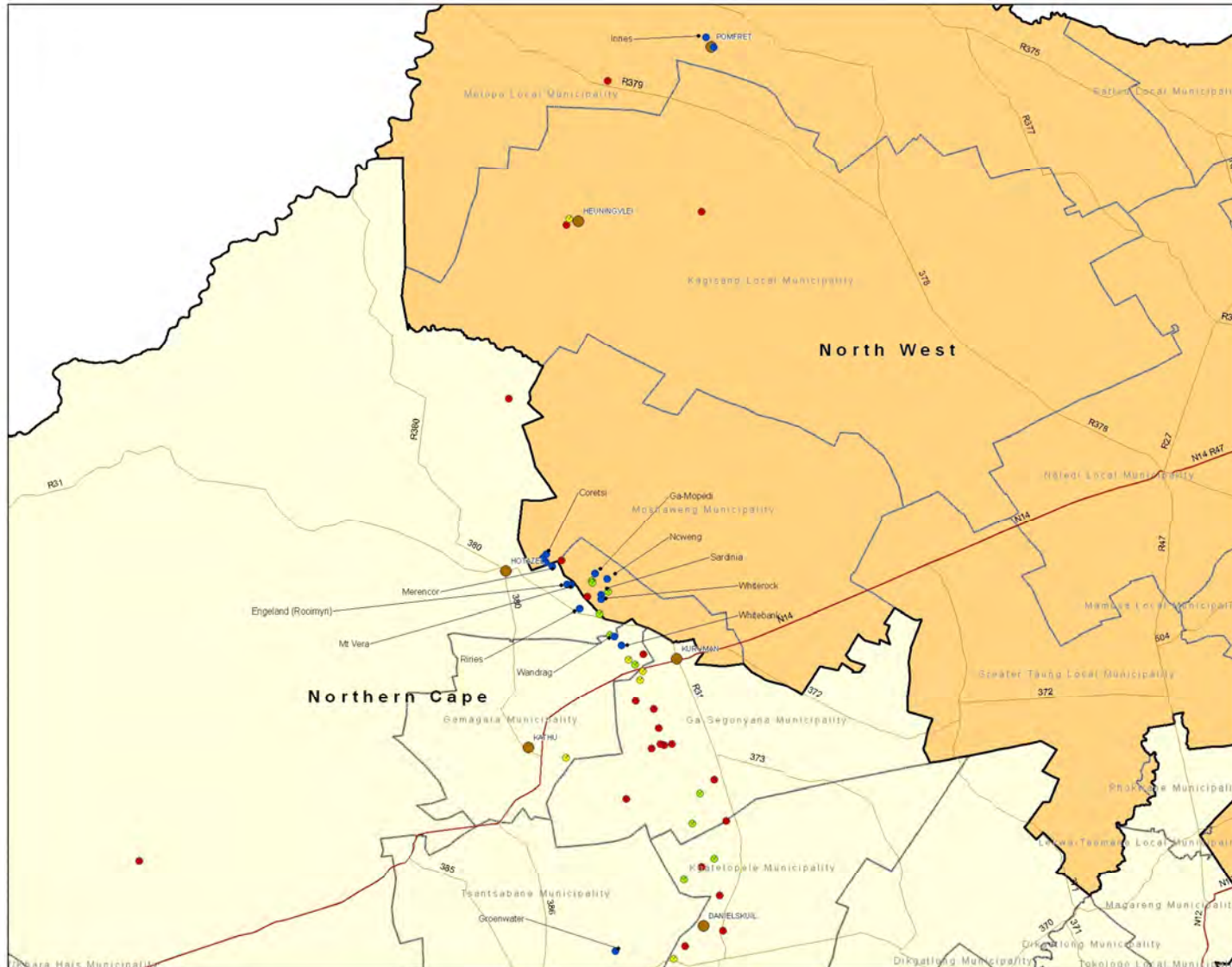
## Legend

- Monitored Asbestos Mines
- Rehabilitation Status of Asbestos Mines**
- No
- Partial
- Yes
- CensusData Placenames
- DWAf Rivers selection
- National Roads
- Mainroads
- Municipal Boundaries
- NW Provincial Boundary
- NC Provincial Boundary

## Locality Map



April 2008



**Figure 2-2:** Map of the distribution of asbestos mines in the Northern Cape and North-West Provinces. Previously rehabilitated dumps are indicated in green, partially rehabilitated dumps in yellow and asbestos dumps where no rehabilitation has been carried out in red points (Map 1 of 2).

### 1.3. Northern Cape Province

Mine sites in the Northern Cape Province also form part of the Savanna biome and sites can be found in the Kalahari mountain bushveldt and Kalahari plateau bushveldt vegetation types. Annual rainfall occurs mainly in the summer months and is extremely erratic varying from 250 mm in the south to 450 mm in the north. Temperatures vary between -9°C to 42°C with an average of 18°C (Bredenkamp *et al.*, 1996). The crocidolite fields of the Northern Cape stretch over 450 km from just south of Prieska on the Orange River to the Botswana border (Hart, 1988). Crocidolite occurs in cross-fibre seams in the banded ironstones of the Asbestos Hills Formation of the Griquatown Group (Howling, 1937; Hart, 1988). The distribution of the asbestos mines in the Northern Cape and North-West Provinces is illustrated in Figure 2-3. Vegetation in general consists of fairly dense bushveldt composed of shrubs and sometimes small trees in mixed grassland. The dominant shrubs are *Tarchonanthus camphoratus*, Threethorn *Rhigozum trichotomum*, Puzzle Bush *Ehretia rigida*, *Grewia flava* and *Maytenus heterophylla*. The grass layer is dominated by *Themeda triandra* and other grasses such as *Aristida diffusa* and *Stipagrostis uniplumis*. Karoo dwarf shrubs are sometimes accompanied by the development of thickets of shrubs and trees including *Rhus ciliata*, *Acacia mellifera* subspecies *destines* and *A. tortilis*. The grass becomes acidic to the north and includes *Diheteropogon amplexans*, *Andropogon schirensis* and *Brachiaria serrata*. *Aristida diffusa*, *Eragrostis lehmanniana*, *Fingerhuthia africana* and *Digitaria eriantha* become dominant in sheltered areas (Bredenkamp *et al.*, 1996).

Due to the poor grazing capacity in this region the local community requested that the revegetated areas be used as grazing fields for animals. Grasses are the dominant growth form in this area. *Heteropogon contortus* was excluded from the species mixture due to its low palatability for grazers.

# Asbestos Dumps in the Northern Cape & North-West Province Map 2 of 2



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Minerals and Energy  
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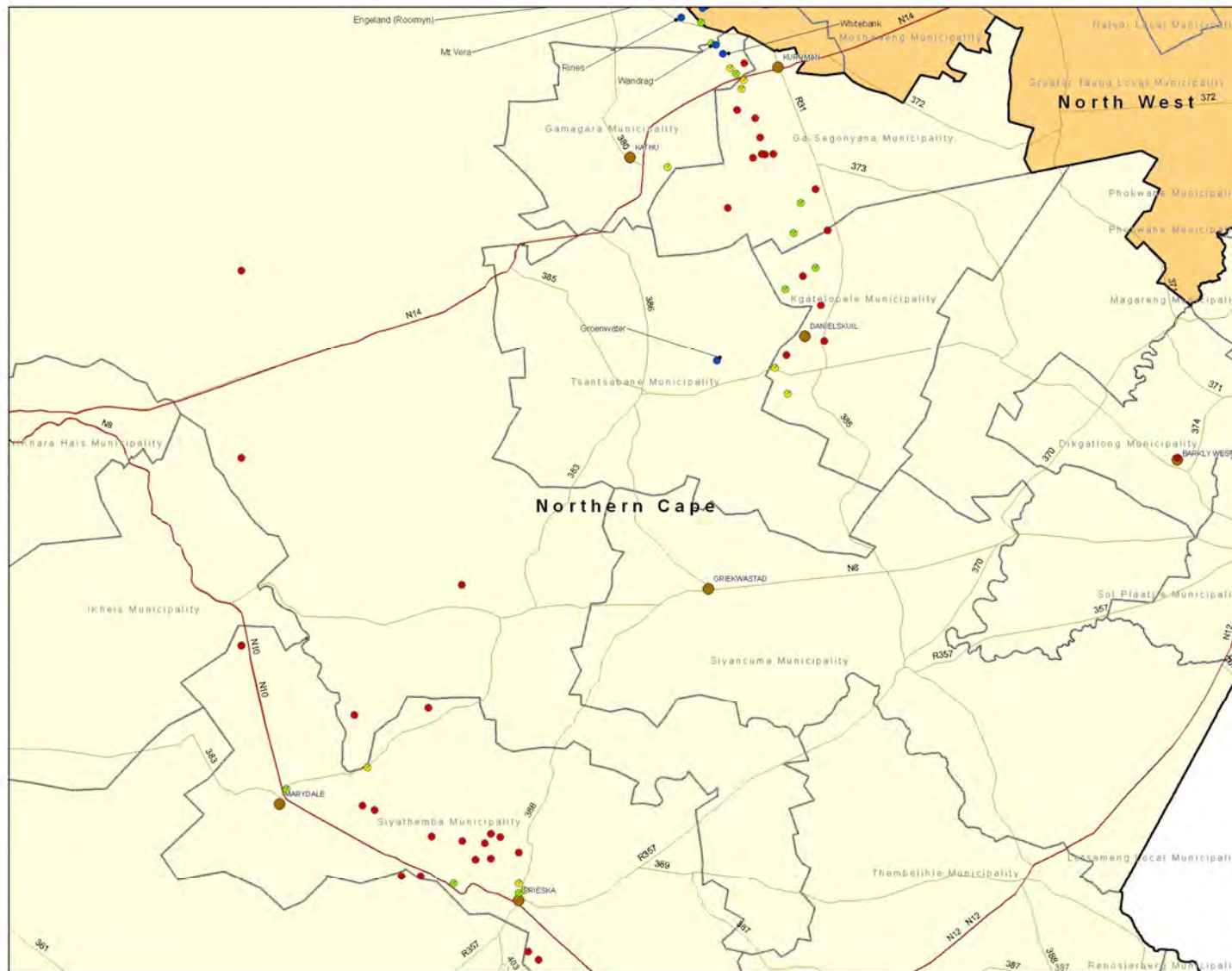
## Legend

- Monitored Asbestos Mines
- Rehabilitation Status of Asbestos Mines
  - No
  - Partial
  - Yes
- CensusData Placenames
- DWAF Rivers selection
- National Roads
- Mainroads
- Municipal Boundaries
- NW Provincial Boundary
- NC Provincial Boundary

## Locality Map



April 2008



**Figure 2-3:** Map of the distribution of asbestos mines in the Northern Cape and North-West Provinces. Previously rehabilitated dumps are indicated in green, partially rehabilitated dumps in yellow and asbestos dumps where no rehabilitation has been carried out in red points (Map 2 of 2).

## 2. QUANTITATIVE DATA

Quantitative factors assessed during the investigation included: soil cover depth; physical and chemical soil properties; analysis of microbial activity; vegetation properties and small mammal abundance. Evaluating the diverse effects of climate and management on soil function requires an integrated assessment of physical, chemical, and biological properties. It is essential that basic soil quality indicators relate to ecosystem functions such as C and N cycling (Doran and Parkin 1994).

### 2.1. Cover depth

Soil cover depth was investigated for each dump and data was recorded on field data sheets. A wayward point number marks the GPS location of the test pits. Three points were selected on the dump for test pits. A hole was dug until asbestos was visible and the depth in millimetres was measured at that specific point. The test pit was photographed and the location on the dump was sited (Redco, 2008).

### 2.2. Physical and chemical soil properties

A random sampling design was used to obtain three composite samples per site (six cores per composite sample). Samples were collected just outside of the quadrates used for the vegetation survey. Samples were clearly marked with GPS co-ordinates of the point where it was sampled as well as the date on which it was sampled. A card with all relevant information was placed inside the bag and the bag was tagged with the same information on the outside. Each sample was then catalogued on a soil sample catalogue (Redco, 2008).

Physical and chemical analyses of soil samples were conducted by an independent laboratory according to standard procedures. A 1:2 (v/v) water extraction procedure was conducted as described by Peech (1965) for the determination of the water-soluble basic cation fraction (Ca, Mg, K and Na). Quantification was done by means of atomic absorption spectrometry with a Spectr. AA-250 (Varian, Australia) using acetylene-air for determining the basic cations (Ramirez-Munoz, 1968). The exchangeable cation concentration was measured by replacement of the exchangeable cations with ammonium by adding excess ammonium acetate solution to the soil samples (Thomas, 1982) and analysed with a Spectr. AA-250 (Varian, Australia). The exchangeable-ion status of the soil samples was used to quantify the percentage base saturation, which expresses the content of exchangeable bases as a percentage of the cation exchange capacity (CEC) measured at pH 7.0 or 8.2. In equation form this becomes the following:

$$B_{sat} = \frac{X_b}{CEC} \times 100\%$$

Where: Bsat = base saturation  
X<sub>b</sub> = sum of exchangeable bases (Ca, Mg, K, and Na)  
CEC = cation exchange capacity

The anions (Cl, NO<sub>3</sub>, and SO<sub>4</sub>) were quantified by means of ion chromatography (Metrohm 761 Compact IC, Switzerland). Concentrations of NH<sub>4</sub> were quantified by means of the ammonia-selective electrode method (Banwart *et al.*, 1972). The pH value and electrical conductivity (EC) of the soil was determined in the 1:2 extract with a calibrated pH/conductivity meter (Radiometer PHM 80, Copenhagen) at 25°C after a 12-hour equilibration period with intermittent stirring.

A P-Bray 1 analysis was also conducted to quantify the P concentration as described by Bray and Kurtz (1945) and organic carbon was determined according to the Walkey-Black procedure (Walkey and Black, 1934).

### **2.3. Analysis of microbial activity**

Dehydrogenase activity is representative of microbial activity and was analysed as an indication of microbial community function. A random sampling design was used to obtain three composite samples per site (six cores per composite sample). Samples were kept at 4°C for enzymatic assays to preserve biological properties. Before analysis, consolidated soil samples were passed through a 2 mm sieve. For the determination of dehydrogenase activity, soil was kept at field water content. Dehydrogenase activity was assayed according to the method of Von Mersi and Schinner (1991) described in Alef and Nannipieri (1995). This method is based on the incubation of soil with the substrate iodinitrotetrazolium chloride (INT) at 40°C for 2 hours followed by colorimetric estimation of the reaction product iodinitrotetrazolium violet-formazan (INF).

Field moist soil (1.0 g) was weighed into a 50 ml screw-cap Erlenmeyer flask and incubated in the dark for 2 hours at 40°C with 1.5 ml Tris (hydroxymethyl)-aminomethane (THAM) buffer and 2 ml INT solution. Controls were performed with sterilised soil (1.0 g samples, autoclaved at 121°C for 20 min). The reaction was terminated by the addition of 10 ml N,N-dimethylformamide/ethanol (1:1 v/v) extraction solution and shaking at 20 min intervals for 1 hour. The soil suspension was filtered through Whatman no. 2 filter paper and the absorbance of the filtrate was measured at 464nm.

A calibration curve was prepared by pipetting 0, 1, 2, and 5 ml of INF solution into test tubes and adding 13.5 ml of extraction solution to each test tube. The calibration concentrations were 0, 100, 200, and 500 µg INF per test.

The dehydrogenase activity is expressed as  $\mu\text{g INF g}^{-1}$  dry weight  $2\text{h}^{-1}$  and calculated as follows:

$$INF = \frac{S1 - S0}{Dwt}$$

Where:  $S1$  =INF ( $\mu\text{g}$ ) of the test  
 $S0$  =INF ( $\mu\text{g}$ ) of the control  
 $dwt$  =dry weight of 1g moist soil  
INF =reported as ( $\mu\text{g g}^{-1}$  dwt  $2\text{h}^{-1}$ )

## 2.4. Vegetation properties

A vegetation survey was conducted in all three provinces. The following factors were noted for every site:

- Province
- Site name and dump number
- Aspect and slope
- Herbaceous crown cover (%)
- Herbaceous crown height (m)
- Woody crown cover (%)
- Woody crown height (m)
- Density (plants per  $\text{m}^2$ )
- Basal cover (%)
- Dominant growth form
- Impact by grazers
- Dominant trees, grasses, forbs and shrubs

Absolute crown cover and crown cover height were estimated for the herbaceous and woody layers of all the sites. Plant density and basal cover were also estimated for all sites. Different quadrature sizes were used to match the type of environment it was used on. On sites where woody species such as *Euphorbia tirucalli* were planted a quadrature size of  $4\text{m}^2$  was used because a smaller quadrature would have had a greater edge effect. Where grass and other herbaceous species were sowed, a  $1\text{m}^2$  quadrature was used (Barbour *et al.*, 1987). The different quadrature sizes were reconciled with each other by converting all cover or other area related data into hectares. The quadrates were randomly placed at three sampling sites on each of the dumps. A quantitative value (percentage) was attributed to every plot and both values (herbaceous and woody cover) were expressed as a percentage per  $\text{m}^2$  surface area (Van Rensburg *et al.*, 2004).

## 2.5. Small mammal abundance

A small mammal survey was conducted in all three provinces. The following factors were noted for every site:

- Province
- Site name and dump number
- Latitude and longitude
- Species
- Toe clip number
- Sex
- Mass (g)
- Lactating
- Pregnant

The small mammal survey was carried out in 20 visits of five consecutive days, by setting small mammal traps on one or more of the trapping grids (traps were arranged in a 5 x 5 configuration, 10 m apart) at each of the sites. Trapping sessions lasted two consecutive days and nights. Traps were checked early morning and all individuals captured were weighed, sexed and their breeding condition noted. New individuals were marked (by toe-clipping), recaptures were recorded and individuals were released. Abundance estimates were based on the number of animals marked and converted to density (individuals per hectare) using the areas covered by trapping grids, assuming no edge effect (Redco, 2008). The results showed that small mammal abundance is not a good parameter to determine the success of the rehabilitation of the dumps and the data was therefore not used.

### **3. QUALITATIVE DATA**

Qualitative factors assessed at all sites in the Limpopo, Northern Cape and North-West provinces included: the footprint area, land use, erosion or flood damage, secondary pollution, damaged water control structures and atmospheric sampling. Qualitative data gathering was more subjective in nature. Consistency was ensured by using the same person as field data collector each time.

#### **3.1. Footprint area**

The footprint area of each rehabilitated dump was surveyed to determine the boundaries of the site. Wayward point, longitude and latitude were noted every time the course changed direction while walking along the boundary of the rehabilitated area. (Redco, 2008)

#### **3.2. Land use**

The type of land use was observed while surveying the footprint area and noted on the field data sheet (Redco, 2008). Land use such as grazing for animals and agriculture was taken into consideration for 'land end use'.

#### **3.3. Erosion or flood damage**

Erosion by wind and water and the associated environmental degradation is a universal concern associated with tailings material (Hossner and Hons, 1992). Erosion is a problem specifically associated with asbestos tailings. Wind and water distribute the asbestos fibres and cause secondary pollution, which is connected to health related risks. Rain splash erosion is important on flat or gently sloping tailings, where the fine fibres are removed from micro-ridges and deposited in adjacent micro-depressions; these fibres can cover and kill emerging seedlings (Moore and Zimmerman, 1977).

Spreadsheets for each province indicate the following factors:

- the dump name on which the erosion was found;
- the type of erosion identified at that specific point on the dump;
- visible secondary pollution; and
- whether the erosion was found in the floodline.

The extent of erosion or flood line damage was visually inspected and quantified in terms of the following factors:

- extent: expressed as a percentage value (%);
- severity: nature and depth;
- potential risk: initiating further or more significant damage.

Erosion and flood damage was evaluated according to weights allocated to the following factors:

- Type: In the most severe cases of erosion such as a donga, the highest weight was allocated, and the smallest weight was given to a rill.
- Visible pollution: If there was visible asbestos pollution at the specific point of erosion a higher weight would be allocated than in the case of no visible pollution.
- In floodline: If the erosion point or type was in the floodline, it will have a higher weight than if it was not in the floodline.

### 3.4. Secondary pollution

Secondary pollution on rehabilitated tailings dumps are assessed as an indication of areas where rehabilitation was not efficient and fibres were exposed to the surface, either in water or air.

Spreadsheets for each province indicate the following factors:

- the dump name on which the secondary pollution was found;
- the area type on which the secondary pollution was found;
- Previously\_Rehab refers to whether the specific area mentioned was previously rehabilitated or not and whether additional attention was required during the follow-up monitoring programmes;
- whether the secondary pollution was found in the floodline or not (where the field data collector was uncertain, the uncertainty was indicated with a question mark).

Secondary pollution was visually identified and the site described in terms of the extent and source of the pollution (Redco, 2008). The secondary pollution was quantified by the percentage of fibre in samples according to the following calculations:

$$\% \text{ Asbestos} = \frac{W3}{W1 - W2} \times 100$$

Where: W1 is the weight of the sample in the bag;

W2 is the weight of the bag; and

W3 is the weight of the fibre extracted from the sample (Redco, 2008).

The extent of secondary pollution was evaluated according to weights allocated to factors measured:

- Area type: If secondary pollution was found on the dump the highest weight would be allocated to this area because it is the area which is monitored and was previously rehabilitated. When the secondary pollution was found in the river or stream, the second highest would be allocated to this area because more fibres would be exposed and transported downstream. If the pollution was found in the veldt or in buildings it would have a lower weight, because the asbestos fibres are not directly exposed to wind;

- Previously rehabilitated: When the secondary pollution was found in previously rehabilitated areas, a higher weight would be allocated than an area which was not rehabilitated before;
- In floodline: Secondary pollution in the floodline would have a higher weight allocated than if it was not in the floodline.

### 3.5. Water control structures

Water control structures installed on rehabilitated asbestos dumps are meant to remove excess water from the tailings and to reduce erosion of the sites, therefore limiting the risk of asbestos fibres being exposed to the surface. Water control structures included gabions, contour walls, retaining walls and speed reducers. These structures were evaluated to determine the reasons for success or failure of the structures. The following aspects were included in the evaluation to determine the reasons for success or failure of the structures: type of structure; type of construction material; condition of structure; is secondary pollution visible; the possible cause of damage and whether the structure is in the flood line.

Spreadsheets for all of the provinces indicating the following factors:

- The dump name on which the damaged water control structure was found;
- WCS\_type refers to the type of water control structure which was damaged;
- Visible\_Secpol refers to whether any secondary pollution was visible at the point where the damaged water control structure was found; and
- whether the damaged water control structure was found in the floodline or not.

The extent of the damage was measured by allocating weights to factors evaluated (Redco, 2008):

- Type of structure: When the damaged water control structure is found to be a contour wall, it will have the highest weight. This structure will not serve its purpose to reduce runoff. In time, this will increase the risk of soil erosion and therefore the risk of asbestos fibres being exposed to the surface.
- Visible pollution: Visible pollution at the point where the water control structure was damaged will have a higher weight, than if there was no visible pollution.
- In floodline: If the damaged water control structure was directly in the floodline it will have a higher weight.

### **3.6. Atmospheric sampling**

An air-sampler pump was installed to determine the air quality in the surrounding areas of the rehabilitated dumps for 8 hours during the first few weeks of the monitoring process. Results found the air to be clean and therefore the air sampling was ceased. Atmospheric sampling is not a good parameter to determine the success of the rehabilitation of the dumps because it may be difficult to determine the origin of the fibres in areas where several dumps occur (Redco, 2008).

## **4. STATISTICAL ANALYSIS**

Statistical analyses were performed using Canoco for Windows 4.5 (Biometris – Plant Research International, Wageningen, The Netherlands; Ter Braak and Smilauer, 1998). Multivariate statistics were performed to investigate the relationship between the different quantitative factors using a Redundancy Analysis (RDA) (Canoco for Windows 4.5) multivariate ordination technique. As the data comprised datasets from three provinces, a covariable descriptor was included to specify the province of origin. This enabled Canoco to factor in differences based on the three provinces and then construct an ordination model looking at the data as a whole set. Multivariate statistics were also performed on data for each of the three provinces to illustrate the relationship between the different quantitative factors and the different sites with the use of a RDA.

## CHAPTER 3: RESULTS AND DISCUSSION

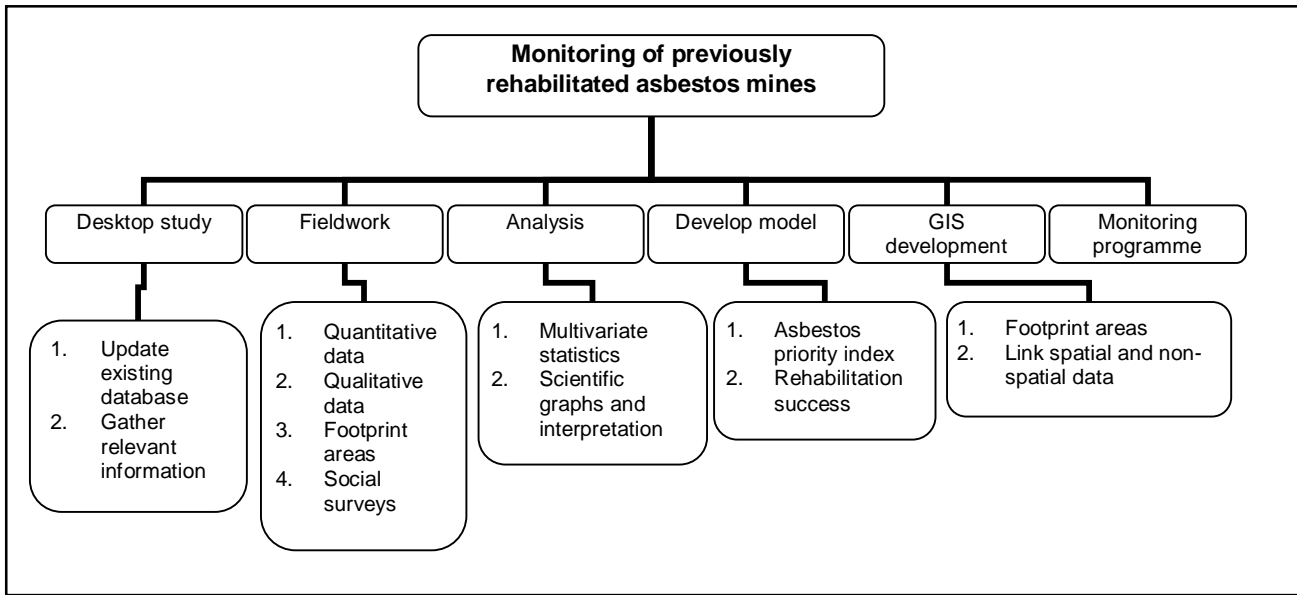
### 1. MONITORING FRAMEWORK

Only 61% of rehabilitated asbestos mines in South Africa were monitored during this study. The Department of Minerals and Energy (DME) guidelines for the maintenance, management and monitoring of rehabilitated asbestos mines in South Africa was consulted during the planning of the monitoring framework for this project. According to these guidelines, a monitoring programme can only be determined after the completion of the total monitoring framework (Figure 3-1), and if the success and failures of all the previously rehabilitated areas have been determined. Awareness and training are two very important components of a monitoring programme. Furthermore, continuous monitoring of rehabilitated sites is critical to ensure that rehabilitated sites do not degrade to their former state.

The larger monitoring project was divided into four phases that was executed over a three-year period and included the following.

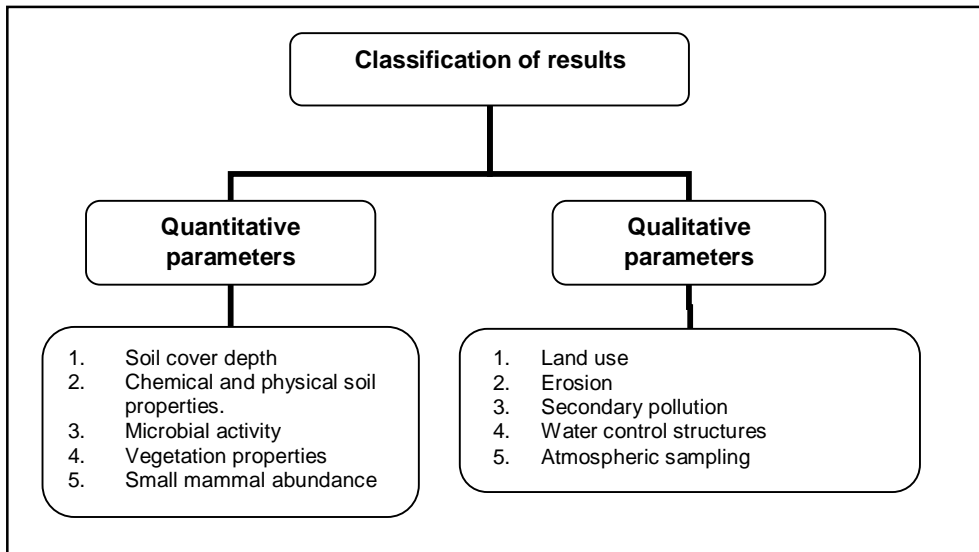
- Phase 1 – This phase formed the basis of the project. The task entailed a desktop study to update available data of all asbestos mines in South Africa.
- Phase 2 – This phase was divided into two sub-phases. Phase 2.1 consisted of a desktop study for data gathering. Phase 2.2 included a detailed assessment of quantitative and qualitative parameters (Figure 3-1).
- Phase 3 – This phase will involve the legal survey.
- Phase 4 – Transfer of liability. This phase was a long-term goal and will not be discussed in this study.

For the purposes of this study, only phase 2 was investigated and discussed in this dissertation. The project framework for the monitoring of the rehabilitated asbestos dumps details the categories that needed to be executed for the completion of the monitoring project (Figure 3-1). For the purposes of this study, only part of the first four categories were investigated and discussed. A holistic approach was applied for the evaluation of different quantitative and qualitative parameters in order to characterise the rehabilitation progress of previously rehabilitated asbestos mining sites located in three provinces. The most prominent aspects governing the rehabilitation process identified from this comprehensive assessment of the quantitative and qualitative data was applied in a Rehabilitation Monitoring Index (RMI). According to the weights assigned to each parameter for the development of the RMI the rehabilitation status of a specific site can be identified for the future development of a model.



**Figure 3-1:** Monitoring project framework for the monitoring of previously rehabilitated asbestos mines in South Africa. The project was divided into different categories, of which this investigation forms part of the first 4 categories where the quantitative and qualitative data was evaluated.

The classification of data according to quantitative and qualitative parameters that were assessed during this study is illustrated in Figure 3-2. Qualitative data included: land use; erosion; secondary pollution; water control structures and atmospheric sampling. Quantitative data included: soil cover depth; chemical and physical soil properties; microbial activity; vegetation properties and small mammal abundance.

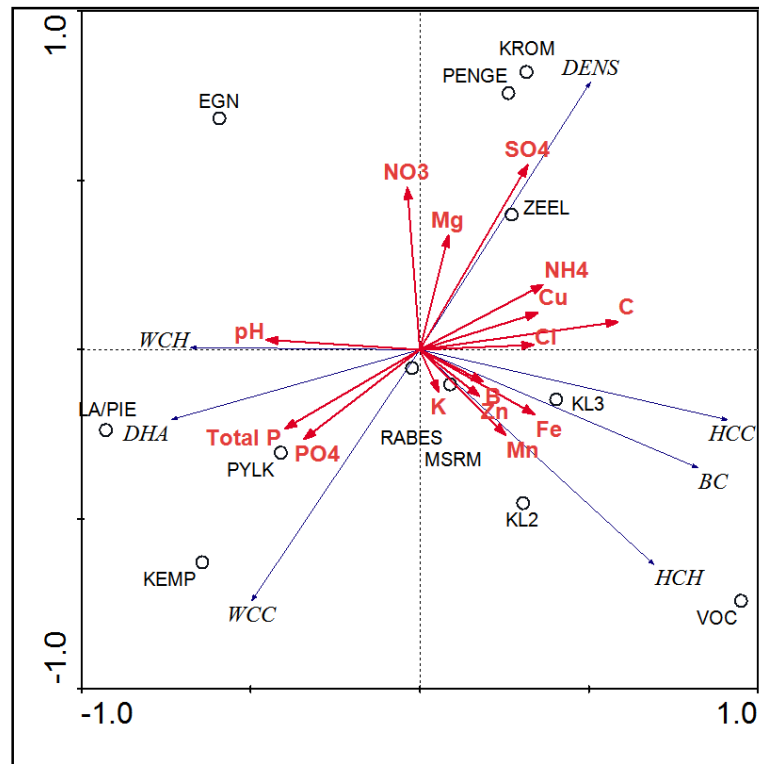


**Figure 3-2:** Framework for the classification of results into quantitative and qualitative factors.

## 2. RESULTS FOR THE LIMPOPO PROVINCE

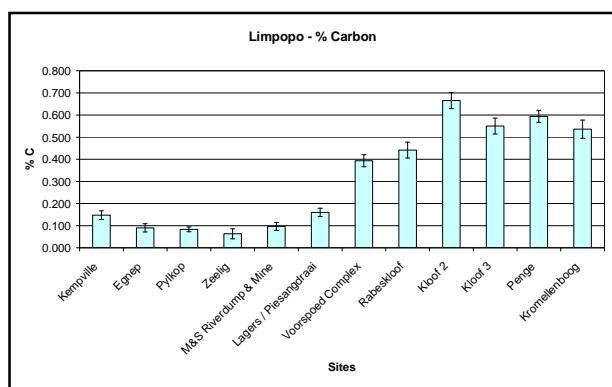
### 2.1. Quantitative results for the Limpopo Province

Twelve sites were monitored during this study in the Limpopo Province. Quantitative factors are represented in bar graphs in Appendix B.2.1. to illustrate individual values of the different factors measured. The relationship between the quantitative parameters and the different sites in the Limpopo Province based on a Redundancy Analysis (RDA) is illustrated in Figure 3-3. Sites where rehabilitation were positively influenced included Penge, Kromellenboog and Zeelig. The most prominent positive factors influencing rehabilitation in the province included pH, NO<sub>3</sub>, SO<sub>4</sub>, Mg, NH<sub>4</sub>, Cu, C and Cl. The most prominent factors influencing rehabilitation negatively in this province were, Zn, B, Fe and Mn. Sites that were influenced negatively by these factors were Kloof 2, Rabeskloof, Pylkop and Lagers/Piesangdraai. There was no relationship between dehydrogenase and percentage organic carbon but an association between dehydrogenase and woody crown cover and woody crown height was evident.

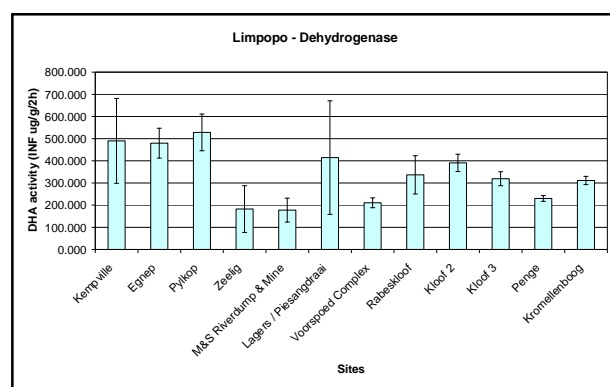


**Figure 3-3:** RDA diagram of quantitative factors for the Limpopo Province. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.498 and 0.255 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height; EGN: Egnep; KROM: Kromellenboog; ZEEL: Zeelig; KL3: Kloof 3; KL2: Kloof2; MSRM: M&S Riverdump; RABES: Rabeskloof; KEMP: Kempville; PYLK: Pylkop; LA/PIE: Lagers/Piesangdraai; VOC: Voorspoed Complex.

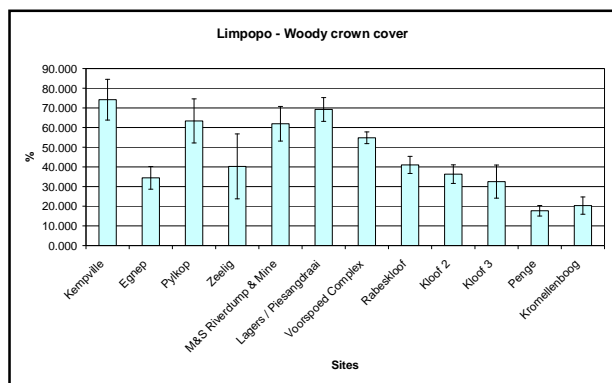
The results for percentage organic carbon, dehydrogenase (microbial) activity and woody crown cover are illustrated in Figure 3-4. In the Limpopo province the percentage organic carbon for the first six sites was low, however the dehydrogenase activity was still high in these sites. According to Appendix B.1.1 the dominant growth form on these sites were trees and consisted of *Acacia tortilis*, *Acacia karroo*, *Acacia nilotica* and *Euphorbia tirucalli*. The species diversity was low in these sites in comparison to the other sites in this province, with a high deviation in the different sites for plant density. The most abundant vegetation cover of the six sites was *Euphorbia tirucalli*. These succulent trees had a low amount of litter, thus explaining the low percentage organic carbon in these six sites. The litter of the leaves form *Acacia* species were a source of nutrients for the microorganisms and can explain why dehydrogenase activity was high in the six sites. Also the complex interactions between trees and grass (competition) and external factors such as herbivory, fire and the time of sampling influenced the percentage organic carbon in these sites.



(a) Percentage organic carbon



(b) Dehydrogenase activity



(c) Woody crown cover

**Figure 3-4:** Bar graphs for (a) percentage organic carbon, (b) dehydrogenase activity and (c) woody crown cover of sites monitored in the Limpopo province.

## 2.2. Qualitative results for the Limpopo Province

### 2.2.1. Erosion

Erosion data for the Limpopo Province are presented in Appendix C.1.1. Erosion was monitored according to the type of erosion present at a specific dump. A total of 21 points of erosion were identified in the Limpopo Province, with 61.9% of these points identified as gully erosion and the other 38.1% as donga erosion. Where secondary pollution was visible, it was mostly associated with donga erosion. 81% of these erosion points were in the floodline. The type of erosion identified on Egnep dump at Bewaarkloof in the Limpopo Province was indicated as a gully (Figure 3-5). If this problem is not addressed, erosion will advance causing large dongas and the risk of exposing asbestos fibres. Where asbestos fibres were already exposed at certain erosion points, the fibres were spread to the surrounding environment causing secondary pollution.



**Figure 3-5:** Gully erosion at Egnep dump in the Limpopo Province.

### 2.2.2. Secondary pollution

The location and type of secondary pollution at each of the sites in the Limpopo Province are presented in Appendix C.1.2. In total, 241 points of secondary pollution were identified in the Limpopo Province, in various areas: 21% on roads, 44.8% in the veldt surrounding the dump, 19.5% on the dump, 0.82% in the riverbank, 1.2% in the streams, 12% in the residential area and 0.4% in buildings. Of the twelve sites monitored, 60.6% of the secondary pollution was found on sites that were previously rehabilitated and not in the floodline.

M & S Riverdump, which is situated on the side of the river is shown in Figure 3-6. This dump was previously rehabilitated and the cover layer can be seen above the asbestos fibres. This damaged dump was a major source of secondary pollution of asbestos fibres into the river.

Asbestos fibres which were visible on the ground surface at the foot of Zeelig dump is shown in Figure 3-7. If these sources of secondary pollution are not rehabilitated, further pollution and distribution of asbestos fibres will occur.



**Figure 3-6:** Secondary pollution in the river at M & S Riverdump.



**Figure 3-7:** Loose asbestos fibres at Zeelig dump indicating secondary pollution on the dump after rehabilitation.

### **2.2.3. Water control structures**

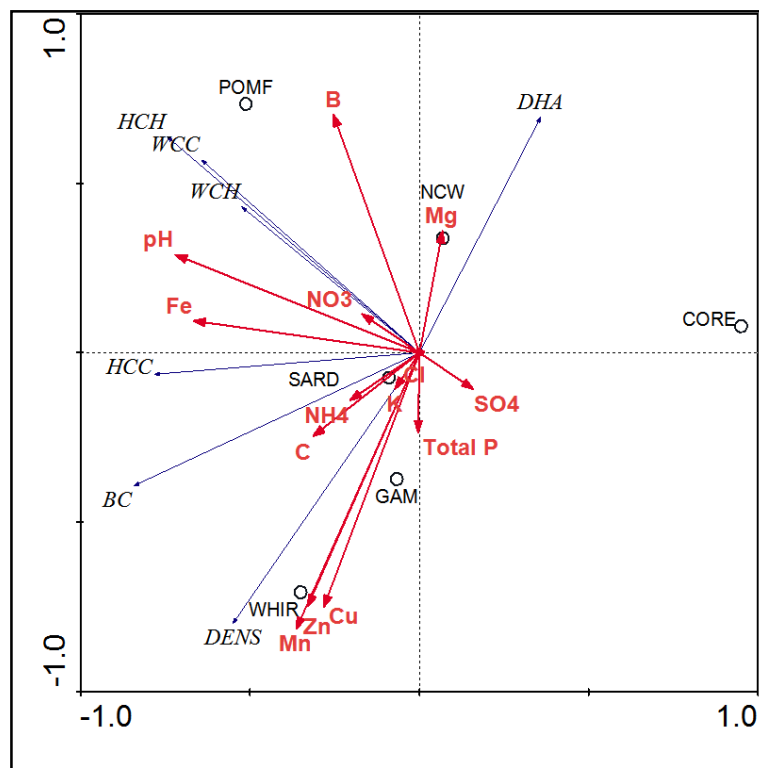
The location and type of water control structures damaged in the Limpopo province are presented in Appendix C.1.3. A total of 94 points were identified in the Limpopo Province where water control structures were damaged. Of these, 28.7% were retaining walls, 55% contour walls, 7.4% gabions, 5.3% waterways, 1.06% weirs and 1.06% channels.

Secondary pollution was also documented at these sites: 78.7% of the points had no visible secondary pollution. Of the 21.3% where secondary pollution was visible, 53.2% were located in the floodline.

### 3. RESULTS FOR THE NORTH-WEST PROVINCE

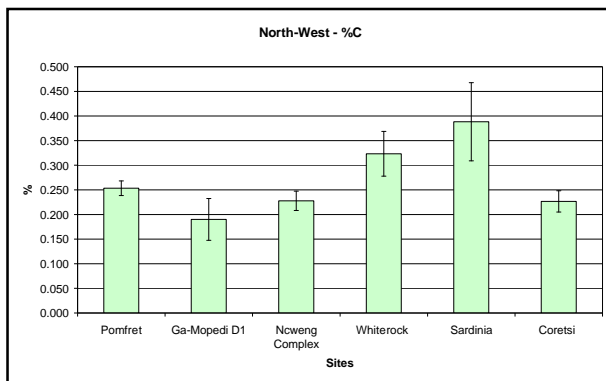
#### 3.1. Quantitative results for the North-West Province

Six sites were monitored in the North-West Province. Quantitative results are illustrated in bar graphs in Appendix B.2.2. to demonstrate individual values for the different parameters measured. The relationship between the quantitative parameters and the different sites in the North-West province based on a RDA is illustrated in Figure 3-8. Sites where rehabilitation were positively influenced included Coretsi and Ncweng. The most prominent positive factors influencing rehabilitation in the province included Fe, pH, NO<sub>3</sub>, B and Mg. The most prominent negative factors influencing rehabilitation was SO<sub>4</sub>, Total P, Mn, Zn, Cu and NH<sub>4</sub>. Sites that were negatively influenced by these factors were Ga-Mopedi, Whiterock and Sardinia.

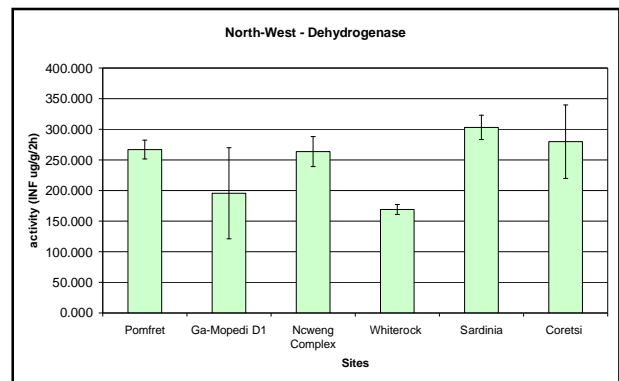


**Figure 3-8:** RDA diagram of quantitative factors for the North-West Province. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.429 and 0.315 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height; POMF: Pomfret; NCW: Ncweng; CORE: Coretsi; WHIR: Whiterock; GAM: Ga-Mopedi; SADR: Sardinia.

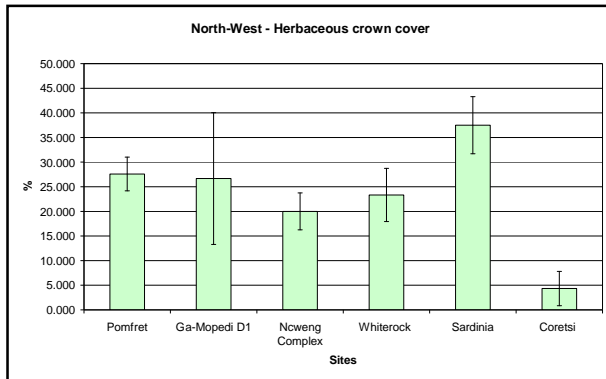
In the North-West Province (Figure 3-9) similar trends could be observed for percentage organic carbon, dehydrogenase (microbial) activity, and the basal and herbaceous cover. This trend between vegetation dynamics and microbial activity might indicate that nutrient cycles were re-established on these sites.



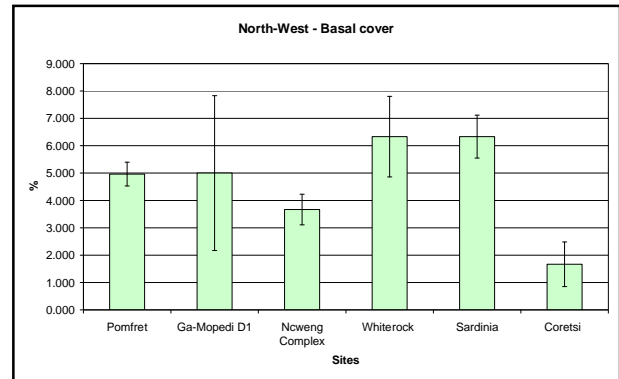
(a) Percentage organic carbon



(b) Dehydrogenase activity



(c) Herbaceous crown cover



(d) Basal cover

**Figure 3-9:** Bar graphs for (a) percentage organic carbon, (b) dehydrogenase activity, (c) herbaceous crown cover and (d) basal cover for sites monitored in the North-West Province.

According to the RDA (Figure 3-8) Whiterock was one of the negatively influenced sites. In comparison to the bar graphs for the individual factors for each province in Appendix B 2.2. it can be seen that Whiterock had the highest levels of heavy metals such as Zn and Cu. Coretsi was the only site in this province with a low plant density and species diversity. This site had a low amount of available N and the Na was higher than in the other sites.

## 3.2. Qualitative results for the North-West Province

### 3.2.1. Erosion

Only two points of erosion were identified in the North-West Province namely at the Pomfret and Whiterock dumps. Erosion data for the North-West province are presented in Appendix C.2.1. At both points gully erosion was found in the floodline. At Pomfret dump no secondary pollution was visible whereas at Whiterock secondary pollution was visible.

### 3.2.2. Secondary pollution

The location and type of secondary pollution identified at each of the sites in the North-West Province are presented in Appendix C.2.2. A total of 62 points of secondary pollution were identified in the North-West Province. Of these, 79% were located on the dump, whereas the other points were located on the roads. All of the sites where the secondary pollution was identified were previously rehabilitated and the pollution was not found in the floodline. Sample collection for secondary pollution is shown in Figure 3-10.



**Figure 3-10:** Soil sampling for secondary pollution in the North-West Province at the Pomfret dump.

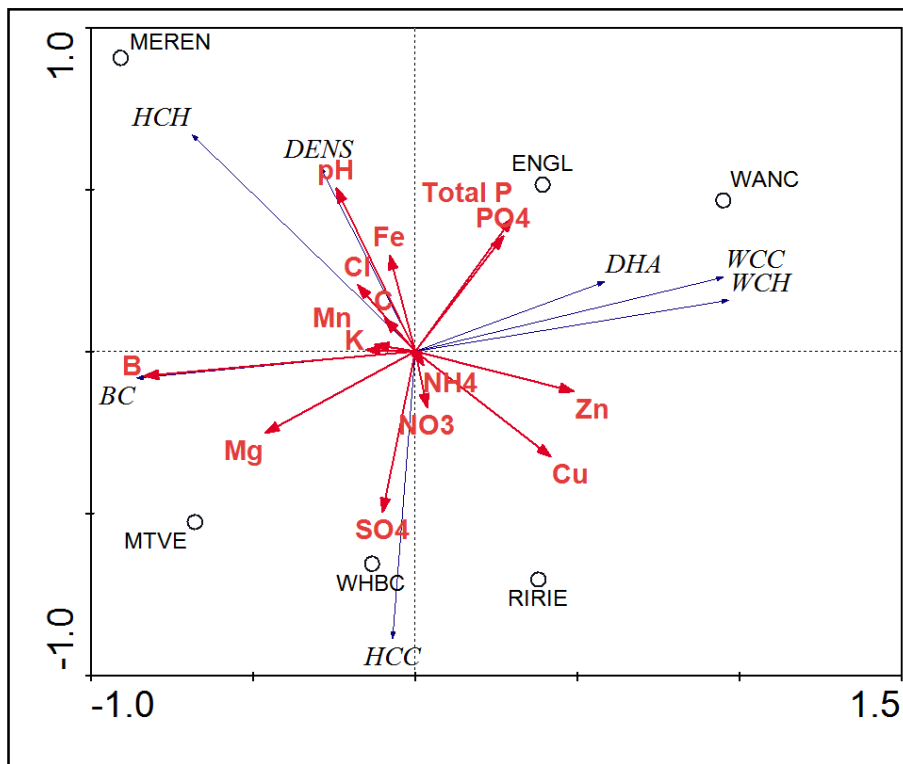
### 3.2.3. Water control structures

Fifteen damaged water control structures were identified in the North-West Province. The location and type of water control structures damaged in the North-West Province are presented in Appendix C.2.3. In total, 80% of the structures were retaining walls with the other 20% being weirs and contour walls. No secondary pollution was visible at any of the sites.

## 4. RESULTS FOR THE NORTHERN CAPE PROVINCE

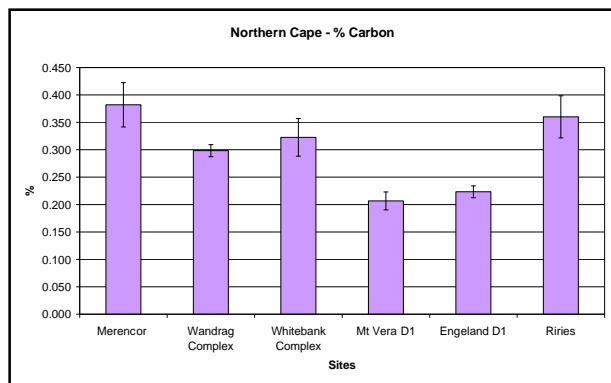
### 4.1. Quantitative results for the Northern Cape Province

Seven sites were monitored during this study in the Northern Cape Province and the quantitative results are presented in Appendix B.2.3. The relationship between the quantitative parameters and the different sites in the Northern Cape Province based on a RDA is illustrated in Figure 3-11. Sites where rehabilitation were positively influenced included Mt Vera, Whitebank complex and Riries. The most prominent positive factors influencing rehabilitation in the province included herbaceous crown cover, Mg and  $\text{NO}_3$ . Sites that were influenced negatively by factors such as  $\text{PO}_4$  were Engeland and Wandrag complex.

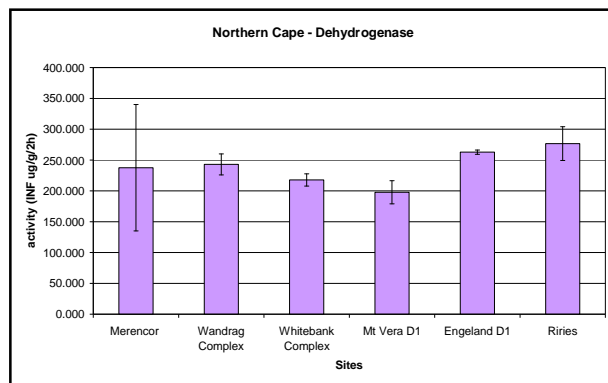


**Figure 3-11:** RDA diagram of quantitative results for the Northern Cape Province. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.498 and 0.242 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height; MEREN; Merencor; ENGL: Engeland; WANC: Wandrag Complex; RIRIE: Riries; WHBC: Whitebank Complex; MTVE: Mt Vera.

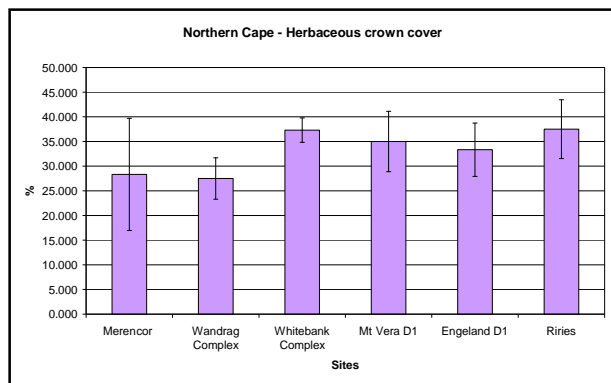
The rationale for rehabilitation in the Northern Cape Province was to establish vegetation (mostly grasses) that can be used for grazing of farm animals. According to Figure 3-12 basal cover and herbaceous crown cover were well established in all of the sites. Seeding mixtures included seeds from the province and therefore the vegetation was well adapted to the arid environment. This is also reflected in the percentage organic carbon and dehydrogenase (microbial) activity for the various sites.



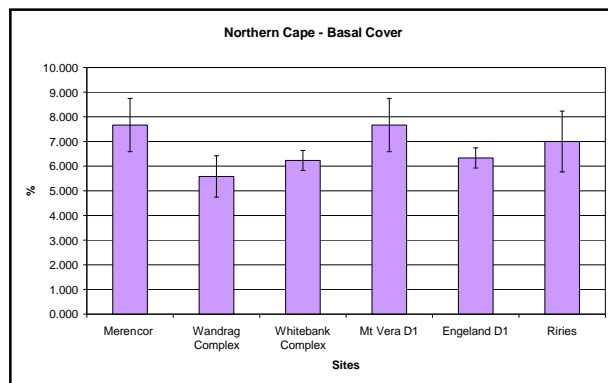
(a) Percentage organic carbon



(b) Dehydrogenase activity



(c) Herbaceous crown cover



(d) Basal cover

**Figure 3-12:** Bar graphs for (a) percentage organic carbon, (b) dehydrogenase activity, (c) herbaceous crown cover and (d) basal cover for sites monitored in the Northern Cape Province.

## **4.2. Qualitative results for the Northern Cape Province**

### **4.2.1. Erosion**

Erosion data for the Northern Cape Province is presented in Appendix C.3.1. Thirteen points of erosion were identified in the Northern Cape Province, with 76.9% of points identified as donga erosion, 15.3% as gully erosion and at one point a sinkhole was identified. No clear association between the type of pollution and the presence of secondary pollution was apparent. At 61.5% of the points, secondary pollution was visible and in most of the points, the erosion was identified in the floodline.

### **4.2.2. Secondary pollution**

The location and type of secondary pollution identified in the Northern Cape Province are presented in Appendix C.3.2. . A total of 127 points of secondary pollution were located in the Northern Cape Province. Of these points, 62% were located on the dumps, while the other points of secondary pollution were located in the veldt surrounding the dumps as well as on the roads. At 60% of the points, secondary pollution was visible and most were not located within the floodline.

### **4.2.3. Water control structures**

In the Northern Cape Province, a total of 34 damaged water control structures were identified. The location and type of water control structures damaged in this province are presented in Appendix C.3.3. Of these points, 58.8% were contour walls, 14% retaining walls, 8% waterways and another 8% were weirs. No secondary pollution was visible at any of the points where the damaged water control structures were found.

Damaged water control structures are shown in Figures 3-13 and 3-14. Damage can occur due to the activities of people and animals or through natural causes such as floods. A damaged gabion where the top wires forming the lids were stolen, is shown in Figure 3-13. A contour wall damaged by people and animals walking over the specific point, thereby creating a path and damaging the structure, is shown in Figure 3-14.



**Figure 3-13:** Damaged waterway in the Northern Cape Province



**Figure 3-14:** Damaged retaining weir 1 in the Northern Cape Province at the Kuruman-East asbestos mine.

A wingwall anchor structure of a gabion retaining wall is shown in Figure 3-15. These structures were used on the Kuruman-East asbestos mine in the Northern Cape Province. This wingwall anchor structure was possibly damaged by floods. Backfill around the wingwall was eroded making the structure unstable and not effective in its design. An example where the gabion structure was damaged by floods, as well as the apron on the overflow side of the retaining weir is shown in Figure 3-15. The result is that runoff is concentrated with increased flow velocities that can cause scouring. It is directed towards the backfilled or covered asbestos dumps and can therefore expose the covered asbestos dump.

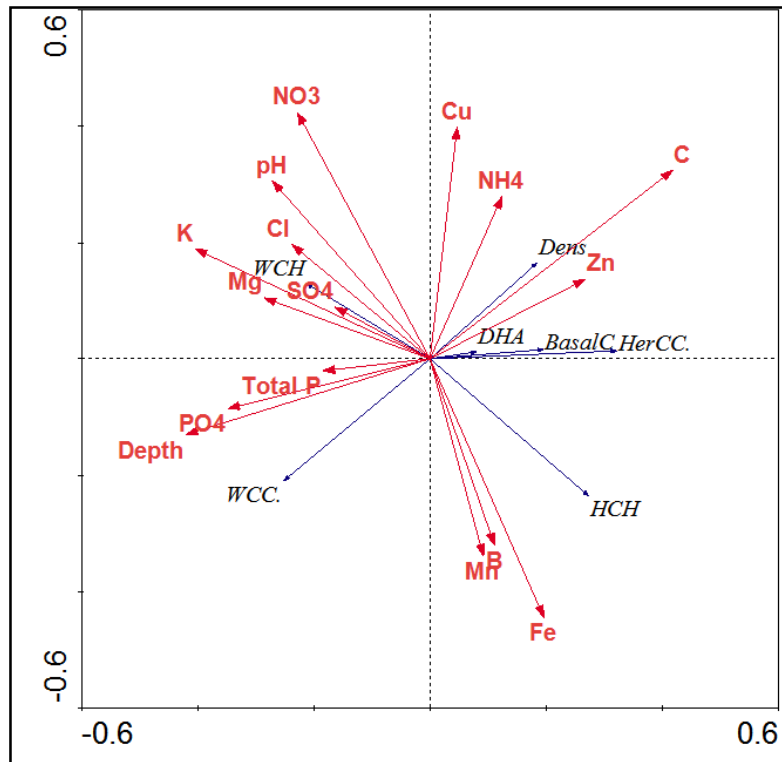


**Figure 3-15:** Damaged retaining weir 2 in the Northern Cape Province, where the gabion structure was damaged by floods.

## CHAPTER 4: GENERAL DISCUSSION AND CONCLUSIONS

### 1. DISCUSSION OF QUANTITATIVE RESULTS

Multivariate statistical analyses (Figure 4-1) were performed on all data from rehabilitated sites of all three of the provinces to determine the most prominent quantitative parameters influencing the progress of rehabilitation at the various sites.



**Figure 4-1:** RDA diagram illustrating the quantitative results for all three provinces. A co-variable descriptor to specify the province of origin was included. Red vectors represent the environmental parameters and blue vectors the vegetation properties and dehydrogenase. Eigenvalues for the first two axes were 0.052 and 0.021 respectively. Key to abbreviations: DHA: dehydrogenase; Dens: density; BasalC: basal cover; HerCC: herbaceous crown cover; HCH: herbaceous crown height; WCC: woody crown cover; WCH: woody crown height.

The RDA was applied to determine the parameters that had the most prominent influence on the rehabilitation of asbestos mines. The length of the arrows in the RDA indicates the importance of the specific parameter. Weights were allocated to each parameter according to its significance and impact (Table 4-1). The parameter with the longest arrow will have the highest weight in the quadrant. Sites were excluded from the RDA diagram to prevent overcrowding of the figure. According to the RDA, parameters can be divided into categories as described in Table 4-1 in order of their importance for rehabilitation of asbestos mines. A discussion of the importance of various quantitative parameters in terms of rehabilitation is indicated in Table 4-2 to validate the weights allocated to the different parameters as indicated in Table 4-1. The four categories into which the different parameters were divided, based on the RDA, included:

- **Success parameters** were the parameters that had the highest influence on rehabilitation of asbestos mines and must be attended to in rehabilitation of asbestos mines.
- **Essentials to be addressed** were parameters with a high influence on the rehabilitation of asbestos mines, they are of great significance in the rehabilitation process and must be addressed.
- **Reasons for failure** were parameters that contributed to the failure of rehabilitation.
- **Non-distinguishable entities** were parameters that had no significant effect on rehabilitation.

Therefore, the order from the most to least important is: success parameters > essentials to be addressed > reasons for failure > non-distinguishable entities.

**Table 4-1:** Table of quantitative weights assigned to the different quantitative parameters. Parameters with the highest weight (expressed as a percentage) had the greatest impact on the rehabilitation process.

<b>Essentials to be addressed</b> (Top left): <ul style="list-style-type: none"> <li>• NO<sub>3</sub></li> <li>• pH</li> <li>• Cl</li> <li>• SO<sub>4</sub></li> <li>• K</li> <li>• Mg</li> <li>• Woody crown height</li> </ul>	<b>25%</b>  20 15 14 10 18 13 10	<b>Success parameter</b> (Top right): <ul style="list-style-type: none"> <li>• Cu</li> <li>• NH<sub>4</sub></li> <li>• C</li> <li>• Density</li> <li>• Zn</li> <li>• Dehydrogenase activity</li> <li>• Basal cover</li> <li>• Herbaceous crown cover</li> </ul>	<b>50%</b>  17 13 18 10 11 10 10 11
<b>Non-distinguishable entities</b> (Bottom left): <ul style="list-style-type: none"> <li>• Total P</li> <li>• PO<sub>4</sub></li> <li>• Depth</li> <li>• Woody crown cover</li> </ul>	<b>10%</b>  10 20 50 20	<b>Reasons for failure</b> (Bottom right): <ul style="list-style-type: none"> <li>• Herbaceous crown height</li> <li>• Fe</li> <li>• B</li> <li>• Mn</li> </ul>	<b>15%</b>  20 50 10 20

**Table 4-2:** Description of different parameters influencing rehabilitation.

Quantitative data	Reasons why parameter is of significance for rehabilitation.	References
<b>1. Essentials to be addressed</b>		
Mg	Mg is a metallic constituent of Chrysotile and Amosite. Nutrient imbalances may have been present because Mg occurred in extremely high concentrations compared to Ca and K. Low Ca:Mg and K:Mg ratios may restrict plant growth. Ca added to the tailings in solution will be rapidly replaced by Mg; the replacement of K is less effective. There are three ways in which Ca and/or Mg levels can affect vegetation: (a) Deficiency of Ca; (b) toxicity of Mg; or (c) unfavourable Ca:Mg ratio. An inverse relationship exists between Mg, Al, B, Co, Mn, P and Na. It was concluded that Mg uptake might have an antagonistic effect and reduce the uptake of other important minerals. Ni toxicity is reduced in the presence of plant nutrients such as N, K and Mg.	Hossner and Hons, 1992; Proctor and Woodell, 1975; Moore and Zimmerman, 1977; Van Rensburg and Pistorius, 1998.
NO <sub>3</sub>	Tailings are almost universally deficient in N. N is absorbed by plants in both NO <sub>3</sub> and NH <sub>4</sub> forms. The application of NO <sub>3</sub> containing fertilisers can stimulate the accumulation of macro-elements particularly Ca and therefore could assist in alleviating Ca deficiency in plants where its uptake is depressed by Mg excess.	Hossner and Hons, 1992; Van Rensburg <i>et al.</i> , 2004; DeGroot <i>et al.</i> , 2005; Ellery and Walker, 1986.
pH	Addition of gypsum/lime to lower pH. Increasing Ca reduces toxicity of heavy metals.	Proctor and Woodell, 1975.
Cl	Due to both the high Mg and Cl contents in the soil, there is a probability that it could form MgCl <sub>2</sub> , which if absorbed by plants, leads to chlorosis as well as the rapid development of brown necrotic lesions, because the metabolism of the plant is disturbed. High Cl content could be responsible for the low P concentrations in plant tissue because of Cl accumulation.	Van Rensburg and Pistorius, 1998.
K	High Mg concentrations are often a cause of poor K status and inhibit plant growth when accompanied by low K levels. K have been reported to reduce the toxicity of Ni.	Proctor and Woodell, 1975; DeGroot <i>et al.</i> , 2005; Van Rensburg and Pistorius, 1998.

Quantitative data	Reasons why parameter is of significance for rehabilitation.	References
<b>2. Success parameters</b>		
NH <sub>4</sub>	Tailings are almost universally deficient in N. N is absorbed by plants in both NO <sub>3</sub> and NH <sub>4</sub> forms.	Hossner and Hons, 1992; Van Rensburg <i>et al.</i> , 2004; DeGroot <i>et al.</i> , 2005; Ellerly and Walker, 1986.
Cu	Heavy metals reduce enzymatic activity and the microbial and microfauna populations in soils. Higher stability of Cu complexes favours the leaching of Ni. Particularly elevated concentrations of Ni, Cr and Co are known to occur. The interaction with other heavy metals and micro-elements such as Fe, the influence of soil pH on heavy metal solubility and organic matter content makes Ni availability a complex process. One of the primary factors affecting Ni uptake in plants is the pH. By increasing the soil pH with liming, a significant reduction of Ni occurs. pH also influences the precipitation of Ni with other compounds, such as phosphates. High Mg concentrations could ameliorate the toxic effect of high Ni availability.	Hossner and Hons, 1992; Proctor and Woodell, 1975; Van Rensburg and Pistorius, 1998.
Zn	High pH leads to Zn and Fe deficiency.	Pistorius, 2006.
%C	Organic matter is critical to bind excessive micro-elements. Increases water-holding capacity, aggregation of soil and nutrient status. Organic matter improves the physical nature of the rooting medium by: <ul style="list-style-type: none"> <li>• increasing water and nutrient holding capacity,</li> <li>• provision of plant nutrients in a slow-release form, facilitating vegetation establishment,</li> <li>• complexing of heavy metals, thereby reducing phytotoxicity.</li> </ul> The presence of organic matter in soils can also reduce Ni toxicity by removing this metal as a chelate complex.	Van Wyk, 1994; Pascual <i>et al.</i> , 2000; Tordoff <i>et al.</i> , 2000; Van Rensburg and Pistorius, 1998.
Microbial activity	Dehydrogenase activity depends on the metabolic state of soil microorganisms and it is used as an indicator of microbial activity in soils. In areas where soil conditions are marginal, the function of soil microbes is critical for supporting plant growth and revegetation success. Plays a fundamental role in the establishment of biogeochemical cycles and are involved in the formation of the soil structure.	Ros <i>et al.</i> , 2003; Pascual <i>et al.</i> , 2000; DeGroot, <i>et al.</i> , 2005.

Quantitative data	Reasons why parameter is of significance for rehabilitation.	References
<b>3. Reasons for failure</b>		
Fe	Main component of Amosite and Crocidolite. Ni toxicity involves an induced Fe deficiency; however due to Fe being a main component of Amosite and Crocidolite, tailings would be enriched in Fe and this together with the addition of organic matter makes Ni availability a complex process.	Van Rensburg <i>et al.</i> , 2004; Proctor and Woodell, 1975; DeGroot, <i>et al.</i> , 2005.
Mn	Intensification of Ni toxicity symptoms in plants caused by high levels of Mn. Ni in soils with high levels of soluble iron may be less toxic and in soils with high levels of soluble Mn more toxic. Mn functions as an enzyme activator in biological systems and is not very soluble under alkaline conditions. Mn precipitates as a hydroxide at high pH values. High Mg concentrations in the soils can reduce Mn uptake owing to the competition between the ions of these metals.	Proctor and Woodell, 1975; Van Rensburg and Pistorius, 1998.
B	Low Ca may exacerbate the phytotoxicity of boron and may cause the build-up of iron in the plant biomass to phytotoxic concentrations. The uptake of K ions is many times higher in plants with a good B status. Conversely, high K availability can intensify even if B is deficient, unlike Ca it cannot reduce B toxicity, seeming rather to intensify it. There is a positive correlation between B uptake and both Mg and K content in grasses. B has been found to be deficient in most asbestos-rich soils.	Van Rensburg <i>et al.</i> , 2004; Van Rensburg and Pistorius, 1998.

Quantitative data	Reasons why parameter is of significance for rehabilitation.	References
<b>4. Non-distinguishable entities</b>		
Total P	Acidification may improve the solubility and availability of P and other plant nutrients that are in short supply, but the benefit may be offset by increased heavy metal toxicity. Phosphorus deficiencies are common. Iron which is abundant combines with P to form unavailable and insoluble phosphates. Similarly P interactions with trace metals are also a plausible explanation for deficiencies in available P.	Ellerly and Walker, 1986; Van Rensburg and Pistorius, 1998.
PO <sub>4</sub>	Soluble or available phosphorus. Mg improves the uptake of phosphorus in plants.	Berger, 1968.
Vegetation density	Where the re-establishment of natural plant communities is the objective, success is recorded on the basis of both the cover vegetation achieved and its composition.	Coaltech, 1997.
Basal cover	Basal cover is the measure of the proportion of ground, at root level that is covered by vegetation and more specifically, by the rooting portion of the cover plants.	Coaltech, 1997.
Woody crown height	Important for the rain drop erosion effect. The foliage of plants breaks raindrops into smaller particles which decreases the effect of erosion.	Redco, 2008.

## 2. DISCUSSION OF QUALITATIVE RESULTS

Qualitative data is data that is difficult to measure, count, or express in numerical terms but describes the characteristics of an object or phenomena in detail, whereas quantitative data defines in numbers. In this study the qualitative data carries less weight, since it is biased and based on assumptions. However, the data is of great importance because it provides a detailed description of the sites, and this information is complementary to quantitative data. Furthermore, certain important aspects that may contribute to the success of rehabilitation can only be expressed in qualitative terms. The qualitative data was not measured and analysed in laboratories and therefore weights were assigned to each parameter (Table 4-3). Weights were assigned according to the importance of the parameter relating to rehabilitation success. Each criteria of a parameter was assigned a certain factor out of a hundred, which was then calculated to a total weight for each parameter measured, expressed as a percentage value.

**Table 4-3:** Weights assigned to qualitative parameters to evaluate rehabilitation practices.

Data	Factor (%)	Combined Weight (%)	Total Weight (%)
<b>Qualitative Data</b>			
<b>1. Erosion</b>			<b>30</b>
1.1 Type		50	
Donga	45		
Gully	35		
Rill	20		
1.2. Visible pollution		20	
Yes	60		
No	40		
1.3. In floodline		20	
Yes	60		
No	40		
<b>2. Secondary pollution</b>			<b>55</b>
2.1 Area type		50	
Dump	35		
River	25		
Road	15		
Veld	10		
Building Other	10		
	5		
2.2 Previously rehabilitated		30	
Yes	60		
No	40		
2.3 In floodline		20	
Yes	60		
No	40		

Data	Factor (%)	Combined Weight (%)	Total Weight (%)
<b>Qualitative Data</b>			
<b>3. Water control structure</b>			<b>15</b>
3.1 Type of structure		50	
Contour wall	40		
Retaining wall	15		
Waterway	15		
Speed reducer	15		
Weir	10		
Other	5		
3.2 Visible pollution		30	
Yes	60		
No	40		
3.3 In floodline		20	
Yes	60		
No	40		

Total Weights were assigned as percentages to qualitative parameters as indicated in Table 4-3. Erosion had the second highest weight because its impact can cause exposure of the covered asbestos in previously rehabilitated areas. Secondary pollution had the highest weight because it describes the presence of asbestos fibres that are exposed to the surrounding environment and pose a threat to people and animals. Water control structures had the lowest weight, since damaged structures will not always lead to the exposure of asbestos, and its main purpose may be to manage stormwater runoff.

### 3. SITE SCORING AND CALCULATION OF THE RMI

The much publicised problem with major asbestos pollution and related health issues in South Africa has called for action and in 2007 the Rehabilitation Prioritisation Index (RPI) was developed. The aim of this prioritisation index was to establish a scientifically based sequence according to which polluted asbestos mines in South Africa ought to be rehabilitated. The RPI determines the need for rehabilitation of asbestos pollution by quantifying the risk associated with a specific pollution site. The database was developed in Microsoft Access and both quantitative and qualitative data were used for the calculation of the RPI value. Qualitative data included variables such as demographic, geographic, safety and aesthetical considerations that was difficult to quantify and was subjective depending on the experience of the individual who collected the information. The RPI contains information for 113 mines and 144 mine dumps from 4 provinces in South Africa. Each mine was assessed according to the different factors and weights was assigned to calculate the RPI value. The cost of rehabilitation for each mine as well as the total cost of rehabilitation of all the mines in a specific province can be determined from the database. The use of the RPI has been implemented by the Department of Minerals and Energy (DME) as part of an integrated and co-operative approach towards the rehabilitation of the asbestos mines. In accordance with this index, 144 derelict and ownerless asbestos mine dumps have been identified, of which only 84 still needed to be rehabilitated at that time (Van Rensburg *et al.*, 2008).

After the rehabilitation of the asbestos mines, it was necessary to determine the success of the rehabilitation measures applied on the asbestos dumps through a monitoring programme as stipulated in the DME guidelines for the maintenance, management and monitoring of rehabilitated asbestos mines in South Africa. Continuous monitoring and maintenance of rehabilitated sites is essential to ensure the sustainability of rehabilitation. The objective of monitoring is to ensure that the agreed rehabilitation process remains on track. Asbestos mines that were already rehabilitated, or partially rehabilitated was monitored to determine the success or failures of the rehabilitation of these mines and to develop the Rehabilitation Monitoring Index (RMI). The aim of the RMI was to evaluate the stability of previously rehabilitated areas by means of multivariate statistics and to determine the main parameters that had the greatest impact on the rehabilitation of the sites. The assessment of the various ecological aspects of previously rehabilitated areas by means of statistical analyses and the assignment of weights to different parameters surveyed will be used in the development of the RMI from which the rehabilitation status of a specific site can be calculated and structured according to a range distribution.

To calculate the RMI value, the sum of the quantitative and qualitative data was calculated. Qualitative data was a more subjective type of data gathering, and assumptions were made for the assignment of weights. In Figure 4-2 a framework for the development of the RMI is indicated with the weights allocated to the different criteria of the quantitative and qualitative parameters. The overall quantitative data component is assigned a weight of 75% and the qualitative data component a weight of 25%. The quantitative data has a higher weight because it is numerical data that is accurate and analysed. An example of the calculation for erosion

is indicated in Table 4-5. If donga erosion was found on a site it was indicated by a 3, showing that it had a higher impact than gully (2) or rill (1) erosion. To calculate the calculated value (Calc\_value), the value of the “donga column” was multiplied by the weight allocated to these criteria.

**Table 4-4:** Example of how the RMI values were calculated for erosion type in the Northern Cape Province.

Northern Cape		Weight	50					Max:	6750	
Waypoint	DUMP_NAME	EROSION_TYPE								
		Donga	Calc_v alue	Gully	Calc_ value	Rill	Calc_ value	Calc_total	Weighed %	Normalised
862	Ettriks	3	135		0		0	135	6750	1
232	Mt Vera		0	2	70		0	70	3500	0.52
560	Kuruman East	3	135		0		0	135	6750	1

Values had to be normalised in order to be able to compare different parameters to each other for the development of the RMI:

- Weighed%: (Calc\_Total)\* Weight

Weighed% is the percentage value of the weight for the total for a specific parameter. The calculated total for a parameter was multiplied by the weight for that specific parameter. For example as indicated in Table 4-5. The Calc\_Total of Erosion Type was multiplied by 50.

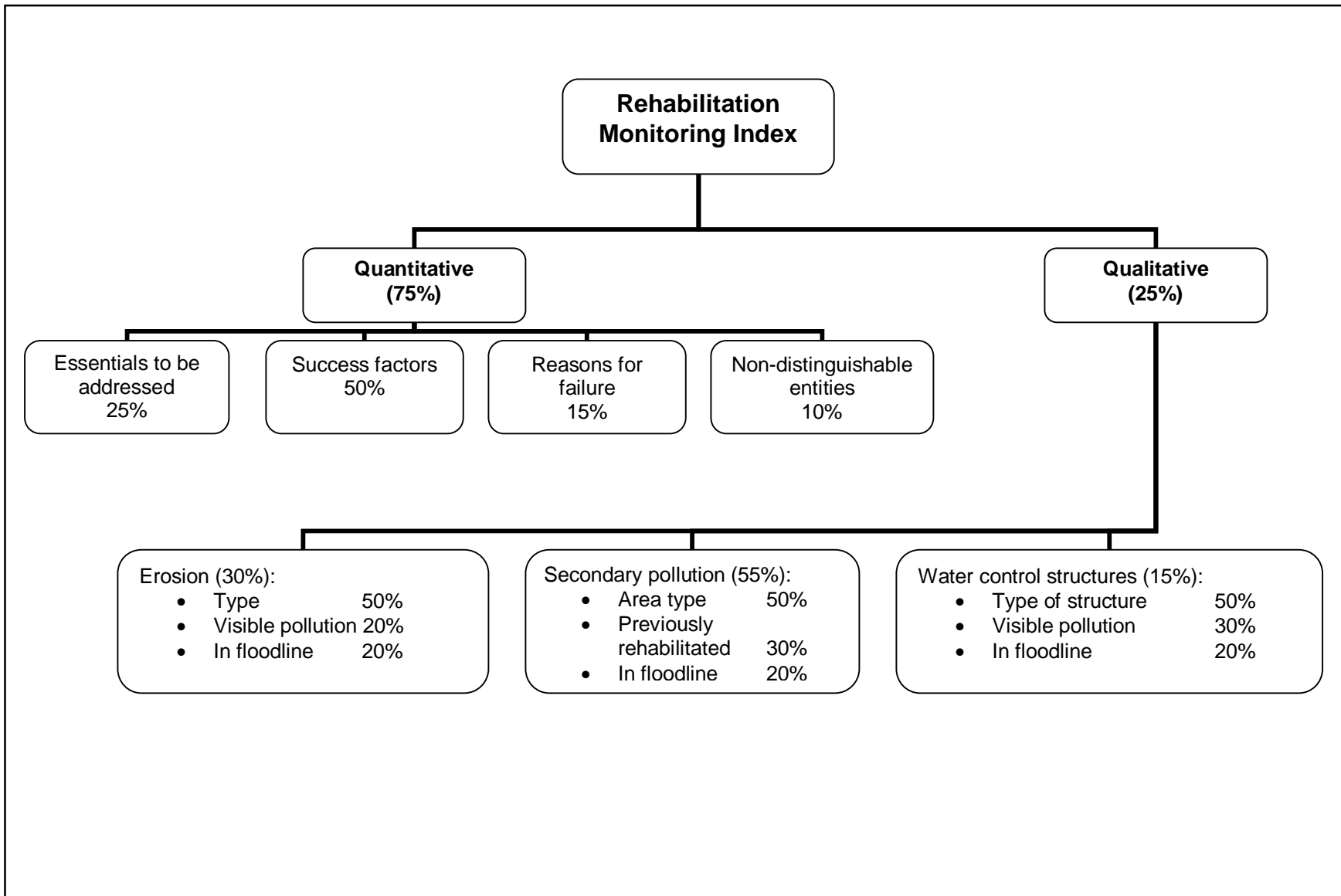
- MAX: [=MAX (first weighed% value in dataset: last weighed% value)]

The maximum value for the weighed% for a specific parameter was calculated by finding the highest value in the field of the database.

- Normalised: [=weighed% at each waypoint/MAX]

In order to attain a normalised value to facilitate comparison of different parameters, the weighed% for a specific parameter was divided by the maximum value of the whole dataset for each waypoint.

Calculations were done for all the erosion criteria, and the sum of the normalised values of these criteria of erosion gave a total for the erosion parameter. These calculations were also applied to the other qualitative and quantitative parameters. The sum of the normalised values calculated for each of these parameters, was condensed to a total of 25% and 75%, respectively for each of the two categories (Figure 4-2). The RMI values were calculated as the sum of the quantitative and the qualitative totals.



**Figure 4-2:** Framework for the development of the RMI values for asbestos rehabilitation indicating the weights allocated to the different criteria of qualitative and quantitative parameters.

A distribution list of the mines according to their RMI values is indicated in Table 4-5. Rehabilitated sites were divided into groups according to their RMI values. Dumps with high RMI values were therefore poorly rehabilitated and dumps with low RMI values were adequately rehabilitated. Three groups were identified to obtain a distribution range of the RMI. The ranges were:

- Highest RMI values (25%) - dumps that were poorly rehabilitated
- Intermediate RMI values (50%) - dumps that were averagely rehabilitated
- Lowest RMI values (25%) – dumps that were well rehabilitated

**Table 4-5:** Distribution range list of mines according to RMI values. Sites with the highest values are in the most need of rehabilitation.

Province	Site	RMI
	<b>Highest RMI values (25%)</b>	
Limpopo	Lagers/Piesangdraai	1.847
Limpopo	Rabeskloof	1.841
Limpopo	Voorspoed	1.820
Limpopo	Egnep	1.801
Limpopo	Pylkop	1.794
Limpopo	Kloof3	1.755
	<b>Intermediate RMI values (50%)</b>	
North-West	Pomfret	1.737
Limpopo	Kempville	1.718
Northern Cape	Wandrag complex	1.691
Limpopo	Kloof2	1.686
North-West	Sardinia	1.684
Northern Cape	Groenwater	1.662
Limpopo	Kromellenboog	1.658
Northern Cape	Engeland	1.656
Limpopo	Penge	1.628
North-West	Whiterock	1.601
Northern Cape	Merencor	1.595
Northern Cape	Whitebank complex	1.592
North-West	Ga-Mopedi	1.585
	<b>Lowest RMI values (25%)</b>	
North-West	Ncweng complex	1.533
Northern Cape	Mt Vera	1.529
Limpopo	Zeelig	1.502
Northern Cape	Riries	1.492
North-West	Coretsi	1.296
Limpopo	M&S Riverdump	1.082

According to these ranges, dumps with the highest RMI values will have the most need for monitoring and follow-up rehabilitation and dumps with the lowest RMI values the least. The list (Table 4-5) shows that asbestos mines in the Limpopo Province were unsuccessfully rehabilitated with the highest RMI values. This corresponds with the qualitative data measured and described in Chapter 3. The Limpopo Province had the highest incidence of erosion, secondary pollution and damaged water control structures of all three provinces, which is due to the higher rainfall in this province and other factors such as topography and the history of rehabilitation on the sites.

Examples as to why sites grouped into certain ranges according to the distribution list (Table 4-5):

- Rabeskloof in the Limpopo Province is classified as an unsuccessfully rehabilitated site. The main reason for this was the high Mn, Zn and Fe values. These are reasons identified in Table 4-2 as reasons for failure of rehabilitation. Rabeskloof had 15 points of both secondary pollution and where the water control structures were damaged. The RDA for the Limpopo Province (Figure 3-3) shows an association of these problem parameters with the Rabeskloof site.
- Wandrag complex sites grouped in the intermediate RMI value range. The main reason for the rehabilitation not being as successful as what was hoped for, was the high number of secondary pollution points in this site.
- Coretsi was located in the North-West Province and formed part of the lowest RMI value range. The question however arises as to what distinguishes Coretsi from other mines in this group, such as Zeelig in terms of the specific RMI value. In terms of the physical and chemical analyses, the only significant difference was that Zeelig had a higher Mn value than Coretsi. Mn was identified as one of the main reasons for failure of rehabilitation but when taking the qualitative factors into consideration, Coretsi had one point of damaged water control structures and seven points where secondary pollution was found, whereas Zeelig had none. Zeelig was situated in the Limpopo Province and the environmental factors such as contours, slope and climate had an influence on the state of rehabilitation. The individual parameters for Coretsi shows that it had the lowest plant density and species diversity in the North-West Province. However, plant density was higher at Coretsi than in Zeelig but not significantly. In the determination of the RMI value, plant density was allocated a factor of 11, which contributed to the section with the highest weight, but it is still not enough to give a suitable description of the site as a holistic ecosystem.

From this example, it is clear that the list in Table 4-5 is a distribution range of the sites and must not be seen as an exact value of the rehabilitation status but rather a range into which a site can be classified. Furthermore, it is necessary that the contribution of qualitative data should carry more weight in the calculation of the RMI as it complements the quantitative data and it visually aids in determining the state of rehabilitation.

The RPI determines the need for rehabilitation of asbestos pollution by quantifying the risk associated with a specific pollution site whereas, the RMI evaluate the stability of previously rehabilitated areas to determine

their rehabilitation status. In Table 4-6 a list of the mine distribution according to the RPI is illustrated. In comparison to the distribution list in Table 4-5, a clear difference can be seen. Sites that were a high risk in the RPI are classified in the intermediate RMI value group. However, sites that had a low risk according to the RPI are mostly classified in the highest RMI value group. According to the RPI the Northern Cape Province was prioritised as the highest risk, whereas in the RMI, sites are located in the intermediate and low RMI groups. In the RPI, the Limpopo Province sites were spread across the whole distribution range and were prioritised as intermediate. However, in the RMI the Limpopo Province was classified as the province with the poorest rehabilitation with all of the sites located in the highest RMI group. One can come to the conclusion that rehabilitation was not sustainable in the Limpopo Province which had been under rehabilitation since 1987. While the RPI and RMI cannot be compared directly, it might be of great revelation to reassess the RPI values of all the sites after rehabilitation and compare this data to the RMI distribution list. Essential parameters such as erosion and damage to waterways are evaluated in both the RPI and the RMI and it is therefore expected that sites with a low RMI value, will also be of low risk to the environment.

**Table 4-6:** Distribution range list according to RPI values. Sites with the highest value had the highest risk in terms of pollution to humans and the environment.

Province	Site	RPI value	Previously rehabilitated
	<b>Highest RPI values (25%)</b>		
Northern Cape	Whitebank	64.96	partial
North-West	Pomfret	63.07	yes
Limpopo	Penge	62.37	yes
Limpopo	Kromellenboog	57.60	yes
Northern Cape	Groenwater	56.15	yes
Northern Cape	Riries	51.68	yes
	<b>Intermediate RPI values (50%)</b>		
Northern Cape	Merencor	50.37	yes
Limpopo	Kloof2	50.24	yes
Limpopo	Voorspoed	49.67	yes
Limpopo	Rabeskloof	46.80	yes
Limpopo	Egnep	45.87	yes
Northern Cape	Mt Vera	45.34	yes
North-West	Coretsi	43.89	yes
North-West	Ga-Mopedi	41.57	partial
Limpopo	Kempville	41.47	yes
Limpopo	M&S Riverdump	39.96	partial
Northern Cape	Engeland	39.67	yes
Limpopo	Kloof3	39.41	yes
	<b>Lowest RPI values (25%)</b>		
Limpopo	Zeelig	37.96	yes
North-West	Ncweng complex	37.76	partial
North-West	Sardinia	37.42	partial
Limpopo	Pylkop	34.45	yes
Limpopo	Lagersdraai/Piesangdraai	33.85	yes
North-West	Whiterock	26.48	yes

#### 4. CONCLUSIONS AND RECOMMENDATIONS

The most critical question for any land manager is how to determine the rehabilitation success or failure of sites. Whatever a particular activity is called (restoration, rehabilitation or repair), the clear pronouncement of goals is essential for its success, and the ability to assess the progress towards success. Numerous attributes can be considered when we aim to set goals for rehabilitation and it is of critical importance that the assessment criteria that are used are linked to the goals of rehabilitation of the specific project. From several articles published by scientists in the rehabilitation and restoration fields it is clear that a more holistic and ecosystem approach must be followed in order to achieve the best possible solution for healthy ecosystems (Hobbs and Harris, 2001). There must be effective interaction between scientific analysis, land-user innovation and the development of principles and tools to make sure those actions taken are based on the best knowledge available. However, to plan rehabilitation to harness intrinsic recovery it is essential that potential resilience must be measured. This can only be done by developing tools to assist in the documentation and communication of assessments and the application of these techniques in the field.

In order to assist the effective rehabilitation of derelict and ownerless asbestos mines it was essential to develop a scientific database to indicate the status of rehabilitation at specific sites – this was achieved by the establishment of the RPI. Following on the implementation and application of the RPI to asbestos sites in South Africa, this investigation focused on the development of the RMI to ensure a mechanism of monitoring that would aid long-term success of rehabilitation. The characterisation of various asbestos mining sites in three provinces was conducted based on a holistic approach that included quantitative and qualitative factors indicative of ecosystem processes and the progress of rehabilitation. From the comprehensive assessments of quantitative and qualitative data applied during the investigation, the most prominent parameters governing the rehabilitation process were identified. Weights were assigned to different parameters based on their relative importance or contribution to the success of rehabilitation and RMI values were calculated for each site according to the weights assigned. When evaluating these data and applying the resulting values in the context of the individual rehabilitated mines, it is clear that the weighted percentages attributed to the quantitative (75%) and qualitative (25%) factors, may need to be reconsidered. It seems that qualitative factors may be of greater significance to the long-term stability of a rehabilitated site than the RMI framework currently allows for. This requires further investigation and would have to be accompanied by the validation of quantitative and qualitative data in order to ensure the integrity and quality of the chosen assessment criteria. This validation of data may be achieved by identifying specific sites from the three provinces assessed in the current investigation and performing additional analyses of assessed parameters to determine the validity and accuracy of conclusions drawn from the assessed parameters thus far. Furthermore, the feasibility of applying an artificial neural network to construct an algorithm to rank the sites in terms of rehabilitation success will be evaluated. This artificial neural network will also validate whether the reasons for success/failure as indicated in the RDA (Figure 4-1) is relevant.

The results obtained from this investigation show that a multidisciplinary approach is a step in the right direction for the monitoring and successful long-term rehabilitation of post-mining sites such as derelict asbestos mines. Significant contributions made by this investigation include the identification of parameters critical to rehabilitation success and the establishment of the RMI for the evaluation of asbestos rehabilitation. Although it is clear that limitations in the current RMI still exist, this investigation is of great meaning for the development of a necessary tool for rehabilitation monitoring.

The final future goal is to establish a reliable and broadly applicable RMI, as well as a database with a user-friendly interface that could be used to access rehabilitation data on any asbestos mine. The database will include a model for rehabilitation that will indicate whether a mine needs rehabilitation or has been rehabilitated and to what extent the rehabilitation has been successful based on specific quantitative and qualitative parameters evaluated in this study. Data obtained and conclusions drawn from this investigation will contribute to the further development of the RMI and updating of the asbestos database of South Africa. The database should be updated by long-term monitoring at regular intervals as specified in the DME guidelines. Continuous monitoring is an essential aspect of rehabilitation that must be taken into consideration when rehabilitation programmes are planned. Since the DME guidelines for the maintenance, management and monitoring of rehabilitated asbestos mines in South Africa does not specify the period of monitoring required to assure all parties of the successful achievement of the rehabilitation goals, this is another aspect that requires attention and future investigation. Ultimately, determining the success of rehabilitation is a complex initiative that should look towards a variety of scientific fields for a combination of techniques and/or approaches to achieve a comprehensive and applicable RMI. In this regard, the current investigation serves greatly to elucidate several competencies and weaknesses of the existing approach.

## REFERENCES

- African Gabions. 2002. Gabion structures in asbestos dump rehabilitation. Urban Green File 7(5) [Cited February 2009]; Available from <http://www.urbangreen.co.za/archives/products2/7-5gabionproducts.htm>
- Alef, K., Nannipieri, P. 1995. Methods in applied soil microbiology and biochemistry. Boston: Academic Press. 576p.
- Banwart, W.L., Bremner, J.M., Tabatabai, M.A. 1972. Determination of ammonium in soil extracts and water samples by an ammonia electrode. Commun Soil Sci Plant Anal 3:449.
- Barbour, M.G., Burk, J.H. & Pitts, W.D. 1987. Terrestrial Plant Ecology. Second edition. The Benjamin/Cummings Publishing Company, Inc., California.
- Berger, K.C. 1968. Introductory soils. New York: Macmillan.
- Bredenkamp, G., Granger, J.E., van Rooyen, N. 1996. Savanna Biome. In: Low, A.B., Robelo, A.G. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.
- Bray, R.H., Kunz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci 59:3945.
- Claassens, S. 2007. Measuring rehabilitation success of coal mining disturbed areas: A spatial and temporal investigation into the use of soil microbial properties as assessment criteria. (Thesis – PhD.Env.Sci). Potchefstroom: North-West University. 125p.
- Coaltech. 2007. Guidelines for the Rehabilitation of Mined Land. Chamber of Mines of South Africa.
- Coombes, A. 2002. Three minerals, three epidemics. Text of talk given by Anthony Coombes at John Pickering Partners attorneys on 27<sup>th</sup> of November 2002. Manchester.
- CSMI, 2008. The Future of Penge. Prospects for People and the Environment. Project Report and Guidelines. Asbestos Relief Trust. [Cited May 2009]; Available from [www.asbestostrust.co.za/documents/Penge\\_Report.pdf](http://www.asbestostrust.co.za/documents/Penge_Report.pdf)
- DEAT. 2001. The Department of Environmental Affairs and Tourism. The National State of the Environment Report for South Africa [Cited February 2009]; Available from <http://www.environment.gov.za/soesa/nsoer/issues/land.htm>
- De Groot, S.H., Claassen, V.P., Scow, K.M. 2005. Microbial community composition on native and drastically disturbed serpentine soils. Soil Biol. Biochem.37: 1427-1435.
- Doran, J.W., Parkin, T.B. 1994. Defining and Assessing Soil Quality. In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B.A. Defining Soil Quality for a Sustainable Environment. Proceedings of a symposium held by the Soil Science Society of America, American Society of Agronomy and the North Central Region Committee on Soil Organic Matter nr.35; 1992 Nov 4-5; Minneapolis.

Eko-Rehab. 2003. Asbestos prioritisation Database.

Ellerly, K.S., Walker, B.H. 1986. Growth characteristics of selected plant species on asbestos tailings from Msauli Mine, eastern Transvaal. *S .Afr. J. Bot.* 52(3):201-206.

Harris, J.A. 2003. Measurements of the soil microbial community for estimating the success of restoration. *Eur. J. Soil Sci.* 54:801-808.

Hobbs, R.J., Harris, J.A. 2001. Restoration Ecology: Repairing the Earth's Ecosystems in the New Millennium. *Restor. Ecol.* 9(2): 239-246.

Holman, J. 2008. Asbestos still a persistent problem in South Africa. *Engineering News* [Cited May 2009]; Available from <http://www.engineeringnews.co.za/print-version/asbestos-still-a-persistent-problem-in-South-Africa.html>

Hart, H.P. 1988. Asbestos in South Africa. *J. S. Afr. I Min. Metall.* 88(6):185-198.

Hill, G.T., Mitkowski, N.A., Aldrich-Wolfe, L., Emele, L.R., Jurkonie, D.D., Ficke, A., Maldonado-Ramirez, S., Lynch, S.T., Nelson, E.B. 2000. Methods for assessing the composition and diversity of soil microbial communities. *App. Soil Ecol.* 15:25-36.

Hossner, L.R., Hons, F.M. 1992. Reclamation of Mine Tailings. In: Lal, R., Stewart, B.A. *Soil Restoration. Volume 17 Advances in Soil Science.* New York: Springer-Verlag.

Howling, G.E. 1937. *Asbestos.* London: Imperial Institute. 88p.

Ibekwe, A.M., Kennedy, A.C., Frohne, P.S., Papiemik, S.K., Yang, C.H., Crowley, D.E. 2002. Microbial diversity along a transect of agronomic zones. *FEMS Microbiol. Ecol.* 39:183-191

Kazan-Allen, L. 2002. South African claimants briefed on Cape Asbestos settlement. International Ban Asbestos Secretariat [Cited May 2009]; Available from [http://www.btinternet.com/~ibas/frames/f\\_lka\\_cape\\_sa\\_claim\\_brief.htm](http://www.btinternet.com/~ibas/frames/f_lka_cape_sa_claim_brief.htm)

Kazan-Allen, L. 2006. Environmental Asbestos fallout in Asia and Africa. International Bam Asbestos Secretariat [Cited May 2009]; Available from [http://btinternet.com/~ibas/lka\\_env\\_asb\\_fallout\\_asia\\_africa.htm](http://btinternet.com/~ibas/lka_env_asb_fallout_asia_africa.htm)

Li, M.S. 2006. Ecological restoration of mineland with particular reference to the metalliferous mine wasteland in China: A review of research and practice. *Sci. Total Environ.* 357:38-53.

Ludwig, J.A., Hindley, N., Barnett, G. 2003. Indicators for monitoring minesite rehabilitation: trends on waste-rock dumps, northern Australia. *Ecol. Indic.* 3:143-153.

McCulloch, J. 2003. Asbestos mining In Southern Africa, 1893-2002. *Int. J. Occup. Environ. Health* 9:230-235.

McCulloch, J. 2003. Women Mining Asbestos in South Africa 1893-1980. *J. South Afr. Stu.* 29(2):413-432.

- McCulloch, J. 2005. Asbestos, Lies and the State: Occupational Disease and South African Science. *Afr. Stu.* 64: 2Des 2005.
- McCulloch, J. 2006. Saving the Asbestos Industry, 1960 to 2006. *Public Health reports* (974) 121(5):609- 614.
- Meyer, D.R. 1980. Nutritional problems associated with the establishments of vegetation on tailings from asbestos mines. *Environmental pollution. Series A, Ecological and biological* 23(4):287-298.
- Moreno-de las Heras, M., Merino-Martín, L., Nicolau, J.M. 2009. Effects of vegetation cover on the hydrology of reclaimed mining soils under Mediterranean-Continental climate. *Catena* 77:39-49.
- Milton, S.J. 2001. Rethinking ecological rehabilitation in arid and winter rainfall regions of southern Africa. *S. Afr. J. Sci.* 97:1-2.
- Moore, T.R., Zimmerman, R.C. 1977. Establishment of vegetation on serpentine asbestos mine wastes, southeastern Quebec, Canada. *J Appl. Ecol.* 14:589-599.
- Morris, M., Harris, J., Hill, T. 2003. Soil microbial communities. In: Humphrey, J.W., Ferris, F., Quine, C.P. *Biodiversity in Britain's Planted Forests*. Edinburgh: Forestry Commission 31-39.
- Morgental, T., Maboeta, M., van Rensburg, L. 2004. Revegetation of heavy metal contaminated mine dumps using locally serpentine-adapted grassland species. *S. Afr. J. Bot.* 70(5):784-789.
- Mulligan, D. 1997. *Environmental Management in the Australian Minerals and Energy Industries: Principles and Practices*. Australia: University of New South Wales 785p.
- Naidoo, B. 2008. Health implications of asbestos-mining are far from over. *Mining weekly*. [Cited June 2009]; Available from <http://www.miningweekly.com/article/health-implications-of-asbestosmining-are-far-from-over-2008-05-23>
- NEDLAC. 2002. History of Asbestos on South Africa. [Cited – Jan 2010]; Available from <http://www.nedlac.org.za/media/6503/app-6.pdf>
- Nel, J. 2006. The current risk of asbestos exposure to the citizens of the Prieska area, Northern Cape Province in South Africa. (Mini-dissertation). Potchefstroom: North-West University. 87p.
- Pascual, J.A., Garcia, C., Hernandez, T., Moreno, J.L., Ros, M. 2000. Soil microbial activity as a biomarker of degradation and remediation processes. *Soil Biol Biochem* 32:1877-1883.
- Peech, M. 1965. Hydrogen-ion activity. In: Black, C.A., editor. *Methods of soil analysis*. Pan 2. Agron Monogr 9. Madison: ASA, pp. 914-926.
- Proctor, J., Woodell, A.R.J. 1975. The ecology of serpentine soils. In: Macfadyen, A. *Advances in Ecological Research*. Volume 9, London: Academic Press. 256-385.

- Ramirez-Monoz, J. 1968. Atomic absorption spectroscopy and analysis by atomic absorption flame photometry. New York: Am Elsevier Publ. Co.
- Redco/Nemai Consortium. 2008. Monitoring of previously rehabilitated asbestos sites in South Africa. Report prepared for the Department of Minerals and Energy. South Africa 140p.
- Remigi, P, Faye, A., Kane, A., Deruaz, A., Thioulouse, J., Cissoko, M., Prin, Y., Galiana, A., Dreyfus, B. and Duponnois, R. 2008. The exotic legume tree species *Acacia holosericea* alters microbial soil functionalities and the structure of the arbuscular mycorrhizal community. *App. Environ. Microbiol.* 74(5): 1485-1493.
- Ros, M., Hernandez, M.T., Garcia, C. 2003. Soil microbial activity after restoration of a semiarid soil by organic amendments. *Soil Biol. and Biochem.* 35: 463-469.
- SER. 2004. Society for Ecological Restoration International Science and Policy Working Group. The SER primer on ecological restoration [cited June 2009]; Available from <http://www.ser.org/>
- Smith, S.N., Pugh, G.J.F. 1979. Evaluation of dehydrogenase as a suitable indicator of soil microflora activity. *Enzyme Microb. Technol.* 1:279-281.
- South Africa. 1965. Atmospheric Pollution Prevention Act No. 45 of 1965. Pretoria: Government Press.
- South Africa. 1994. Constitution of the Republic of South Africa 108 of 1994. Pretoria; Government Press.
- South Africa. 1991. Minerals Act No. 50 of 1991. Pretoria: Government Press.
- South Africa. 2002. Mineral and Petroleum resources development Act No. 28 of 2002. Pretoria: Government Press.
- South Africa. 1911. Mines and Works Act of 1911. Pretoria; Government Press.
- South Arica. 1998. National Environmental Management Act No. 107 of 1998. Pretoria: Government Press.
- Tate, R.L. (III), Rogers, B.F. 2002. Soil ecosystem properties, microbial diversity, and ecosystem assessments. In: Violante, A., Huang, P.M., Bollag, J.M., Gianfreda, L., editors. *Developments in soil science, volume 28B*, New York: Elsevier. pp 79-93.
- Ter Braak, C.F., Smilauer, P. 1998. *Canoco reference manual for user's guide to Canoco community ordination*, ver. 4. New York: Microcomputer Power.
- Tordoff, G.M., Baker, A.J.M., Willis, A.J. 2000. Current approaches to the revegetation and reclamation of metalliferous mine wastes. *Chemosphere* 41:219-228.
- Traoré, S., Thiombiano, L., Millogo, J.R., Guinko, S. 2006. Carbon and nitrogen enhancement in Camisols and Vertisols by *Acacia* spp. in eastern Burkina Faso: Relation to soil respiration and microbial biomass. *App. Soil Ecol.* 35:660-669.

Van Rensburg, L., Pistorius, L. 1998. An investigation into the problems associated with revegetating chrysotile tailings. *S. Afr. J Plant and Soil* 15(4):130-140.

Van Rensburg, L., Maboeta, M.S., Morgental, T.L. 2004. Rehabilitation of co-disposed diamond tailings: growth medium rectification procedures and indigenous grass establishment. *Water Air Soil Pollut.* 154:101-113.

Van Rensburg, L., Claassens, S., Bezuidenhout, J.J., Jansen van Rensburg, P.J. 2008. Rehabilitation of asbestos mining waste: a Rehabilitation Prioritisation Index (RPI) for South Africa. *S. Afr. J. Environ. Geol.* 57:267-273.

Van Wyk, S. 1994. 'n Strategie vir die rehabilitasie van versteurde mynbougebiede in suidelike Afrika. (Proefskrif – PhD Omgewings wetenskappe). Potchefstroom Universiteit vir Christelike Hoer Onderwys. Suid-Afrika 327p

Virta, R.L. 2003. Worldwide Asbestos Supply and Consumption trends from 1900 through 2003. U.S. Geological Survey Circular 1298 80p.

Von Mersi, W., Schinner, F. 1991. An improved and accurate method for determining dehydrogenase activity of soils with iodinitrotetrazolium chloride. *Biol. Fertil. Soils* 11:216-220.

Voigt, W. 2007. *Euphorbia tirucalli*. [Cited January 2010]; Available from <http://www.plantzafrica.com/plantefg/euphorbtirucal.htm>

Walkley, A., Black, I.A. 1934. An examination of the Degiareff method for determining SOM and a proposed modification of the chromic acid titration method. *Soil Sci.* 37:29-38.

**APPENDIX A:  
RECORD OF MINES**

Province	General location	Site name	Dump name	Latitude	Longitude	Amount of dumps	
Limpopo	Bewaarkloof	Bew.Kloof Kempville	Kempville	24°10.5' S	29°46.8' E	1	
		Bew.Kloof Egnep	Egnep	24°09.8' S	29°48.0' E	1	
		Bew.Kloof Pylkop	Pylkop	24°09.8' S	29°48.0' E	1	
		Bew.Kloof Zeelig	Zeelig	24°10.0' S	29°46.8' E	1	
		Bew.Kloof M&S (Riverdump & Mine)	M&S (Riverdump & Mine)	24°10.5' S	29°46.5' E	1	
		Lagers/Piesangdraai	Lagers/Piesangdraai	24°11.5' S	29°47.2' E	1	
		Voorspoed Complex	Voorspoed	24°11.2' S	29°49.0' E	8	
		Rabeskloof	Rabeskloof	24°11.2' S	29°49.0' E	3	
		Bew.Kloof 2 consolidated	Kloof 2	24°09.0' S	29°48.0' E	11	
		Bew.Kloof 3	Kloof 3	24°09.8' S	29°48.0' E	2	
		Burgersfort	Penge	Penge	24°22.7' S	30°16.5' E	18
			Kromellenboog	Kromellenboog	24°27.5' S	30°22.5' E	4
		North-West	Pomfret	Pomfret	Innes	25°48.0' S	23°30.7' E
Pomfret	Pomfret			25°49.6' S	23°31.67' E	8	
Coretsi	Coretsi			27°12.0' S	23°05.5' E	1	
Coretsi East	Coretsi East			27°12.0' S	23°05.5' E	1	
Coretsi South	Coretsi South			27°10.75' S	23°4.75' E	1	
Coretsi West	Coretsi West			27°11.3' S	23°04.5' E	1	
Ncweng complex	Ncweng South2 A			Ncweng South2 A	27°31' S	23°20.0' E	1
	Ncweng South2 B			Ncweng South2 B	27°31' S	23°20.0' E	1
	Ncweng South 2 C			Ncweng South 2 C	27°31' S	23°20.0' E	1
	Ncweng South 2 D			Ncweng South 2 D	27°31' S	23°20.0' E	1
	Ncweng South 1 A			Ncweng South 1 A	27°31' S	23°20.0' E	1
	Ncweng South 1B			Ncweng South 1B	27°31' S	23°20.0' E	1
	Ncweng Bloubank			Ncweng Bloubank	27°31' S	23°20.0' E	1
	Ncweng North 1			Ncweng North 1	27°31' S	23°20.0' E	1
Ncweng North 2	Ncweng North 2			27°31' S	23°20.0' E	1	
Ncweng North 3	Ncweng North 3			27°31' S	23°20.0' E	1	
Ncweng North 4	Ncweng North 4			27°31' S	23°20.0' E	1	
Sardinia	Sardinia	Sardinia	27°15.25' S	23°13.75' E	2		
	Bruin Kol 1	Bruin Kol 1	27°15.25' S	23°13.75' E	1		
	Bruin Kol 2	Bruin Kol 2	27°15.25' S	23°13.75' E	1		
Ga-Mopedi	Ga-Mopedi	Ga-Mopedi	-	-	1		
	Whiterock	Whiterock	27°17.7' S	23°15.0' E	1		

Province	General location	Site name	Dump name			Amount of dumps
Northern Cape	Kuruman	Wandrag Complex	Wandrag	27°31' S	23°20.0' E	2
			Exit	27°31' S	23°20.0' E	2
			Ettrik	27°31' S	23°20.0' E	1
			Annex	27°31' S	23°20.0' E	1
		Mt Vera	Mt Vera	27°16.25' S	23°09.0' E	1
		Riries	Riries	27°19.6' S	23°10.5' E	4
		Merencor	Merencor	27°13.0' S	23°05.75' E	1
		Engeland (Rooimyn)	Engeland	27°15.75' S	23°08.75' E	1
		Whitebank Complex	Whitebank	27°25.75' S	23°17.75' E	3
			Central Mill	27°31' S	23°20.0' E	5
			Kuruman East	27°31' S	23°20.0' E	2
			Fourshaft	27°31' S	23°20.0' E	1
			Whitekloof	27°31' S	23°20.0' E	4
			Whitedale	27°31' S	23°20.0' E	3
	Daniëlskuil	Groenwater	Groenwater	28°14.5' S	23°16.2' E	3

**APPENDIX B QUANTITATIVE RESULTS**  
**APPENDIX B.1. VEGETATION SURVEY RESULTS**  
B.1.1. Limpopo Province

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
Kempville	1.0	0.2	85.0	3.9	2.0	2.1	Trees	3	Euph tir	90	Jaca mim	Euph tir	45	Dios lyc	Pani max	100		Hypo sp.	70	Cucu met
	1.0	0.2	85.0	3.9	2.0	2.1	Trees	3	Acac tor	5	Teco sta	Teco sta	40	Meli aze				Hibi mic	15	
	1.0	0.2	85.0	3.9	2.0	2.1	Trees	3	Meli aze	2		Goss her	10					Cony bon	5	
	1.0	0.2	80.0	5.0	3.9	4.2	Trees	3	Euph tir	50		Euph tir	99		Pani max	100		Hypo sp.	80	
	1.0	0.2	80.0	5.0	3.9	4.2	Trees	3	Acac tor	45		Dios lyc	1					Abu pre	15	
	1.0	0.2	80.0	5.0	3.9	4.2	Trees	3	Meli aze	5								Abut ang	5	
	9.8	0.2	57.5	3.4	8.5	2.8	Trees	3	Euph tir	80		Euph tir	85	Dios lyc	Pani max	100		Lant rug	40	Rhyn tot
	9.8	0.2	57.5	3.4	8.5	2.8	Trees	3	Acac kar	15		Celt afr	5	Flue vir				Abut ang	20	Zorn sp.
	9.8	0.2	57.5	3.4	8.5	2.8	Trees	3	Acac tor	5		Teco sta	5	Gymn bux				Hypo sp.	5	Cucu met
	9.8	0.2	57.5	3.4	8.5	2.8	Trees	3												Momo bal
Eg nep	2.8	0.1	25.0	3.4	10.5	1.8	Trees	3	Euph tir	50	Acac tor	Dich cin	55	Bala mau	Pani max	100		Lant rug	60	Momo bal
	2.8	0.1	25.0	3.4	10.5	1.8	Trees	3	Dich cin	35		Euph tir	40	Grew flave				Hypo sp.	30	
	2.8	0.1	25.0	3.4	10.5	1.8	Trees	3	Acac nil	5		Gymn bux	2					Rhyn tot	5	
	2.3	0.1	39.5	5.9	33.5	2.8	Trees	3	Bala mau	50	Dich cin	Dich cin	70		Pani max	95		-		
	2.3	0.1	39.5	5.9	33.5	2.8	Trees	3	Acac tor	30	Gymn bux	Euph tir	30		Aris bip	3		-		
	2.3	0.1	39.5	5.9	33.5	2.8	Trees	3	Euph tir	10	Dodo ang				Aris ads	2		-		
	2.3	0.1	39.5	5.9	33.5	2.8	Trees	3			Hipp lon									
	2.3	0.1	38.8	4.4	9.5	3.3	Trees	3	Euph tir	70	Dich cin	Euph tir	45	Papp cap	Pani max	90		Hibi mic	65	Cyat lan
	2.3	0.1	38.8	4.4	9.5	3.3	Trees	3	Acac tor	20		Dich cin	35		Enne cen	5		Abut son	20	Pent ins
	2.3	0.1	38.8	4.4	9.5	3.3	Trees	3	Zizi muc	5		Acac tor	10		Aris ads	5		Rhyn min	5	Hypo sp.
Pylkop	1.3	0.2	51.3	1.9	9.0	4.0	Trees & shrubs	1	Euph tir	70	Acac nil	Euph tir	60	Zizi muc	Enne cen	55	Uroc mos	Indi sp.	40	Rhyn sp.
	1.3	0.2	51.3	1.9	9.0	4.0	Trees & shrubs	1	Acac tor	15		Acac tor	20		Aris bip	25		Hibi mic	35	Hypo sp.
	1.3	0.2	51.3	1.9	9.0	4.0	Trees & shrubs	1	Dich cin	10		Dich cin	18		Pani max	15		Achy asp	10	Teph pur
	4.3	0.2	81.3	1.7	13.3	4.5	Shrubs	1	Euph tir	40	Grew bic	Euph tir	50	Acac nil	Pani max	80		Abut aus	45	Rhyn sp.
	4.3	0.2	81.3	1.7	13.3	4.5	Shrubs	1	Acac tor	30		Dich cin	20	Grew bic	Enne cen	20		Achy asp	40	Rhyn min
	4.3	0.2	81.3	1.7	13.3	4.5	Shrubs	1	Dich cin	15		Acac tor	20					Hypo sp.	5	Hibi mic
	1.3	0.1	57.5	1.6	5.0	2.0	Shrubs	1	Euph tir	45		Acac tor	50	Plec arm	Enne cen	80	Aris con	Rhyn min	40	Pell cal
	1.3	0.1	57.5	1.6	5.0	2.0	Shrubs	1	Acac tor	35		Dich cin	25		Pani max	10		Achy asp	30	Abut aus
	1.3	0.1	57.5	1.6	5.0	2.0	Shrubs	1	Dich cin	20		Euph tir	20		Aris bip	5		Indi sp.	20	
	1.3	0.1	57.5	1.6	5.0	2.0	Shrubs	1	Dich cin	35		Acac tor	30	Bala mau	Uroc mos	50		Rhyn min	50	Psia pun
Zeelig	16.3	0.1	14.5	3.7	31.5	6.3	Trees	2	Dich cin	25	Hipp lon	Acac tor	30	Bala mau	Uroc mos	50		Rhyn min	50	Psia pun
	16.3	0.1	14.5	3.7	31.5	6.3	Trees	2	Acac tor	30	Bala mau	Euph tir	30	Zizi muc	Pani max	35		Sida cor	30	
	16.3	0.1	14.5	3.7	31.5	6.3	Trees	2	Euph tir	20		Dich cin	20		Aris ads	15		Hibi mic	15	
	8.8	0.2	46.3	2.1	19.5	4.0	Trees	1	Euph tir	35	Zizi muc	Acac tor	30	Grew flave	Pani max	80		Hypo sp.	45	Sarc vim
	8.8	0.2	46.3	2.1	19.5	4.0	Trees	1	Dich cin	30		Dich cin	30	Zizi muc	Uroc mos	15		Sida cor	10	Abu pre
	8.8	0.2	46.3	2.1	19.5	4.0	Trees	1	Acac tor	25		Euph tir	20		Enne cen	5		Rhyn min	10	Lant rug
	8.8	0.2	46.3	2.1	19.5	4.0	Trees	1												Psia pun
	4.3	0.2	60.0	3.5	7.3	3.3	Trees	1	Euph tir	65		Euph tir	50	Grew flave	Pani max	100		Hibi mic	30	Hypo sp.
	4.3	0.2	60.0	3.5	7.3	3.3	Trees	1	Dich cin	20		Dich cin	25					Rhyn min	30	Achy asp
	4.3	0.2	60.0	3.5	7.3	3.3	Trees	1	Acac tor	15		Acac tor	20					Abut son	30	

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m <sup>2</sup> )	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs	
M&S (Riverdump & Mine)	20.8	0.3	54.5	3.5	35.8	7.5	Trees	2	Euph tir	40	Grew flave	Euph tir	50	Grew flave	Pani max	80	Seta ver	Pavo bur	30	Cyat sp.	
	20.8	0.3	54.5	3.5	35.8	7.5	Trees	2	Dich cin	25		Dich cin	30	Rhus pyr	Enne cen	10		Abut son	20	Cham sp.	
	20.8	0.3	54.5	3.5	35.8	7.5	Trees	2	Acac tor	20		Acac tor	10	Rhus pen	Uroc mos	5		Abut ang	10	Sida cor	
	20.8	0.3	54.5	3.5	35.8	7.5	Trees	2						Zizi muc						Achy asp	
	20.8	0.3	54.5	3.5	35.8	7.5	Trees	2						Gynn bux						Plect sp.	
	0.5	0.1	76.3	4.4	2.8	3.0	Trees	3	Euph tir	50		Euph tir	100		Pani max	100		Achy asp	60		
	0.5	0.1	76.3	4.4	2.8	3.0	Trees	3	Acac tor	30								Sola sp.	40		
	0.5	0.1	76.3	4.4	2.8	3.0	Trees	3	Dich cin	20											
	2.3	0.2	55.0	5.7	9.8	3.8	Trees	3	Euph tir	35	Acac tor	Euph tir	60	Rhus pen	Pani max	70		Abut son	40	Plect sp.	
	2.3	0.2	55.0	5.7	9.8	3.8	Trees	3	Acac nil	35		Dich cin	20	Gynn bux	Uroc mos	30		Achy asp	30	Leuc gla	
	2.3	0.2	55.0	5.7	9.8	3.8	Trees	3	Acac kar	25		Zizi muc	15						Cyat sp.	25	
	Lagers/Piesangdra ai	0.5	0.1	78.8	4.8	1.0	2.3	Trees	3	Euph tir	70	Acac tor	-			Pani max	100		-		
0.5		0.1	78.8	4.8	1.0	2.3	Trees	3	Dich cin	15		-						-			
0.5		0.1	78.8	4.8	1.0	2.3	Trees	3	Acac nil	10		-						-			
1.5		0.1	66.3	5.5	4.8	4.3	Trees	3	Euph tir	75		Acac tor	45	Euph tir	Pani max	100		Abut son	35		
1.5		0.1	66.3	5.5	4.8	4.3	Trees	3	Dich cin	15		Zizi muc	30	Dich cin				Hibi mic	35		
1.5		0.1	66.3	5.5	4.8	4.3	Trees	3	Acac tor	10		Xime ame	10					Abut ang	30		
0.3		0.1	62.5	6.3	1.8	3.5	Trees	3	Euph tir	80		Euph tir	100		Pani max	100		-			
0.3		0.1	62.5	6.3	1.8	3.5	Trees	3	Dich cin	10								-			
0.3		0.1	62.5	6.3	1.8	3.5	Trees	3	Acac tor	10								-			
Voorspoed		48.0	0.3	33.0	1.3	13.0	5.8	Shrubs	1	Euph tir	100		Euph tir	65		Erag rig	45	Aris con	Herm gla	30	Walt ind
		48.0	0.3	33.0	1.3	13.0	5.8	Shrubs	1				Acac tor	30		Pani max	35		Melh acu	25	Zinn per
		48.0	0.3	33.0	1.3	13.0	5.8	Shrubs	1				Mund ser	5		Meli rep	15		Indi sp.	10	Achy asp
	48.0	0.3	33.0	1.3	13.0	5.8	Shrubs	1												Hibi mic	
	7.3	0.2	65.0	2.6	5.0	3.3	Trees & shrubs	1	Euph tir	35		Euph tir	55		Pani max	80		Rhyn min	30	Zinn per	
	7.3	0.2	65.0	2.6	5.0	3.3	Trees & shrubs	1	Acac tor	35		Acac tor	25		Aris con	20		Tage min	20	Hibi mic	
	7.3	0.2	65.0	2.6	5.0	3.3	Trees & shrubs	1	Dich cin	30		Dich cin	20					Acal ind	15	Cony bon	
	7.3	0.2	65.0	2.6	5.0	3.3	Trees & shrubs	1											Melh acu		
	7.3	0.2	65.0	2.6	5.0	3.3	Trees & shrubs	1											Teph pur		
	7.3	0.2	65.0	2.6	5.0	3.3	Trees & shrubs	1											Acro inf		
	24.0	0.3	70.0	1.6	20.0	6.0	Shrubs	1	Euph tir	60		Euph tir	70	Flue vir	Cenc cil	40	Meli rep	Rhyn tot	30	Acro inf	
	24.0	0.3	70.0	1.6	20.0	6.0	Shrubs	1	Acac tor	40		Acac tor	20		Aris con	20	Enne cen	Zinn per	20	Tage min	
	24.0	0.3	70.0	1.6	20.0	6.0	Shrubs	1				Grew flave	5		Pani max	15	Erag rig	Hibi mic	20	Walt ind	
	24.0	0.3	70.0	1.6	20.0	6.0	Shrubs	1											Acal ind		
	24.0	0.3	70.0	1.6	20.0	6.0	Shrubs	1											Rhyn min		
24.0	0.3	70.0	1.6	20.0	6.0	Shrubs	1											Cera tri			
26.3	0.3	63.8	1.6	18.3	5.8	Trees & shrubs	1	Euph tir	75	Rhus lep	Euph tir	80	Grew flava	Pani max	30	Meli rep	Melh acu	35	Tage min		
26.3	0.3	63.8	1.6	18.3	5.8	Trees & shrubs	1	Acac tor	18		Crot mon	10		Enne cen	20	Uroc mos	Psia pun	30	Herm gla		
26.3	0.3	63.8	1.6	18.3	5.8	Trees & shrubs	1	Crot mon	5		Acac tor	5		Aris ads	15	Aris con	Pavo bur	20			
38.0	0.3	63.8	1.6	16.5	6.3	Shrubs	1	Euph tir	45	Dich cin	Euph tir	65	Dich cin	Aris con	50	Enne cen	Melh acu	20	Tage min		

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
Voorspoed	38.0	0.3	63.8	1.6	16.5	6.3	Shrubs	1	Acac tor	35		Acac tor	15		Meli rep	15	Erag rig	Walt ind	15	Sida cor
	38.0	0.3	63.8	1.6	16.5	6.3	Shrubs	1	Mund ser	10		Mund ser	10		Pani max	15		Zinn per	10	Herm gla
	38.0	0.3	63.8	1.6	16.5	6.3	Shrubs	1												Cony bon
	38.0	0.3	63.8	1.6	16.5	6.3	Shrubs	1												Hibi mic
	38.0	0.3	63.8	1.6	16.5	6.3	Shrubs	1												Teph pur
	11.3	0.2	68.8	2.5	11.0	4.8	Trees	1	Euph tir	65	Crot mon	Euph tir	80	Acac nil	Pani max	55	Uroc mos	Melh acu	35	Zinn per
	11.3	0.2	68.8	2.5	11.0	4.8	Trees	1	Acac nil	15		Acac tor	5	Crot mon	Meli rep	25		Rhyn tot	20	Bide pil
	11.3	0.2	68.8	2.5	11.0	4.8	Trees	1	Acac tor	10		Grew flava	5		Aris con	10		Walt ind	20	Tage min
	11.3	0.2	68.8	2.5	11.0	4.8	Trees	1												Psia pun
	11.3	0.2	68.8	2.5	11.0	4.8	Trees	1												Cony bon
	23.8	0.3	50.0	1.5	8.8	7.0	Shrubs	2	Acac tor	40	Dich cin	Euph tir	60	Grew flava	Pani max	50	Cenc cil	Tage min	35	Flav bid
	23.8	0.3	50.0	1.5	8.8	7.0	Shrubs	2	Euph tir	30	Grew flava	Acac tor	25	Dich cin	Seta ver	30		Abut ang	30	Zinn per
	23.8	0.3	50.0	1.5	8.8	7.0	Shrubs	2	Acac nil	15	Acac sen lei	Acac nil	10		Enne cen	15		Sida cor	15	Rhyn tot
	23.8	0.3	50.0	1.5	8.8	7.0	Shrubs	2												Cath ros
	28.8	0.3	58.8	1.6	7.3	6.0	Shrubs	2	Acac tor	40	Grew flava	Euph tir	60		Pani max	70		Abut ang	25	Abut ram
	28.8	0.3	58.8	1.6	7.3	6.0	Shrubs	2	Euph tir	30	Crot mon	Acac tor	20		Enne cen	20		Leon dys	20	Sida rho
	28.8	0.3	58.8	1.6	7.3	6.0	Shrubs	2	Acac nil	15		Acac nil	20		Seta ver	10		Flav bid	20	Rhyn min
	28.8	0.3	58.8	1.6	7.3	6.0	Shrubs	2												Hibi mic
	28.8	0.3	58.8	1.6	7.3	6.0	Shrubs	2												Merr tri
	8.3	0.3	60.0	1.6	10.3	4.5	Trees & shrubs	1	Euph tir	50	Dich cin	Euph tir	40	Rici com	Enne cen	40	Meli rep	Melh acu	35	Flav bid
	8.3	0.3	60.0	1.6	10.3	4.5	Trees & shrubs	1	Acac tor	35		Acac tor	40		Aris ads	25	Seta ver	Abut ram	30	Chen alb
	8.3	0.3	60.0	1.6	10.3	4.5	Trees & shrubs	1	Acac nil	10		Acac nil	20		Pani max	10	Erag rig	Teph pur	20	Tage min
	8.3	0.3	60.0	1.6	10.3	4.5	Trees & shrubs	1												Zinn per
	8.3	0.3	60.0	1.6	10.3	4.5	Trees & shrubs	1												Walt ind
	8.3	0.3	60.0	1.6	10.3	4.5	Trees & shrubs	1												Achy asp
	12.0	0.2	31.3	1.4	15.8	4.8	Shrubs	2	Euph tir	60		Euph tir	75		Enne cen	40		Flav bid	25	Abut ram
	12.0	0.2	31.3	1.4	15.8	4.8	Shrubs	2	Acac tor	40		Acac tor	25		Seta ver	30		Abut aus	25	Zinn per
	12.0	0.2	31.3	1.4	15.8	4.8	Shrubs	2							Pani max	30		Tage min	20	Acal ind
	12.0	0.2	31.3	1.4	15.8	4.8	Shrubs	2												Walt ind
	32.5	0.3	41.3	1.4	22.5	7.8	Shrubs	1	Acac tor	55		Euph tir	70	Dich cin	Enne cen	100		Zinn per	25	Bide bip
	32.5	0.3	41.3	1.4	22.5	7.8	Shrubs	1	Euph tir	45		Acac tor	15					Tage min	15	Abut ram
	32.5	0.3	41.3	1.4	22.5	7.8	Shrubs	1				Acac nil	10					Acal ind	10	Sida cor
	32.5	0.3	41.3	1.4	22.5	7.8	Shrubs	1												Hibi mic
	32.5	0.3	41.3	1.4	22.5	7.8	Shrubs	1												Abut ang
	32.5	0.3	41.3	1.4	22.5	7.8	Shrubs	1												Malv cor
	32.5	0.4	50.0	1.6	20.5	8.0	Trees & shrubs	2	Acac tor	60		Euph tir	70	Dich cin	Enne cen	70	Meli rep	Abut ram	40	Amar hyb
	32.5	0.4	50.0	1.6	20.5	8.0	Trees & shrubs	2	Euph tir	30		Acac tor	20		Uroc mos	15	Seta ver	Tage min	15	Malv cor
	32.5	0.4	50.0	1.6	20.5	8.0	Trees & shrubs	2	Grew flava	10		Grew flava	5		Erag rig	5	Ente mac	Abut ang	15	Acal ind
	32.5	0.4	50.0	1.6	20.5	8.0	Trees & shrubs	2												Bide bip
	31.8	0.3	57.5	1.4	19.5	6.8	Shrubs	1	Euph tir	40	Nico gla	Euph tir	60	Nico gla	Enne cen	50	Meli rep	Tage min	30	Flav bid
	31.8	0.3	57.5	1.4	19.5	6.8	Shrubs	1	Acac nil	30	Rici com	Acac tor	20	Rici com	Aris con	20	Cenc cil	Zinn per	25	Melh acu
	31.8	0.3	57.5	1.4	19.5	6.8	Shrubs	1	Acac tor	15		Acac nil	10		Pani max	20		Cony bon	15	Blum gar
	35.5	0.4	40.0	1.2	7.5	7.3	Shrubs	1	Euph tir	40	Dich cin	Euph tir	50	Acac nil	Cenc cil	40	Aris con	Tage min	30	Rhyn min



Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
Rabeskloof	1.5	0.1	60.0	3.5	3.8	3.0	Trees	3	Euph tir	80		Casi per	50	Gymn bux	Pani max	100		Lant rug	35	Abut ram
	1.5	0.1	60.0	3.5	3.8	3.0	Trees	3	Acac tor	10		Euph tir	30					Sida cor	35	
	1.5	0.1	60.0	3.5	3.8	3.0	Trees	3	Dich cin	10		Rhus gue	10					Tage min	20	
	17.5	0.1	46.3	4.0	11.5	5.8	Trees	3	Euph tir	70	Rhus gue	Euph tir	60	Casi per	Pani max	100		Rhyn tot	70	
	17.5	0.1	46.3	4.0	11.5	5.8	Trees	3	Acac tor	10	Acac nil	Acac nil	20	Grew gra				Pell cal	30	
	17.5	0.1	46.3	4.0	11.5	5.8	Trees	3	Dich cin	10		Fleu vir	10							
	2.3	0.2	56.3	4.1	4.0	4.5	Trees	3	Euph tir	75		-			Pani max	90		Cyat lan	50	
	2.3	0.2	56.3	4.1	4.0	4.5	Trees	3	Dich cin	15		-			Enne cen	10		Sene sp.	30	
	2.3	0.2	56.3	4.1	4.0	4.5	Trees	3	Acac tor	10		-						Rhyn tot	20	
	10.5	0.2	40.0	6.1	5.5	3.0	Trees	3	Acac nil	40	Acac sen le	Grew flave	60		Pani max	80		Pupa lap	60	Lant rug
	10.5	0.2	40.0	6.1	5.5	3.0	Trees	3	Acac tor	25		Fleu vir	35		Seta ver	20		Psia pun	20	Abut ram
	10.5	0.2	40.0	6.1	5.5	3.0	Trees	3	Euph tir	25		Ehre amo	5					Abut son	10	
	26.3	0.2	41.3	3.3	12.0	5.3	Trees	2	Euph tir	30	Acac nil	Grew bic	40	Dich cin	Pani max	100		Psia pun	35	Pupa lap
	26.3	0.2	41.3	3.3	12.0	5.3	Trees	2	Dich cin	25	Grew bic	Euph tir	20	Flue vir				Lant rug	30	Sida cor
	26.3	0.2	41.3	3.3	12.0	5.3	Trees	2	Acac tor	20		Acac nil	20					Rhyn tot	20	Pell cal
	26.3	0.2	41.3	3.3	12.0	5.3	Trees	2												Abut son
	1.3	0.1	32.5	7.8	4.8	2.8	Trees	2	Euph tir	40	Acac tor	Dich cin	30	Papp cap	Pani max	100		Psia pun	60	
	1.3	0.1	32.5	7.8	4.8	2.8	Trees	2	Acac nil	30	Flue vir	Euph tir	25	Flue vir				Pupa lap	30	
	1.3	0.1	32.5	7.8	4.8	2.8	Trees	2	Dich cin	10		Rhus pen	10	Acac tor				Abut ram	10	
	1.3	0.1	32.5	7.8	4.8	2.8	Trees	2				Acac nil								
	9.5	0.2	40.0	3.2	15.3	5.8	Trees	2	Euph tir	40	Acac nil	Dich cin	35	Acac tor	Pani max	100		Dicl een	50	
	9.5	0.2	40.0	3.2	15.3	5.8	Trees	2	Dich cin	30		Ehre amo	30	Grew gra				Pupa lap	40	
	9.5	0.2	40.0	3.2	15.3	5.8	Trees	2	Acac tor	20		Euph tir	30	Gymn sen				Goss her	10	
	3.0	0.1	32.5	5.2	8.0	3.3	Trees	2	Dich cin	60	Acac tor	Ehre amo	50	Grew gra	Pani max	100		Psia pun	30	Sida dre
	3.0	0.1	32.5	5.2	8.0	3.3	Trees	2	Euph tir	25	Pyro his	Euph tir	40					Dicl een	30	
	3.0	0.1	32.5	5.2	8.0	3.3	Trees	2	Acac nil	10		Plec arm	5					Hibi mic	30	
	31.1	0.2	20.0	1.2	30.0	8.5	Shrubs	2	Dodo ang	35	Acac sen le	Euph tir	60	Grew flave	Erag rig	35		Blep sub	40	Sida cor
	31.1	0.2	20.0	1.2	30.0	8.5	Shrubs	2	Dich cin	30	Acac tor	Dich cin	25		Mell rep	35		Walt ind	20	Teph pur
	31.1	0.2	20.0	1.2	30.0	8.5	Shrubs	2	Euph tir	20		Dodo ang	10		Aris bip	30		Indi sp.	20	
Kloof 2	3.8	0.2	25.0	3.8	8.3	3.3	Trees	1	Euph tir	30	Dich cin	Euph tir	20	Dich cin	Aris ads	40		Abut son	35	Dicl een
	3.8	0.2	25.0	3.8	8.3	3.3	Trees	1	Acac tor	30	Hipp lon	Acac tor	20	Flue vir	Aris bip	30		Tage min	20	Zinn per
	3.8	0.2	25.0	3.8	8.3	3.3	Trees	1	Acac nil	20	Grew bic	Domb aut	10	Opun fic	Enne cen	30		Bide bip	20	Pell cal
	3.8	0.2	25.0	3.8	8.3	3.3	Trees	1						Elae tra						Psia pun
	3.8	0.2	25.0	3.8	8.3	3.3	Trees	1						Grew bic						
	1.8	0.1	28.8	2.9	3.5	1.8	Trees	3	Euph tir	40	Dich cin	Acac tor	30	Acac nil	Pani max	75		Hibi mic	60	
	1.8	0.1	28.8	2.9	3.5	1.8	Trees	3	Acac tor	20	Hipp lon	Euph tir	30	Dich cin	Aris bip	15		Lant rug	40	
	1.8	0.1	28.8	2.9	3.5	1.8	Trees	3	Acac nil	15	Domb aut	Flue vir	15	Papp cap	Aris ads	10				
	11.3	0.3	25.0	2.1	6.0	3.3	Trees	2	Euph tir	50	Flue vir	Acac tor	35	Dich cin	Pani max	85		Hibi mic	60	Perg dae

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs	
Kloof 2	11.3	0.3	25.0	2.1	6.0	3.3	Trees	2	Dich cin	15		Euph tir	15	Crot mon	Enne cen	5		Cyat sp.	5		
	11.3	0.3	25.0	2.1	6.0	3.3	Trees	2						Domb aut							
	8.8	0.2	27.5	2.0	9.5	5.5	Trees	3	Euph tir	45		Acac tor	30	Xime ame	Pani max	100		Rhyn min	40	Abut aus	
	8.8	0.2	27.5	2.0	9.5	5.5	Trees	3	Acac tor	30		Euph tir	25	Flue vir				Crota sp.	30	Barl sp.	
	8.8	0.2	27.5	2.0	9.5	5.5	Trees	3	Dich cin	25		Dich cin	20	Cler gla				Hibi mic	30	Psia pun	
	8.8	0.2	27.5	2.0	9.5	5.5	Trees	3						Zizi muc							
	8.8	0.2	27.5	2.0	9.5	5.5	Trees	3						Grew flave							
	10.8	0.2	30.0	2.2	11.8	7.3	Trees	3	Euph tir	50	Domb aut	Euph tir	30	Flue vir	Pani max	85		Rhyn tot	40	Tage min	
	10.8	0.2	30.0	2.2	11.8	7.3	Trees	3	Acac tor	20	Flue vir	Dich cin	30		Enne cen	15		Abu pre	20	Vign fru	
	10.8	0.2	30.0	2.2	11.8	7.3	Trees	3	Dich cin	15		Acac tor	20					Rhyn min	10	Perg dae	
	0.8	0.1	50.0	4.0	4.8	3.3	Trees	3	Euph tir	40	Acac nil	Euph tir	35	Flue vir	Pani deu	90		Abut ram	40	Rhyn min	
	0.8	0.1	50.0	4.0	4.8	3.3	Trees	3	Acac tor	30	Flue vir	Dich cin	30	Domb rot	Pani max	10		Hibi mic	20	Rhyn tot	
	0.8	0.1	50.0	4.0	4.8	3.3	Trees	3	Dich cin	20		Acac tor	20	Grew bic				Acan his	20		
	7.5	0.2	23.8	4.6	15.3	3.3	Trees	1	Euph tir	50	Acac tor	Euph tir	30	Domb rot	Aris ads	40	Cenc cil	Tage min	30	Zinn per	
	7.5	0.2	23.8	4.6	15.3	3.3	Trees	1	Domb rot	20	Crot mon	Dich cin	30	Rici com	Pani deu	20	Meli rep	Lant rug	15	Walt ind	
	7.5	0.2	23.8	4.6	15.3	3.3	Trees	1	Dich cin	15	Rici com	Obet ten	15	Acac tor	Pani max	20		Rhyn sp.	15	Rhyn tot	
	7.5	0.2	23.8	4.6	15.3	3.3	Trees	1						Flue vir						Vign vex	
	10.0	0.2	38.8	3.9	6.0	4.3	Trees	1	Euph tir	45	Dich cin	Acac tor	40	Rhus pen	Pani deu	85		Abut aus	30	Rhyn min	
	10.0	0.2	38.8	3.9	6.0	4.3	Trees	1	Acac tor	30		Dich cin	20	Flue vir	Aris ads	15		Pseu sp.	20	Merr tri	
	10.0	0.2	38.8	3.9	6.0	4.3	Trees	1	Acac nil	15		Euph tir	20					Crota sp.	20	Lant rug	
	10.0	0.2	38.8	3.9	6.0	4.3	Trees	1												Psia pun	
	21.3	0.2	6.3	1.6	19.8	7.5	Shrubs	1	Euph tir	50	Acac tor	Euph tir	60	Acac nil	Meli rep	70	Hete con	Melh acu	25	Walt ind	
	21.3	0.2	6.3	1.6	19.8	7.5	Shrubs	1	Dich cin	25		Dich cin	15	Xime ame	Pani max	10	Enne sco	Dich inte	25	Teph pur	
	21.3	0.2	6.3	1.6	19.8	7.5	Shrubs	1	Acac nil	15		Acac tor	10	Domb aut	Aris ads	10		Rhyn min	15	Rhyn tot	
	21.3	0.2	6.3	1.6	19.8	7.5	Shrubs	1													Tage min
	0.5	0.1	81.3	3.4	1.5	1.8	Trees	2	Euph tir	75		Rhus pen	35		Pani max	100		Rhyn min	35	Zinn per	
	0.5	0.1	81.3	3.4	1.5	1.8	Trees	2	Acac tor	20		Celt afr	35					Rhyn tot	30	Vign vex	
	0.5	0.1	81.3	3.4	1.5	1.8	Trees	2	Zizi muc	5		Acac tor	30					Chei sp.	20		
	4.3	0.2	47.4	4.0	4.0	3.5	Trees	2	Euph tir	50	Flue vir	Rhus pen	25	Euph tir	Pani max	90		Pavo bur	40	Chei sp.	
	4.3	0.2	47.4	4.0	4.0	3.5	Trees	2	Acac tor	20	Acac caf	Acac tor	25	Dich cin	Enne cen	10		Hibi mic	15	Tage min	
	4.3	0.2	47.4	4.0	4.0	3.5	Trees	2	Dich cin	15		Flue vir	20	Ehre amo				Pell cal	15	Bide bip	
	4.3	0.2	47.4	4.0	4.0	3.5	Trees	2						Cant ine						Cony bon	
	4.3	0.2	47.4	4.0	4.0	3.5	Trees	2						Rhus lep							
	46.3	0.3	18.8	5.0	9.8	4.5	Trees	1	Euph tir	40	Spir afr	Acac tor	50	Rhus pen	Pani max	85		Hibi sp.	25	Sene sp.	
	46.3	0.3	18.8	5.0	9.8	4.5	Trees	1	Acac tor	30		Euph tir	20	Domb rot	Meli rep	10		Rhyn min	25	Pupa lap	
	46.3	0.3	18.8	5.0	9.8	4.5	Trees	1	Dich cin	20		Dich cin	10		Enne cen	5		Psia pun	15	Hibi mic	
	46.3	0.3	18.8	5.0	9.8	4.5	Trees	1												Pell cal	
	1.0	0.1	78.8	2.7	2.3	1.3	Trees	1	Euph tir	50	Dich cin	Euph tir	50		Pani max	100		Dicl een	50		
	1.0	0.1	78.8	2.7	2.3	1.3	Trees	1	Acac tor	30		Acac tor	50					Rhyn min	50		
	1.0	0.1	78.8	2.7	2.3	1.3	Trees	1	Flue vir	10											
	1.8	0.2	75.0	3.4	4.8	2.8	Trees	1	Euph tir	45		Acac tor	35	Dich cin	Pani max	90		Sene sp.	35	Abut son	
	1.8	0.2	75.0	3.4	4.8	2.8	Trees	1	Acac tor	35		Euph tir	30	Rhus gue	Meli rep	5		Rhyn min	30	Pell cal	
	1.8	0.2	75.0	3.4	4.8	2.8	Trees	1	Dich cin	20		Grew flave	25	Lant cam	Tric mon	5		Merr tri	15	Lant rug	

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
Kloof 2	1.8	0.2	75.0	3.4	4.8	2.8	Trees	1												Abut aus
	1.8	0.2	75.0	3.4	4.8	2.8	Trees	1												Hibi mic
	25.0	0.2	45.0	2.8	6.5	3.5	Trees	1	Euph tir	40		Euph tir	35	Flue vir	Pani max	90		Rhyn min	25	Tage min
	25.0	0.2	45.0	2.8	6.5	3.5	Trees	1	Acac tor	40		Acac tor	30		Cymb val	10		Vign fru	20	Hibi mic
	25.0	0.2	45.0	2.8	6.5	3.5	Trees	1	Dich cin	20		Dich cin	30					Bide bip	10	Pell cal
	25.0	0.2	45.0	2.8	6.5	3.5	Trees	1												Dicl een
	61.3	0.3	32.5	5.0	12.8	6.8	Trees	2	Dich cin	35	Flue vir	Dich cin	30	Flue vir	Pani max	100		Plum zey	25	Bide bip
	61.3	0.3	32.5	5.0	12.8	6.8	Trees	2	Euph tir	30	Teco sta	Euph tir	30					Psia pun	15	Achy asp
	61.3	0.3	32.5	5.0	12.8	6.8	Trees	2	Acac nil	20		Teco sta	25					Abut ram	15	Hibi mic
	19.5	0.3	43.8	4.0	7.3	5.0	Trees	1	Euph tir	40	Xime ame	Euph tir	30	Xime ame	Cenc cil	60	Erag rig	Zinn per	30	Tage min
	19.5	0.3	43.8	4.0	7.3	5.0	Trees	1	Dich cin	30	Grew flave	Flue vir	25		Pani max	25		Abut ram	25	Rhyn min
	19.5	0.3	43.8	4.0	7.3	5.0	Trees	1	Acac tor	15		Dich cin	25		Aris bip	10		Psia pun	20	Melh acu
	20.0	0.3	35.0	3.9	6.8	4.5	Trees	2	Euph tir	40	Acac nil	Euph tir	30	Rhus pen	Cenc cil	80		Ocym ame	20	Leuc neu
	20.0	0.3	35.0	3.9	6.8	4.5	Trees	2	Dich cin	30	Grew flave	Flue vir	20	Hipp lon	Pani max	20		Plum zey	15	Rhyn min
	20.0	0.3	35.0	3.9	6.8	4.5	Trees	2	Acac tor	15	Teco sta	Teco sta	20	Gymn bux				Pell cal	10	Tage min
	20.0	0.3	35.0	3.9	6.8	4.5	Trees	2												Psia pun
	20.0	0.3	35.0	3.9	6.8	4.5	Trees	2												Bide bip
	20.0	0.3	35.0	3.9	6.8	4.5	Trees	2												Trag sp.
	30.0	0.3	20.0	1.0	12.8	6.8	Shrubs	1	Trem ori	40	Budd salv	Euph tir	60		Meli rep	45	Cyno dac	Loph cor	40	
	30.0	0.3	20.0	1.0	12.8	6.8	Shrubs	1	Dich cin	30	Acac tor	Dich cin	30		Both ins	25	Erag chl	Psia pun	35	
	30.0	0.3	20.0	1.0	12.8	6.8	Shrubs	1	Euph tir	10		Acac tor	10		Pani deu	20		Teph pur	25	
	72.5	0.6	7.5	2.1	9.0	8.3	Grasses	1	Dich cin	40	Acac tor	Dich cin	35	Rhus pen	Both ins	60	Cymb val	Rhyn tot	40	Pell cal
	72.5	0.6	7.5	2.1	9.0	8.3	Grasses	1	Trem ori	30	Rhus chi	Euph tir	30	Acac kar	Pani deu	20		Tage min	20	Geig bur
	72.5	0.6	7.5	2.1	9.0	8.3	Grasses	1	Euph tir	20		Acac tor	15		Pani max	10		Sene sp.	20	Psia pun
	70.0	0.7	22.5	5.4	10.8	7.3	Trees	1	Dich cin	35	Acac tor	Dich cin	45	Xime caf	Pani deu	60		Lant rug	25	Pell cal
	70.0	0.7	22.5	5.4	10.8	7.3	Trees	1	Euph tir	30	Rhus lep	Euph tir	25	Ficu sur	Pani max	40		Rhyn tot	25	Merr tri
	70.0	0.7	22.5	5.4	10.8	7.3	Trees	1	Trem ori	15		Acac tor	10	Zizi muc				Tage min	20	Sene sp.
	70.0	0.7	22.5	5.4	10.8	7.3	Trees	1												Psia pun
Kloof 3	2.8	0.2	31.3	2.9	8.0	3.0	Trees	2	Acac tor	40	Dich cin	Euph tir	30	Acac nil	Pani max	100		Achy asp	35	Chei sp.
	2.8	0.2	31.3	2.9	8.0	3.0	Trees	2	Euph tir	30		Acac tor	20	Flue vir				Pell cal	20	Abut ang
	2.8	0.2	31.3	2.9	8.0	3.0	Trees	2	Acac nil	15		Dich cin	15	Acac sen lei				Hibi mic	15	Lant rug
	32.5	0.2	21.3	1.4	19.0	8.0	Shrubs	2	Euph tir	30	Acac nil	Euph tir	30	Acac nil	Pani max	30	Aris ads	Hibi mic	35	
	32.5	0.2	21.3	1.4	19.0	8.0	Shrubs	2	Acac tor	30		Acac tor	20	Grew vil	Aris bip	20	Enne cen	Chei sp.	35	
	32.5	0.2	21.3	1.4	19.0	8.0	Shrubs	2	Dich cin	25		Dich cin	15	Flue vir	Aris con	10	Meli rep	Rhyn min	30	
	32.5	0.2	21.3	1.4	19.0	8.0	Shrubs	2									Erag rig			
	4.5	0.2	45.0	2.6	6.8	5.3	Trees	1	Euph tir	60	Dich cin	Euph tir	40	Flue vir	Pani max	100		Achy asp	30	Conv sag
	4.5	0.2	45.0	2.6	6.8	5.3	Trees	1	Acac tor	25		Acac tor	30					Chei sp.	20	Abut aus
	4.5	0.2	45.0	2.6	6.8	5.3	Trees	1	Acac nil	10		Dich cin	20					Rhyn min	15	Hibi mic
Penge	11.3	0.2	20.0	2.9	22.0	5.8	Trees	2	Acac tor	70		Acac tor	50	Euph ing	Cenc cil	40	Uroc mos	Achy asp	50	Cyat lan
	11.3	0.2	20.0	2.9	22.0	5.8	Trees	2	Dich cin	25		Dich cin	35		Enne cen	25		Hibi mic	25	
	11.3	0.2	20.0	2.9	22.0	5.8	Trees	2	Acac nil	5		Acac nil	10		Erag rig	20		Abut aus	15	
	5.3	0.1	2.8	1.6	10.5	2.5	Grasses	3	Acac tor	45	Albi ant	Acac tor	70		Cenc cil	40	Aris con	Teph pur	35	Hibi mic
	5.3	0.1	2.8	1.6	10.5	2.5	Grasses	3	Acac nig	25		Dich cin	30		Enne cen	30	Erag leh	Corc kir	30	Indi sp.







Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs	
Kromellenboog	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3	Acac tor	60		Acac tor	45		Cyno dac	35	Erag leh	Boer ere	20	Sola pan	
	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3	Dich cin	25		Dich cin	35		Aris con	30	Uroc mos	With som	15	Gomp fru	
	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3	Acac nil	15		Acac nil	20		Aris sca	15	Trag ber	Alte pun	10	Indi sp.	
	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3												Gomph cel	
	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3												Evol als	
	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3												Sida cor	
	14.8	0.1	18.8	2.1	28.8	4.0	Trees	3												Sola inc	
	19.3	0.3	0.0	0.0	31.8	2.8	Forbs	3	-			-			Cyno dac	35	Aris con	With som	20	Corc asp	
	19.3	0.3	0.0	0.0	31.8	2.8	Forbs	3	-			-			Uroc mos	20	Meli rep	Boer ere	15	Bide bip	
	19.3	0.3	0.0	0.0	31.8	2.8	Forbs	3	-			-			Aris ads	10	Erag rac	Sola pan	15	Perg dae	
	19.3	0.3	0.0	0.0	31.8	2.8	Forbs	3									Erag leh			Schk pin	
	19.3	0.3	0.0	0.0	31.8	2.8	Forbs	3												Senn sp.	
	19.3	0.3	0.0	0.0	31.8	2.8	Forbs	3												Arge och	
	4.3	0.1	27.5	1.6	9.3	2.5	Trees	2	Euph tir	50	Bala mau	Acac tor	35	Cada ter	Aris con	40	Aris ads	Rhyn min	35	Poly vir	
	4.3	0.1	27.5	1.6	9.3	2.5	Trees	2	Dich cin	20	Flue vir	Euph tir	25	Acac nil	Pani max	30		Teph pur	Euph tir	30	Aste sp.
	4.3	0.1	27.5	1.6	9.3	2.5	Trees	2	Acac tor	10	Acac nil	Dich cin	20	Flue vir	Meli rep	20		Hibi mic		15	Psia pun
	10.5	0.1	8.8	1.2	16.8	3.3	Shrubs	2	Euph tir	35	Flue vir	Euph tir	60	Acac nil	Aris con	35	Pani max	Teph pur	25	Aste sp.	
	10.5	0.1	8.8	1.2	16.8	3.3	Shrubs	2	Acac tor	30		Acac tor	20		Aris ads	25		Rhyn min	20	Bide bip	
	10.5	0.1	8.8	1.2	16.8	3.3	Shrubs	2	Dich cin	25		Dich cin	15		Meli rep	25		Boer ere	15	Melh acu	
	10.5	0.1	8.8	1.2	16.8	3.3	Shrubs	2												Sida cor	
	26.3	0.2	46.3	2.9	24.0	5.0	Trees	1	Euph tir	55	Capp tom	Acac tor	40	Euph tir	Pani max	80		Pavo bur	35	Abut son	
	26.3	0.2	46.3	2.9	24.0	5.0	Trees	1	Dich cin	25		Dich cin	30	Flue vir	Aris con	10		Rhyn min	30	Sida cor	
	26.3	0.2	46.3	2.9	24.0	5.0	Trees	1	Acac tor	10		Grew vil	15		Uroc mos	10		Sola pan	15	Hibi mic	
	1.3	0.2	16.3	1.1	2.8	1.3	Shrubs	2	Dich cin	55	Acac tor	Euph tir	65	Acac tor	Meli rep	40		Rhyn min	50		
	1.3	0.2	16.3	1.1	2.8	1.3	Shrubs	2	Acac nil	30		Acac nil	15		Aris ads	40		Rhyn tot	50		
	1.3	0.2	16.3	1.1	2.8	1.3	Shrubs	2	Euph tir	10		Dich cin	10		Aris con	20					
	7.5	0.1	7.5	1.1	30.5	3.8	Shrubs	2	Dich cin	40	Acac nil	Euph tir	60	Acac nil	Aris ads	35	Aris bip	Teph pur	30	Bulb bur	
	7.5	0.1	7.5	1.1	30.5	3.8	Shrubs	2	Euph tir	30	Bala mau	Acac tor	20		Meli rep	30		Boer ere	20	Indi neb	
	7.5	0.1	7.5	1.1	30.5	3.8	Shrubs	2	Acac tor	20		Dich cin	15		Aris con	20		Rhyn tot	10	Eury ped	
	7.5	0.1	7.5	1.1	30.5	3.8	Shrubs	2												Poly vir	
	7.5	0.1	7.5	1.1	30.5	3.8	Shrubs	2												Psia pun	
	8.0	0.2	45.0	5.3	12.0	3.8	Trees	2	Euph tir	60	Acac tor				Pani max	75		Rhyn min	50	Cony bon	
	8.0	0.2	45.0	5.3	12.0	3.8	Trees	2	Dich cin	20	Flue vir				Meli rep	15		Teph pur	30	Psia pun	
	8.0	0.2	45.0	5.3	12.0	3.8	Trees	2	Acac exu	10					Aris ads	10		Aste sp.	10	Sida cor	

## **APPENDIX B.1. VEGETATION SURVEY RESULTS**

### **B.1.2. North-West Province**

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low, 2=moderate, 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
Pomfret	60.0	0.3	10.0	0.3	32.0	5.0	Grasses	2	Acac tor	70		Acac mel	30	Acac tor	Hete con	40	Erag rig	Gomp fru	50	
	60.0	0.3	10.0	0.3	32.0	5.0	Grasses	2	Term ser	30		Term ser	25		Meli rep	20	Aris mer	Cera tri	50	
	60.0	0.3	10.0	0.3	32.0	5.0	Grasses	2				Acac eri	25		Cenc cil	20	Hypha hir			
	40.0	0.2	5.0	0.5	33.0	6.0	Grasses	1	-			Acac eri	45	Acac tor	Hete con	60	Aris con	Bulb bur	100	
	40.0	0.2	5.0	0.5	33.0	6.0	Grasses	1	-			Acac cal	35		Meli rep	20	Stip uni			
	40.0	0.2	5.0	0.5	33.0	6.0	Grasses	1	-			Acac mel	10		Erag rig	10	Fing afr			
	50.0	0.2	5.0	1.0	48.0	7.0	Grasses	1	Acac tor	30	Grew occ	Acac tor	30	Acac eri	Hete con	30	Meli rep	Gomp fru	40	
	50.0	0.2	5.0	1.0	48.0	7.0	Grasses	1	Zizi muc	30		Term ser	25	Rhus ten	Cenc cil	20	Aris sti	Senn ita	30	
	50.0	0.2	5.0	1.0	48.0	7.0	Grasses	1	Acac eri	30		Acac mel	20		Erag rig	10	Aris mer	Verb enc	30	
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3	Acac lue lue	30	Acac eri	Acac mel	35	Grew flava	Cenc cil	15	Erag rig	Trib zey	20	Acal ang
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3	Acac mel	20	Grew flava	Acac lue lue	20	Ehre rig	Stip uni	10	Schm pap	Comm pen	20	Perg dae
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3	Acac tor	20	Pros gla	Rhus ten	10	Zizi muc	Aris sti	10	Meli rep	Senn ita	5	Sola pan
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3									Erag tri			Abut ram
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3									Uroc pan			Pavo bur
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3									Aris con			Cera tri
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3									Fing afr			Alte pun
	30.0	0.1	0.0	0.0	12.0	10.0	Grasses	3									Pani max			
	10.0	0.1	40.0	2.0	22.0	3.0	Trees	3	Acac mel	30	Grew flava	Acac mel	25	Term ser	Hete con	40	Uroc pan	Cera tri	20	Verb enc
	10.0	0.1	40.0	2.0	22.0	3.0	Trees	3	Acac tor	20	Bosc alb	Acac tor	20	Grew flava	Cenc cil	30		Perg dae	15	Comm pen
	10.0	0.1	40.0	2.0	22.0	3.0	Trees	3	Acac lue lue	15	Term ser	Rhus ten	15	Grew occ	Aris con	20		Acal ang	15	Trib zey
	10.0	0.1	40.0	2.0	22.0	3.0	Trees	3			Opun fic				Ehre rig					Heli sp.
	10.0	0.1	40.0	2.0	22.0	3.0	Trees	3												Citr lan
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3	Term ser	30	Grew flava	Acac lue lue	25	Rhus ten	Aris con	30	Erag tri	Trib zey	20	Cera tri
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3	Acac lue lue	25	Grew occ	Grew flava	15	Dich cin	Schm pap	30	Stip uni	Elep ele	10	Citr lan
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3	Dich cin	20	Acac eri	Term ser	10	Pros gla	Cenc cil	15	Pani max	Acal ang	10	Comm pen
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3							Bosc alb		Enne sco			Cleo mon
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3							Ehre rig					Teph cap
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3							Acac mel					Hibi tri
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3												Cocc ses
	15.0	0.1	25.0	1.8	30.0	3.0	Trees	3												Tapi ole
	40.0	0.3	20.0	2.8	17.0	6.0	Trees	2	Acac mel	60		Acac mel	70		Hete con	40	Meli rep	Poly hot	100	
	40.0	0.3	20.0	2.8	17.0	6.0	Trees	2	Acac lue lue	40		Acac lue lue	30		Aris sti	20	Aris mer			
	40.0	0.3	20.0	2.8	17.0	6.0	Trees	2							Stip uni	15	Fing afr			
	40.0	0.3	20.0	2.8	17.0	6.0	Trees	2									Aris con			
	15.0	0.3	0.0	0.0	18.0	5.0	Grasses	2	-			-			Hete con	35	Meli rep	Senn ita	60	
	15.0	0.3	0.0	0.0	18.0	5.0	Grasses	2	-			-			Fing afr	25	Stip uni	Tapi ole	40	
	15.0	0.3	0.0	0.0	18.0	5.0	Grasses	2	-			-			Cenc cil	15	Aris con			
	60.0	0.4	10.0	4.0	14.0	8.0	Grasses	1	Acac mel	50		Acac mel	60		Hete con	70	Fing afr			
	60.0	0.4	10.0	4.0	14.0	8.0	Grasses	1	Acac lue lue	40		Acac lue lue	35		Stip uni	15	Meli rep			
	60.0	0.4	10.0	4.0	14.0	8.0	Grasses	1	Acac eri	10		Acac eri	5		Hype dis	5				
	15.0	0.2	15.0	3.5	10.0	3.0	Trees	3	Acac mel	75		Acac mel	40		Stip uni	35	Hete con	Walt ind	40	Verb enc
	15.0	0.2	15.0	3.5	10.0	3.0	Trees	3	Dich cin	25		Bosc alb	35		Schm pap	20	Anth pub	Senn ita	25	Tapi ole
	15.0	0.2	15.0	3.5	10.0	3.0	Trees	3				Dich cin	25		Cenc cil	20	Aris con	Hibi mic	20	
	5.0	0.1	35.0	2.5	6.0	2.0	Trees	3	Acac mel	70		Acac mel	50	Dich cin	Hete con	55	Aris ads	Walt ind	50	Lant rug
	5.0	0.1	35.0	2.5	6.0	2.0	Trees	3	Dich cin	20		Acac lue lue	20	Grew occ	Aris con	15	Meli rep	Sola pan	35	
	5.0	0.1	35.0	2.5	6.0	2.0	Trees	3	Acac lue lue	10		Bosc alb	15		Cenc cil	10		Acal ang	10	
	5.0	0.2	25.0	2.0	7.0	3.0	Trees	3	Dich cin	55		Acac mel	40	Ehre rig	Stip uni	30	Enne sco	Helio ova	25	Sarc vim
	5.0	0.2	25.0	2.0	7.0	3.0	Trees	3	Acac mel	45		Dich cin	25	Bosc alb	Aris con	20	Cenc cil	Hermb odo	20	Gomp fru
	5.0	0.2	25.0	2.0	7.0	3.0	Trees	3				Grew occ	15		Fing afr	15	Meli rep	Hibi mic	15	Lant rug
	5.0	0.2	25.0	2.0	7.0	3.0	Trees	3									Erag ech			Sola tet
	5.0	0.2	25.0	2.0	7.0	3.0	Trees	3									Hete con			Perg dae



## **APPENDIX B.1. VEGETATION SURVEY RESULTS**

### **B.1.3. Northern Cape Province**



Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low, 2=moderate, 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
Sardinia	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.			Acac mel	60		Hete con	20	Digi eri	Evol als	20	Walt ind
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.			Lyci cin	40		Stip uni	15	Pani col	Sida rho	15	Senn ita
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.						Anth pub	15	Meli ner	Stac sp.	10	Corc asp
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.							Meli rep				Gise pha
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.							Cenc cil				Leuc sp.
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.							Erag pal				Myrs afr
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.							Trag ber				Verb enc
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.											Sesa tri
	55.0	0.1	2.0	0.6	33.0	8.0	Grasses	2	.											Cera tri
	25.0	0.2	0.0	0.0	13.0	3.0	Grasses	2	.						Hete con	35	Uroc pan	Walt ind	30	Lime vis
	25.0	0.2	0.0	0.0	13.0	3.0	Grasses	2	.						Cenc cil	30	Trag ber	Cera tri	30	Gise pha
	25.0	0.2	0.0	0.0	13.0	3.0	Grasses	2	.						Meli rep	20	Aris con	Teph pur	20	Corc asp
	25.0	0.2	0.0	0.0	13.0	3.0	Grasses	2	.											Gomp fru
	25.0	0.2	0.0	0.0	13.0	3.0	Grasses	2	.											Kyph ang
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.			Acac mel	40	Eher rig	Hete con	30	Meli rep	Walt ind	20	Acal ang
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.			Eucl und	30		Stip uni	20	Schm pap	Evol als	20	Stac sp.
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.			Tarc cam	20		Anth pub	15	Meli ner	Sida rho	10	Cera tri
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.											Senn ita
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.								Pani col			Corc asp
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.								Digi eri			Gomp fru
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.											Gise pha
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.											Kyph ang
	50.0	0.2	5.0	1.0	38.0	7.0	Grasses	2	.											Feli mur
	40.0	0.1	1.0	0.2	17.0	7.0	Grasses	2	.			Acac mel	80		Hete con	30	Anth pub	Walt ind	30	Tage min
	40.0	0.1	1.0	0.2	17.0	7.0	Grasses	2	.			Tarc cam	20		Cenc cil	25	Cyno dac	Senn ita	20	Bide bip
	40.0	0.1	1.0	0.2	17.0	7.0	Grasses	2	.						Meli rep	20	Aris con	Gomp fru	15	Schk pin
	40.0	0.1	1.0	0.2	17.0	7.0	Grasses	2	.											Sola nig
	40.0	0.1	1.0	0.2	17.0	7.0	Grasses	2	.											Sals kal
	30.0	0.1	5.0	1.5	29.0	7.0	Grasses	3	.	Acac eri	100	Tarc cam	60		Cenc cil	40	Uroc pan	Walt ind	40	Teuc tri
	30.0	0.1	5.0	1.5	29.0	7.0	Grasses	3	.			Rhus sp.	30		Hete con	25	Meli rep	Schk pin	35	Melh pro
	30.0	0.1	5.0	1.5	29.0	7.0	Grasses	3	.			Eucl und	10		Aris con	15	Cyno dac	Gomp fru	15	Myrs afr
	25.0	0.3	0.0	0.0	34.0	6.0	Grasses	3	.						Cenc cil	60		Gomp fru	35	Tage min
	25.0	0.3	0.0	0.0	34.0	6.0	Grasses	3	.						Hete con	30		Senn ita	25	Schk pin
	25.0	0.3	0.0	0.0	34.0	6.0	Grasses	3	.						Meli rep	10		Bide bip	15	Cera tri
White Rock	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.	Acac mel	90	Acac mel	50		Aris con	50	Cenc cil	Myrs afr	20	Boer ere
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.	Pros gla	10	Acac heb	40		Hete con	20	Meli rep	Walt ind	15	Suth sp.
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.			Rhig obo	10		Stip uni	10	Erag leh	Poly hot	10	Acal ang
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.											Herm sp.
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.											Evol als
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.											Cera tri
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.											Gomp fru
	25.0	0.1	5.0	1.0	74.0	7.0	Grasses	3	.											Teuc tri
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.			Acac mel	35	Grew flava	Meli rep	40	Schm pap	Myrs afr	20	Poly hot
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.			Acac heb	30	Acac eri	Aris con	30	Erag leh	Pter spe	10	Boer ere
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.			Tarc cam	15	Rhig obo	Hete con	20	Aris mer	Walt ind	10	Senn ita
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.								Elio mut			Evol als
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Teuc tri
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Tapi ole
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Rhyn tot
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Gomp fru
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Apto sp.
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Sola inc
	15.0	0.2	3.0	1.0	38.0	4.0	Grasses	3	.											Geig bur
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3	.	Acac eri	40	Acac mel	40	Acac eri	Aris con	30	Trag ber	Senn ita	25	Geig bur
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3	.	Acac mel	35	Tarc cam	25	Acac kar	Meli rep	20	Cenc cil	Walt ind	20	Boer ere
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3	.	Tarc cam	25	Zizi muc	20		Stip uni	20	Hete con	Myrs afr	10	Tapi ole
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3	.								Schm pap			Gomp fru

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3												Sola sp.
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3												Indi sp.
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3												Cera tri
	30.0	0.1	20.0	2.2	67.0	8.0	Grasses	3												Aloe her
Mt Vera	30.0	0.2	2.0	0.8	31.0	6.0	Grasses	2	-			Grew flava	80		Meli rep	35	Aris con	Walt ind	30	Sida sp.
	30.0	0.2	2.0	0.8	31.0	6.0	Grasses	2	-			Acac mel	20		Cenc cil	30	Erag leh	Melo can	25	Ptero vis
	30.0	0.2	2.0	0.8	31.0	6.0	Grasses	2	-						Stip uni	20	Digi eri	Evol als	20	Cera tri
	30.0	0.2	2.0	0.8	31.0	6.0	Grasses	2	-								Hete con			Senn ita
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2	-						Cenc cil	45	Stip uni	Walt ind	25	Hibi mic
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2	-						Aris con	25	Erag leh	Ptero vis	15	Evol als
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2	-						Meli rep	20		Sida sp.	10	Koha ama
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2												Cera tri
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2												Acal ang
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2												Teph pur
	30.0	0.2	0.0	0.0	50.0	9.0	Grasses	2												Corc asp
	45.0	0.2	0.0	0.0	29.0	8.0	Grasses	2	-						Cenc cil	40	Aris con	Evol als	20	Aloe her
	45.0	0.2	0.0	0.0	29.0	8.0	Grasses	2	-						Meli rep	20	Stip uni	Sida sp.	15	Ptero vis
	45.0	0.2	0.0	0.0	29.0	8.0	Grasses	2	-						Erag leh	15	Schm pap	Cera tri	10	Gise pha
	45.0	0.2	0.0	0.0	29.0	8.0	Grasses	2									Digi eri			Walt ind
	45.0	0.2	0.0	0.0	29.0	8.0	Grasses	2												Hibi mic
	45.0	0.2	0.0	0.0	29.0	8.0	Grasses	2												Teph pur
Engeland	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2	-						Hete con	40	Aris con	Cera tri	20	Schk pin
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2	-						Cenc cil	35	Digi eri	Gomp fru	20	Acal ang
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2	-						Meli rep	15	Schm pap	Tage min	10	Poly hot
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2												Teuc tri
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2												Cleo mon
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2												Sonc wil
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2												Geig bur
	35.0	0.2	0.0	0.0	61.0	6.0	Grasses	2												Walt ind
	25.0	0.1	3.0	1.2	81.0	6.0	Grasses	2	-			Grew flava	65		Aris con	45	Stip uni	Schk pin	60	Sida sp.
	25.0	0.1	3.0	1.2	81.0	6.0	Grasses	2	-			Acac mel	35		Meli rep	30	Cenc cil	Gise pha	25	Cera tri
	25.0	0.1	3.0	1.2	81.0	6.0	Grasses	2	-						Uroc mos	10	Enne cen	Poly hot	10	Cleo rub
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2	Acac kar	55		Grew flava	60		Hete con	25	Hypa hir	Gomp fru	15	Trb zey
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2	Grew flava	40		Acac mel	40		Cenc cil	20	Erag leh	Barl sp.	10	Hibi mic
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2	Zizi muc	5					Meli rep	10	Stip uni	Geig bur	10	Rhyn tot
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2									Aris con			Sida sp.
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2									Schm pap			Evol als
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2									Enne cen			Acal ang
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2									Erag ech			Bide bip
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2									Sorg hal			Melo can
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2												Senn ita
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2												Schk pin
	40.0	0.3	10.0	2.0	28.0	7.0	Grasses	2												Cleo mon
Coretsi	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3	-			Acac mel	70		Aris con	50	Cyno dac	Walt ind	30	Myrs afr
	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3	-			Pros gla	30		Meli rep	30		Senn ita	25	Boer ere
	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3							Stip obt	15		Gomp fru	10	Cera tri
	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3												Evol als
	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3												Schk pin
	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3												Kyph ang
	10.0	0.1	5.0	0.8	18.0	3.0	Forbs	3												Sida sp.
	2.0	0.1	1.0	1.2	2.0	1.0	Forbs	3	-			Pros gla	100		Meli rep	55		Schk pin	65	Aloe her
	2.0	0.1	1.0	1.2	2.0	1.0	Forbs	3	-						Aris con	45		Senn ita	20	
	2.0	0.1	1.0	1.2	2.0	1.0	Forbs	3	-									Tage min	10	
	1.0	0.1	0.0	0.0	14.0	1.0	Forbs	3	-						Aris con	100		Walt ind	55	Senn ita
	1.0	0.1	0.0	0.0	14.0	1.0	Forbs	3	-									Tage min	30	
	1.0	0.1	0.0	0.0	14.0	1.0	Forbs	3	-									Schk pin	10	

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low; 2=moderate; 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs	
Ruries	60.0	0.2	10.0	1.4	9.0	11.0	Grasses	2	Acac mel	60		Pros gla	35		Cenc cil	50	Hete con	Indi sp.	30	Walt ind	
	60.0	0.2	10.0	1.4	9.0	11.0	Grasses	2	Pros gla	40		Acac eri	35		Schm pap	25	Aris con	Poly hot	20	Gomp fru	
	60.0	0.2	10.0	1.4	9.0	11.0	Grasses	2				Acac mel	30		Meli rep	10	Stip uni	Koha ama	15	Cera tri	
	60.0	0.2	10.0	1.4	9.0	11.0	Grasses	2									Fing afr				Gaza kre
	40.0	0.2	0.0	0.0	43.0	7.0	Grasses	1	-				-		Meli rep	30	Stip uni	Melo can	40	Teph cap	
	40.0	0.2	0.0	0.0	43.0	7.0	Grasses	1	-				-		Aris con	25	Cymb plu	Walt ind	15	Corc asp	
	40.0	0.2	0.0	0.0	43.0	7.0	Grasses	1	-				-		Cenc cil	15	Schm pap	Indi sp.	10	Myrs afr	
	40.0	0.2	0.0	0.0	43.0	7.0	Grasses	1	-				-								Koha ama
	35.0	0.2	5.0	0.8	48.0	9.0	Grasses	1	-				Acac eri	65		Cenc cil	35	Stip uni	Melo can	30	Corc asp
	35.0	0.2	5.0	0.8	48.0	9.0	Grasses	1	-				Acac eri	25		Meli rep	30	Schm pap	Chama mim	30	Geig bur
	35.0	0.2	5.0	0.8	48.0	9.0	Grasses	1	-				Acac mel	10		Hete con	10	Aris con	Indi sp.	20	Gise pha
	40.0	0.3	2.0	1.5	7.0	6.0	Grasses	2		Acac eri	100		Acac eri	90		Cenc cil	60	Schm pap	Melo can	70	
	40.0	0.3	2.0	1.5	7.0	6.0	Grasses	2					Rhig tri	10		Hete con	20		Senn ita	30	
	40.0	0.3	2.0	1.5	7.0	6.0	Grasses	2								Meli rep	15				
	30.0	0.1	0.0	0.0	22.0	6.0	Grasses	3	-				-		Stip uni	40	Aris con	Gomp fru	30	Thes sp.	
	30.0	0.1	0.0	0.0	22.0	6.0	Grasses	3	-				-		Cenc cil	25	Meli rep	Poly hot	30	Feli mur	
	30.0	0.1	0.0	0.0	22.0	6.0	Grasses	3	-				-			Hete con	20	Schm pap	Nido ano	20	Trib zey
	20.0	0.1	5.0	1.2	9.0	3.0	Grasses	2		Pros gla	60		Acac eri	70		Cenc cil	25	Schm pap	Melo can	20	Poly hot
	20.0	0.1	5.0	1.2	9.0	3.0	Grasses	2		Acac eri	40		Acac mel	30		Stip uni	25	Hete con	Senn ita	15	Geig bur
	20.0	0.1	5.0	1.2	9.0	3.0	Grasses	2								Meli rep	20	Aris con	Blum gar	15	Suth sp.
	20.0	0.1	5.0	1.2	9.0	3.0	Grasses	2									Hypa hir				Teph cap
	20.0	0.1	5.0	1.2	9.0	3.0	Grasses	2									Cymb plu				
	20.0	0.1	5.0	1.2	9.0	3.0	Grasses	2									Erag rig				
	Merencor	10.0	0.2	0.0	0.0	31.0	6.0	Grasses	2	-			-			Stip uni	25	Aris con	Walt ind	40	Cera tri
		10.0	0.2	0.0	0.0	31.0	6.0	Grasses	2	-			-			Meli rep	20	Aris mer	Evol als	30	Alte pun
		10.0	0.2	0.0	0.0	31.0	6.0	Grasses	2	-			-			Cenc cil	20	Enne cen	Sida sp.	10	Dico sp.
		10.0	0.2	0.0	0.0	31.0	6.0	Grasses	2									Brac nig			
10.0		0.2	0.0	0.0	31.0	6.0	Grasses	2									Dihe amp				
35.0		0.3	1.0	0.5	52.0	8.0	Grasses	2	-				Acac mel	100		Stip uni	35	Erag leh	Gise pha	20	Hibi mic
35.0		0.3	1.0	0.5	52.0	8.0	Grasses	2	-							Schm pap	25	Meli rep	Walt ind	15	Acal ang
35.0		0.3	1.0	0.5	52.0	8.0	Grasses	2	-							Aris mer	15	Uroc mos	Teph pur	10	Cera tri
35.0		0.3	1.0	0.5	52.0	8.0	Grasses	2									Aris con				Cleo rub
35.0		0.3	1.0	0.5	52.0	8.0	Grasses	2									Rhyn nig				Rhyn tot
35.0		0.3	1.0	0.5	52.0	8.0	Grasses	2									Cenc cil				Senn ita
40.0		0.3	0.0	0.0	50.0	9.0	Grasses	2	-				-			Stip uni	40	Erag leh	Evol als	30	Indi hed
40.0		0.3	0.0	0.0	50.0	9.0	Grasses	2	-				-			Meli rep	20	Cenc cil	Walt ind	20	Cera tri
40.0		0.3	0.0	0.0	50.0	9.0	Grasses	2	-				-			Schm pap	15	Aris con	Sida sp.	15	Acal ang
40.0		0.3	0.0	0.0	50.0	9.0	Grasses	2									Fing afr				Cleo rub
40.0		0.3	0.0	0.0	50.0	9.0	Grasses	2									Aris mer				Gise pha
Wandrag Complex		35.0	0.2	2.0	0.3	22.0	4.0	Grasses	2	-			Acac mel	100		Hypa hir	45	Stip uni	Thes sp.	35	Walt ind
		35.0	0.2	2.0	0.3	22.0	4.0	Grasses	2	-						Cenc cil	20	Erag rig	Evol als	30	Teph pur
		35.0	0.2	2.0	0.3	22.0	4.0	Grasses	2	-						Meli rep	15		Blum gar	25	Gomp fru
		50.0	0.4	10.0	1.5	19.0	10.0	Grasses	2		Acac mel	100		Grew flava	50		Hypa hir	55	Meli rep	Cleo mon	30
	50.0	0.4	10.0	1.5	19.0	10.0	Grasses	2					Acac mel	50		Schm pap	25	Erag rig	Cera tri	25	Myrs afr
	50.0	0.4	10.0	1.5	19.0	10.0	Grasses	2								Stip uni	10	Hete con	Chen car	15	Walt ind
	50.0	0.4	10.0	1.5	19.0	10.0	Grasses	2									Aris con				Indi hed
	40.0	0.1	2.0	1.8	27.0	10.0	Grasses	2		Acac mel	60		Acac mel	100		Meli rep	30	Hete con	Blum gar	20	Evol als
	40.0	0.1	2.0	1.8	27.0	10.0	Grasses	2		Zizi muc	40					Cenc cil	20	Aris con	Gomp fru	15	Teph pur
	40.0	0.1	2.0	1.8	27.0	10.0	Grasses	2								Hypa hir	20	Erag leh	Indi sp.	15	Geig bur
40.0	0.1	2.0	1.8	27.0	10.0	Grasses	2									Stip uni				Cera tri	

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low, 2=moderate, 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs		
Wandrag Complex	40.0	0.1	2.0	1.8	27.0	10.0	Grasses	2												Walt ind		
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2	Acac mel	50		Acac mel	30	Tarc cam	Hypa hir	25	Stip uni	Barl sp.	20	Gomp cel		
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2	Lyci cin	30		Lyci cin	25	Cada aph	Hete con	20	Schm pap	Blum gar	10	Herm gla		
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2	Zizi muc	20		Zizi muc	20		Cenc cil	20	Aris con	Evol als	10	Sida rho		
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2									Meli rep				Bide bip	
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2									Aris mer				Tage min	
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2									Uroc mos				Geig bur	
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2													Hibi mic	
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2													Phyl par	
	30.0	0.2	5.0	1.7	21.0	5.0	Grasses	2													Chen car	
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3	Lyci cin	35		Lyci cin	30	Tarc cam	Cenc cil	40	Aris con	Blum gar	30	Myrs afr		
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3	Zizi muc	30		Zizi muc	30		Hypa hir	30	Meli rep	Tage min	20	Data fer		
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3	Acac mel	25		Grew flava	15	Eucl und	Hete con	15		Chen car	10	Trnb ter		
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3													Gomp fru	
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3													Feli mur	
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3													Geig bur	
	10.0	0.1	10.0	1.2	30.0	3.0	Grasses	3													Schk pin	
	20.0	0.1	5.0	1.0	40.0	5.0	Grasses	2	Acac mel	100		Acac mel	100		Hete con	25	Hypa hir	Blum gar	20	Jarne sp.		
	20.0	0.1	5.0	1.0	40.0	5.0	Grasses	2								Meli rep	20	Cenc cil	Barl sp.	20	Phyl par	
	20.0	0.1	5.0	1.0	40.0	5.0	Grasses	2								Stip uni	15	Brac nig	Gomp fru	15	Cleo mon	
	20.0	0.1	5.0	1.0	40.0	5.0	Grasses	2										Enne cen				Teph pur
	20.0	0.1	5.0	1.0	40.0	5.0	Grasses	2										Schm pap				Tage min
	15.0	0.1	5.0	2.0	35.0	3.0	Grasses	3	Acac kar	65		Acac kar	40		Cenc cil	35	Aris con	Walt ind	45	Indi sp.		
	15.0	0.1	5.0	2.0	35.0	3.0	Grasses	3	Lyci cin	35		Acac mel	30		Hete con	30	Meli rep	Teph pur	35			
	15.0	0.1	5.0	2.0	35.0	3.0	Grasses	3				Lyci cin	30		Hypa hir	20	Erag leh	Geig bur	15			
	15.0	0.1	5.0	2.0	35.0	3.0	Grasses	3										Schm pap				
	10.0	0.2	0.0	0.0	13.0	2.0	Grasses	2	-			-			Cenc cil	30	Hete con	Cera tri	30	Walt ind		
	10.0	0.2	0.0	0.0	13.0	2.0	Grasses	2	-			-			Hypa hir	20	Aris con	Bide bip	20	Poll cam		
	10.0	0.2	0.0	0.0	13.0	2.0	Grasses	2	-			-			Meli rep	15	Stip uni	Schk pin	20			
	10.0	0.2	0.0	0.0	13.0	2.0	Grasses	2									Uroc mos					
	10.0	0.2	20.0	1.8	12.0	3.0	Trees	3	Tarc cam	40	Acac kar	Tarc cam	35		Cenc cil	50		Walt ind	100			
	10.0	0.2	20.0	1.8	12.0	3.0	Trees	3	Acac mel	30		Acac mel	35		Hypa hir	30						
	10.0	0.2	20.0	1.8	12.0	3.0	Trees	3	Zizi muc	20		Acac kar	30		Hete con	20						
	35.0	0.2	20.0	1.2	51.0	8.0	Grasses	1	Acac mel	70		Acac mel	70		Hete con	40	Stip uni	-				
	35.0	0.2	20.0	1.2	51.0	8.0	Grasses	1	Acac kar	30		Acac kar	20		Cenc cil	40		-				
35.0	0.2	20.0	1.2	51.0	8.0	Grasses	1				Tarc cam	10		Meli rep	10		-					
40.0	0.2	15.0	1.5	37.0	7.0	Grasses	1	Acac mel	100		Acac mel	80		Cenc cil	30	Erag leh	Teuc tri	30	Verb enc			
40.0	0.2	15.0	1.5	37.0	7.0	Grasses	1				Zizi muc	20		Schm pap	30	Meli rep	Senn ita	25	Teph pur			
40.0	0.2	15.0	1.5	37.0	7.0	Grasses	1							Hete con	15	Stip uni	Cleo rub	15	Cera tri			
40.0	0.2	15.0	1.5	37.0	7.0	Grasses	1									Aris con				Gomp fru		
35.0	0.3	0.0	0.0	22.0	7.0	Grasses	1	-			-			Hete con	40	Meli rep	Senn ita	30	Cleo mon			
35.0	0.3	0.0	0.0	22.0	7.0	Grasses	1	-			-			Cenc cil	20	Schm pap	Cera tri	20	Chen car			
35.0	0.3	0.0	0.0	22.0	7.0	Grasses	1	-			-			Erag leh	20	Enne cen	Teuc tri	15	Data fer			
35.0	0.3	0.0	0.0	22.0	7.0	Grasses	1													Indi sp.		
Whitebank Complex	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1	-		-			Meli rep	20	Erag tri	Ptero vis	20	Heli sp.			
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1	-		-			Hete con	15	Hypa hir	Evol als	10	Indi sp.			
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1	-		-			Enne cen	10	Pani max	Schk pin	10	Walt ind			
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1									Aris con				Poly hot	
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1									Stip uni				Ursi nan	
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1									Tric gra				Phyl par	
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1									Elio mut					
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1									Erag sup					
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1										Fing afr				
	40.0	0.2	0.0	0.0	58.0	7.0	Grasses	1									Schm pap					
	30.0	0.2	5.0	1.0	38.0	4.0	Grasses	2	-			Acac mel	100		Aris con	35	Meli ner	Geig bur	25	Bide bip		
	30.0	0.2	5.0	1.0	38.0	4.0	Grasses	2	-						Meli rep	20	Elio mut	Walt ind	20	Pupa lap		
	30.0	0.2	5.0	1.0	38.0	4.0	Grasses	2	-						Aris mer	10	Hete con	Tage min	15	Heli sp.		

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Whitebank Complex	30.0	0.2	5.0	1.0	38.0	4.0	Grasses	2									Micr caf			Sida cor								
	30.0	0.2	5.0	1.0	38.0	4.0	Grasses	2									Stip uni			Indi sp.								
	35.0	0.2	0.0	0.0	45.0	6.0	Grasses	2	-								Aris con	40	Aris mer	Melo can	30	Schk pin						
	35.0	0.2	0.0	0.0	45.0	6.0	Grasses	2	-								Meli rep	20	Erag cur	Walt ind	25	Tage min						
	35.0	0.2	0.0	0.0	45.0	6.0	Grasses	2	-								Hypa hir	10	Cenc cil	Indi sp.	10	Arge och						
	35.0	0.2	0.0	0.0	45.0	6.0	Grasses	2									Micr caf					Ptero vis						
	35.0	0.2	0.0	0.0	45.0	6.0	Grasses	2									Elio mut					Lant rug						
	35.0	0.2	0.0	0.0	45.0	6.0	Grasses	2														Poly hot						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2	-			Nico gla	45				Aris con	30	Anth pub	Blum gar	30	Poll cam						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2	-			Rhus sp.	35				Meli rep	20	Aris sti	Walt ind	15	Schk pin						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2	-			Eucl und	20				Brac nig	10	Schm pap	Indi sp.	10	Ptero vis						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2														Teph pur						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2														Arge och						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2														Evol als						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2														Ursi nan						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2														Poly vir						
	30.0	0.1	5.0	0.8	60.0	9.0	Grasses	2														Bide pil						
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3	-									Cyno dac	30	Stip uni	Walt ind	20	Tage min					
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3	-									Meli rep	15	Erag sup	Schk pin	15	Datu str					
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3	-									Aris con	10	Hypa hir	Tribr ter	10	Arge och					
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3														Senn ita						
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3														Poly vir						
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3														Erag leh						
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3														Schm pap						
	35.0	0.1	0.0	0.0	39.0	8.0	Grasses	3														Enne cen						
	25.0	0.2	2.0	0.8	28.0	5.0	Grasses	2	-			Eucl und	40	Rhig obo			Meli rep	30	Brac nig	Geig bur	25	Tage min						
	25.0	0.2	2.0	0.8	28.0	5.0	Grasses	2	-			Ehre rig	30	Cada aph			Hete con	20	Erag tri	Indi sp.	20	Arge och						
	25.0	0.2	2.0	0.8	28.0	5.0	Grasses	2	-			Tarc cam	15				Aris con	10	Elio mut	Poly hot	20	Schk pin						
	25.0	0.2	2.0	0.8	28.0	5.0	Grasses	2														Erag cap						
	25.0	0.2	2.0	0.8	28.0	5.0	Grasses	2														Erag leh						
	30.0	0.3	2.0	0.5	18.0	3.0	Grasses	2	-			Acac mel	100				Enne cen	50	Hypa hir	Chry cil	20	Bide bip						
	30.0	0.3	2.0	0.5	18.0	3.0	Grasses	2	-									Aris con	15	Aris mer	Dico cap	15	Chen alb					
	30.0	0.3	2.0	0.5	18.0	3.0	Grasses	2	-									Hete con	10	Meli rep	Schk pin	10	Ursi nan					
	30.0	0.3	2.0	0.5	18.0	3.0	Grasses	2														Oste mic						
	30.0	0.3	2.0	0.5	18.0	3.0	Grasses	2														Tage min						
	30.0	0.3	2.0	0.5	18.0	3.0	Grasses	2														Feli mur						
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1	-													Sida cor						
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1	-									Enne cen	35	Erag leh	Schk pin	30	Arge och					
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1	-													Meli rep	25	Aris ads	Nena mic	25	Ptero vis	
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1	-													Stip uni	15	Aris con	Chry cil	10	Heli zey	
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1															Hypa hir				Bulb his	
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1															Aris mer				Tage min	
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1															Schm pap				Sida cor	
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1															Erag cur				Suth fru	
	55.0	0.3	0.0	0.0	69.0	8.0	Grasses	1															Digi eri					
	20.0	0.2	3.0	0.7	23.0	4.0	Grasses	2				Acac mel	100										Meli rep	30	Hypa hir	Ursi nan	25	Tage min
	20.0	0.2	3.0	0.7	23.0	4.0	Grasses	2															Enne cen	20	Erag leh	Schk pin	25	Indi sp.
	20.0	0.2	3.0	0.7	23.0	4.0	Grasses	2															Aris con	15	Stip uni	Chry cil	10	Chen alb
	20.0	0.2	3.0	0.7	23.0	4.0	Grasses	2																Aris jun				Feli mur
	20.0	0.2	3.0	0.7	23.0	4.0	Grasses	2															Digi eri				Dico cap	
	40.0	0.2	0.0	0.0	31.0	8.0	Grasses	1	-														Hete con	25	Aris con	Schk pin	45	Arge och
	40.0	0.2	0.0	0.0	31.0	8.0	Grasses	1	-														Cenc cil	25	Hypa hir	Indi sp.	30	
	40.0	0.2	0.0	0.0	31.0	8.0	Grasses	1	-														Meli rep	15	Erag leh	Tage min	15	
	40.0	0.2	0.0	0.0	31.0	8.0	Grasses	1																Pogo squ				
	40.0	0.2	0.0	0.0	31.0	8.0	Grasses	1															Anth pub					
	65.0	0.4	1.0	0.8	15.0	10.0	Grasses	1	-			Acac pod	100										Cenc cil	40	Anth pub	Schk pin	70	
	65.0	0.4	1.0	0.8	15.0	10.0	Grasses	1	-														Hete con	20	Enne cen	Boer ere	30	

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low, 2=moderate, 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs	
Whitebank Complex	65.0	0.4	1.0	0.8	15.0	10.0	Grasses	1							Meli rep	10	Cyno dac				
	65.0	0.4	1.0	0.8	15.0	10.0	Grasses	1							Digi eri						
	65.0	0.4	1.0	0.8	15.0	10.0	Grasses	1							Schm pap						
	30.0	0.2	0.0	0.0	42.0	6.0	Grasses	1	-						Meli rep	30	Aris con	Schk pin	100		
	30.0	0.2	0.0	0.0	42.0	6.0	Grasses	1	-						Hete con	30	Digi eri				
	30.0	0.2	0.0	0.0	42.0	6.0	Grasses	1	-						Cenc cil	20	Cyno dac				
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2	Acac pod	100		Acac pod	60		Aris con	25	Hete con	Schk pin	30	Oste sp.	
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2				Acac mel	40		Meli rep	15	Enne cen	Tage min	20	Arge och	
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2							Stip uni	10	Cenc cil	Chry cil	15	Hermb odo	
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2									Hypa hir			Feli mur	
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2									Cymb exc			Indi ses	
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2									Dihe amp				
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2									Schm pap				
	15.0	0.1	3.0	2.0	67.0	3.0	Grasses	2									Fing afr				
	10.0	0.2	0.0	0.0	44.0	2.0	Grasses	2	-						Meli rep	35	Stip uni	Schk pin	30	Corc asp	
	10.0	0.2	0.0	0.0	44.0	2.0	Grasses	2	-						Hete con	20	Schm pap	Tage min	20	Indi sp.	
	10.0	0.2	0.0	0.0	44.0	2.0	Grasses	2	-						Aris con	15	Erag leh	Chry cil	10	Sola nig	
	10.0	0.2	0.0	0.0	44.0	2.0	Grasses	2									Brac nig			Gomp fru	
	10.0	0.2	0.0	0.0	44.0	2.0	Grasses	2									Pani max			Melh pro	
	15.0	0.1	0.0	0.0	51.0	4.0	Grasses	2	-						Aris con	20	Cymb exc	Schk pin	30	Indi sp.	
	15.0	0.1	0.0	0.0	51.0	4.0	Grasses	2	-						Meli rep	20	Hete con	Chry cil	30	Oste sp.	
	15.0	0.1	0.0	0.0	51.0	4.0	Grasses	2	-						Stip uni	15	Aris ads	Feli mur	15	Blum gar	
	15.0	0.1	0.0	0.0	51.0	4.0	Grasses	2									Brac nig			Suth fru	
	15.0	0.1	0.0	0.0	51.0	4.0	Grasses	2									Schm pap				
	15.0	0.1	0.0	0.0	51.0	4.0	Grasses	2									Fing afr				
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1	-			Rhus lan	100		Hypa hir	25	Schm pap	Indi sp.	40	Heli sp.	
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1	-						Meli rep	15	Aris con	Tage min	30	Gomp fru	
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1	-						Erag leh	10	Aris ads	Schk pin	10	Chry cil	
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1									Brac nig			Geig bur	
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1									Cenc cil			Indi alt	
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1									Fing afr			Melh pro	
	40.0	0.2	1.0	0.5	30.0	5.0	Grasses	1									Cyno dac				
	30.0	0.3	0.0	0.0	19.0	5.0	Grasses	1	-						Aris con	25	Meli rep	Geig bur	20	Teuc tri	
	30.0	0.3	0.0	0.0	19.0	5.0	Grasses	1	-						Erag leh	20	Erag rig	Indi alt	15	Tage min	
	30.0	0.3	0.0	0.0	19.0	5.0	Grasses	1	-						Hypa hir	20	Brac nig	Indi sp.	10	Schk pin	
	30.0	0.3	0.0	0.0	19.0	5.0	Grasses	1									Schm pap			Sals sp.	
	30.0	0.3	0.0	0.0	19.0	5.0	Grasses	1									Cenc cil			Feli mur	
	30.0	0.3	0.0	0.0	19.0	5.0	Grasses	1												Myrs afr	
	45.0	0.3	0.0	0.0	22.0	6.0	Grasses	2	-						Meli rep	30	Aris con	Indi sp.	25	Indi ses	
	45.0	0.3	0.0	0.0	22.0	6.0	Grasses	2	-						Hypa hir	20	Aris ads	Evol als	20	Indi alt	
	45.0	0.3	0.0	0.0	22.0	6.0	Grasses	2	-						Schm pap	15	Brac nig	Tage min	20	Geig bur	
	45.0	0.3	0.0	0.0	22.0	6.0	Grasses	2									Fing afr			Jame atr	
	45.0	0.3	0.0	0.0	22.0	6.0	Grasses	2												Gomph cel	
	25.0	0.1	0.0	0.0	12.0	3.0	Grasses	2	-						Cenc cil	50	Aris con	-			
	25.0	0.1	0.0	0.0	12.0	3.0	Grasses	2	-						Meli rep	20	Erag rig	-			
	25.0	0.1	0.0	0.0	12.0	3.0	Grasses	2	-						Digi eri	10	Anth pub	-			
	25.0	0.1	0.0	0.0	12.0	3.0	Grasses	2									Hete con				
	30.0	0.1	1.0	0.2	27.0	6.0	Grasses	2	-			Acac mel	100		Cenc cil	50	Erag leh	Chen car	80		
	30.0	0.1	1.0	0.2	27.0	6.0	Grasses	2	-						Hete con	30	Brac nig	Mons sp.	20		
	30.0	0.1	1.0	0.2	27.0	6.0	Grasses	2	-						Meli rep	10	Uroc pan				
	55.0	0.2	0.0	0.0	39.0	8.0	Grasses	2	-						Cenc cil	60	Meli rep	-			
	55.0	0.2	0.0	0.0	39.0	8.0	Grasses	2	-						Hete con	25	Anth pub	-			
	55.0	0.2	0.0	0.0	39.0	8.0	Grasses	2	-								Erag leh	10	Digi eri	-	
	50.0	0.1	0.0	0.0	26.0	6.0	Grasses	2	-						Cenc cil	45	Anth pub	Evol als	70		
	50.0	0.1	0.0	0.0	26.0	6.0	Grasses	2	-						Hete con	30	Erag leh	Indi sp.	30		
	50.0	0.1	0.0	0.0	26.0	6.0	Grasses	2	-						Meli rep	10	Schm pap				
	35.0	0.3	0.0	0.0	23.0	9.0	Grasses	2	-						Cenc cil	55	Aris con	Cleo rub	100		

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low, 2=moderate, 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
	35.0	0.3	0.0	0.0	23.0	9.0	Grasses	2							Hete con	15	Pani max			
	35.0	0.3	0.0	0.0	23.0	9.0	Grasses	2							Digi eri	15	Meli rep			
	30.0	0.1	0.0	0.0	21.0	7.0	Grasses	2							Cenc cil	60	Cyno dac	Pupa lap	100	
	30.0	0.1	0.0	0.0	21.0	7.0	Grasses	2							Hete con	15	Digi eri			
	30.0	0.1	0.0	0.0	21.0	7.0	Grasses	2							Meli rep	10	Erag leh			
	30.0	0.1	0.0	0.0	21.0	7.0	Grasses	2									Erag tri			
	15.0	0.2	5.0	2.5	12.0	2.0	Grasses	2	Acac mel	100		Acac mel	60		Cenc cil	45	Brac nig	Sida sp.	30	Teuc tri
	15.0	0.2	5.0	2.5	12.0	2.0	Grasses	2				Eucl und	30		Hete con	20	Meli rep	With som	30	Tage min
	15.0	0.2	5.0	2.5	12.0	2.0	Grasses	2				Rhus sp.	10		Erag leh	15	Anth pub	Lant rug	30	
	15.0	0.2	5.0	2.5	12.0	2.0	Grasses	2									Aris jun			
	15.0	0.2	5.0	2.5	12.0	2.0	Grasses	2									Schm pap			
	40.0	0.3	5.0	3.0	7.0	8.0	Grasses	2	Acac mel	90		Acac mel	40	Grew flava	Cenc cil	60	Stip uni	-		
	40.0	0.3	5.0	3.0	7.0	8.0	Grasses	2	Popu wis	10		Eucl und	30		Hete con	15	Erag leh	-		
	40.0	0.3	5.0	3.0	7.0	8.0	Grasses	2				Zizi muc	20		Aris mer	10	Schm pap	-		
	35.0	0.2	0.0	0.0	41.0	7.0	Grasses	2							Hete con	30	Pogo squ	Blum gar	75	
	35.0	0.2	0.0	0.0	41.0	7.0	Grasses	2							Meli rep	20	Erag leh	Poll cam	25	
	35.0	0.2	0.0	0.0	41.0	7.0	Grasses	2							Cenc cil	15	Hypa hir			
	35.0	0.2	0.0	0.0	41.0	7.0	Grasses	2									Schm pap			
	35.0	0.2	0.0	0.0	41.0	7.0	Grasses	2									Aris con			
	50.0	0.2	0.0	0.0	41.0	7.0	Grasses	2							Hete con	25	Cenc cil	-		
	50.0	0.2	0.0	0.0	41.0	7.0	Grasses	2							Schm pap	15	Meli rep	-		
	50.0	0.2	0.0	0.0	41.0	7.0	Grasses	2							Aris con	10	Erag leh	-		
	50.0	0.2	0.0	0.0	41.0	7.0	Grasses	2									Hypa hir			
	50.0	0.2	0.0	0.0	41.0	7.0	Grasses	2									Erag rig			
	50.0	0.2	0.0	0.0	41.0	7.0	Grasses	2									Enne des			
	30.0	0.3	3.0	0.5	15.0	6.0	Grasses	2				Acac eri	60		Hete con	40	Schm pap	-		
	30.0	0.3	3.0	0.5	15.0	6.0	Grasses	2				Grew flava	40		Cenc cil	30	Anth pub	-		
	30.0	0.3	3.0	0.5	15.0	6.0	Grasses	2							Meli rep	15	Erag leh	-		
	55.0	0.2	0.0	0.0	28.0	8.0	Grasses	2							Hete con	25	Aris con			
	55.0	0.2	0.0	0.0	28.0	8.0	Grasses	2							Erag leh	20	Meli rep	Gomp fru	80	
	55.0	0.2	0.0	0.0	28.0	8.0	Grasses	2							Cenc cil	15	Trag ber	Koha ama	20	
	55.0	0.2	0.0	0.0	28.0	8.0	Grasses	2									Schm pap			
	55.0	0.2	0.0	0.0	28.0	8.0	Grasses	2									Anth pub			
	55.0	0.2	0.0	0.0	28.0	8.0	Grasses	2									Digi eri			
Groenwater	65.0	0.1	2.0	0.5	65.0	11.0	Grasses	-				Acac kar	100		Aris con	25	Schm pap	Chry cil	30	Medi lac
	65.0	0.1	2.0	0.5	65.0	11.0	Grasses	-							Erag leh	20	Erag tri	Pent glo	25	Trib ter
	65.0	0.1	2.0	0.5	65.0	11.0	Grasses	-							Erag ech	15	Cenc cil	Sela spe	10	Melh pro
	65.0	0.1	2.0	0.5	65.0	11.0	Grasses	-									Digi eri			
	65.0	0.1	2.0	0.5	65.0	11.0	Grasses	-									Cyno dac			
	65.0	0.1	2.0	0.5	65.0	11.0	Grasses	-									Pasp dil			
	50.0	0.1	0.0	0.0	55.0	7.0	Grasses	-							Erag leh	35	Aris con	Sela spe	35	Medi lac
	50.0	0.1	0.0	0.0	55.0	7.0	Grasses	-							Hete con	25	Meli rep	Chry cil	35	
	50.0	0.1	0.0	0.0	55.0	7.0	Grasses	-							Cenc cil	20	Erag ech	Pent glo	15	
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-				Acac kar	60		Cenc cil	30	Aris con	Chry cil	20	Arge och
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-				Lycl cin	20		Erag ech	15	Erag tri	Pent glo	15	Herm ves
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-				Zizi muc	20		Erag leh	10	Cyno dac	Medi lac	10	Arct arc
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-									Digi eri			
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-									Schm pap			
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-									Hete con			
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-												
	60.0	0.1	5.0	1.0	39.0	10.0	Grasses	-												
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses	-				Acac mel	100		Aris con	20	Cyno dac	Chry cil	50	Sela spe
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses	-							Erag leh	15	Trag ber	Poly hot	20	Bulbi aby
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses	-							Meli rep	10	Erag ech	Lime vis	10	
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses	-									Hypa hir			
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses	-									Cenc cil			
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses	-									Erag tri			

Site name	Herbaceous crown cover (%)	Herb. Crown height (m)	Woody crown cover (%)	Woody crown height (m)	Density (plants per m²)	Basal cover (%)	Dominant growth form	Impact by grazers (1=low, 2=moderate, 3=high)	Dominant trees	%	Other trees	Dominant shrubs	%	Other shrubs	Dominant grasses	%	Other grasses	Dominant forbs	%	Other forbs
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses										Them tri			
	45.0	0.2	1.0	0.2	41.0	5.0	Grasses										Digi eri			
	25.0	0.1	10.0	1.2	28.0	3.0	Grasses	-				Acac kar	60		Aris con	35	Hete con	Chry cil	40	Lime vis
	25.0	0.1	10.0	1.2	28.0	3.0	Grasses	-				Acac heb	30		Erag ech	20	Cenc cil	Geig bur	15	Hibi tri
	25.0	0.1	10.0	1.2	28.0	3.0	Grasses	-				Zizi muc	10		Erag leh	15	Meli rep	Poly hot	10	Pent glo
	25.0	0.1	10.0	1.2	28.0	3.0	Grasses	-									Trag ber			Poll cam
	25.0	0.1	10.0	1.2	28.0	3.0	Grasses	-									Digi eri			
	40.0	0.1	0.0	0.0	38.0	5.0	Grasses	-							Meli rep	30	Cyno dac	Chry cil	40	Arge och
	40.0	0.1	0.0	0.0	38.0	5.0	Grasses	-							Aris con	15	Hete con	Teph pur	15	Bulbi aby
	40.0	0.1	0.0	0.0	38.0	5.0	Grasses	-							Cenc cil	15	Erag leh	Indi alt	10	Herm ves
	40.0	0.1	0.0	0.0	38.0	5.0	Grasses	-									Aris mer			Melh pro
	40.0	0.1	0.0	0.0	38.0	5.0	Grasses	-												Lebe spi
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-				Grew flava	80		Aris jun	40	Meli rep	Arge och	25	Gomp fru
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-				Acac mel	20		Erag leh	20	Cyno dac	Chry cil	20	Phyl par
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-							Aris con	10	Brac nig	Trago dub	10	Poll cam
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-									Aris mer			Aspa sp.
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-									Stip uni			Sonc sp.
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-												Kyph ang
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-												Guil den
	10.0	0.3	2.0	1.2	9.0	2.0	Grasses	-												Geig bur
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-							Cenc cil	25	Schm pap	Chry cil	60	Gise pha
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-							Erag leh	15	Anth pub	Lime vis	15	Sesa tri
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-							Stip uni	10	Hete con	Pent glo	10	
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-									Erag tri			
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-									Erag ech			
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-									Digi eri			
	60.0	0.3	0.0	0.0	25.0	10.0	Grasses	-									Them tri			
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-							Cenc cil	30	Anth pub	Chry cil	35	Herm tom
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-							Stip uni	20	Erag ech	Senn ita	15	Indi alt
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-							Erag leh	10	Digi eri	Herm ves	10	Lime vis
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-									Schm pap			Oste mic
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-									Aris con			Poll cam
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-									Stip obt			
	60.0	0.2	0.0	0.0	18.0	10.0	Grasses	-									Trag ber			

## **APPENDIX B.1. VEGETATION SURVEY RESULTS**

### **B.1.4. List of species abbreviations**

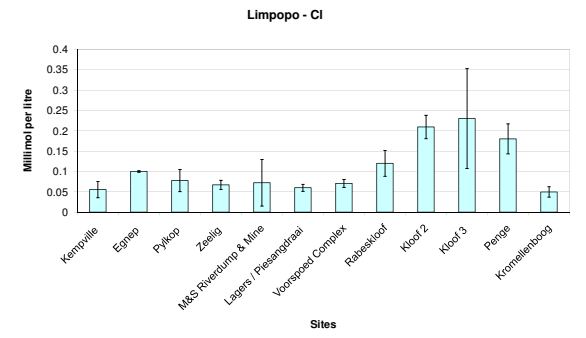
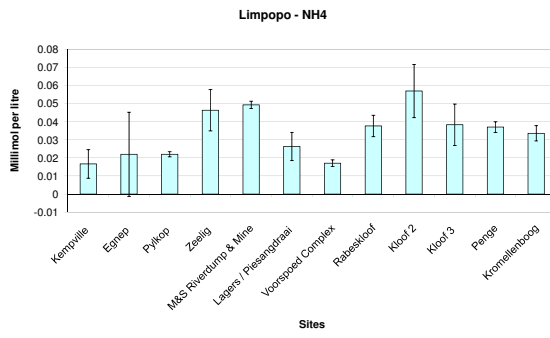
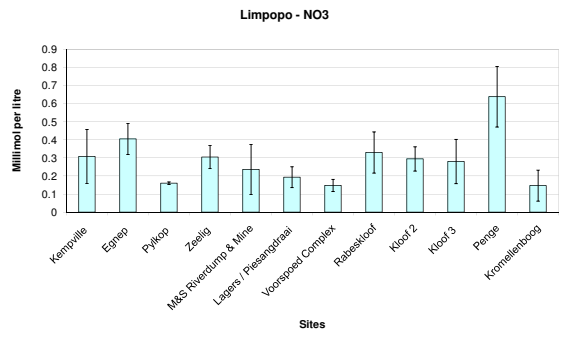
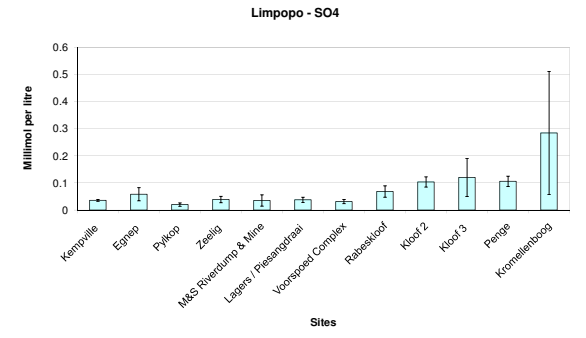
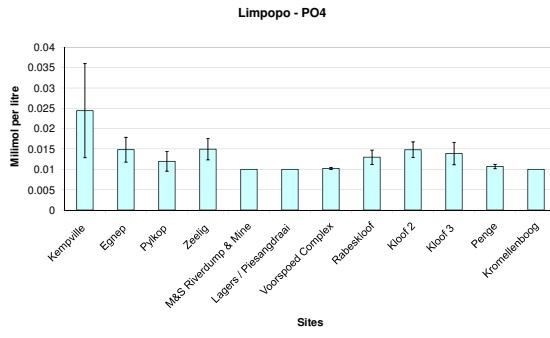
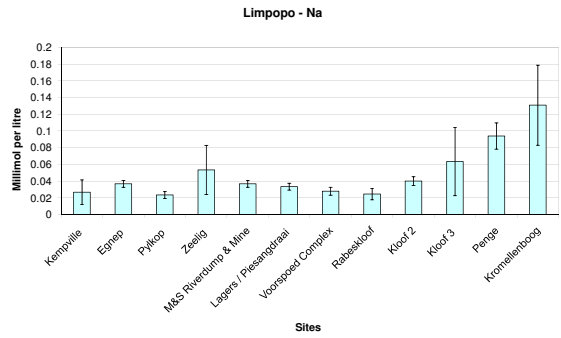
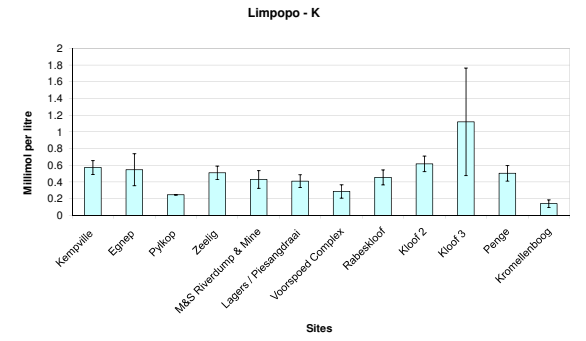
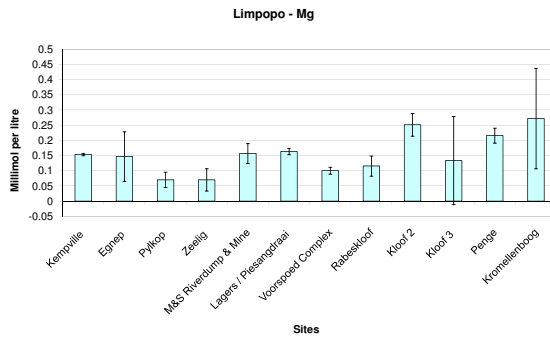
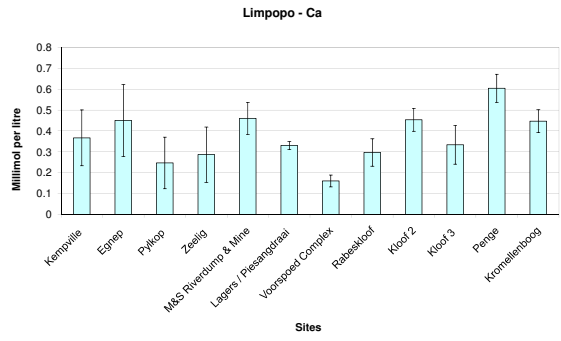
Abbreviation	Species name	Abbreviation	Species name
Abru pre	<i>Abrus precatorius</i>	Hete con	<i>Heteropogon contortus</i>
Abut ang	<i>Abutilon angulatum</i>	Hibi mic	<i>Hibiscus micranthus</i>
Abut aus	<i>Abutilon austro-africanum</i>	Hibi pus	<i>Hibiscus pusillus</i>
Abut ram	<i>Abutilon ramosum</i>	Hibi tri	<i>Hibiscus trionium</i>
Abut son	<i>Abutilon sonderatianum</i>	Hipp lon	<i>Hippocratea longipetiolata</i>
Acac caf	<i>Acacia caffra</i>	Hypa hir	<i>Hyparrhenia hirta</i>
Acac eri	<i>Acacia erioloba</i>	Hype dis	<i>Hyperthelia dissoluta</i>
Acac eru	<i>Acacia erubescens</i>	Hypo sp.	<i>Hypoestis</i> species
Acac exu	<i>Acacia exuvialis</i>	Indi dal	<i>Indigofera daleoides</i>
Acac heb	<i>Acacia hebeclada</i>	Indi hed	<i>Indigofera hedyantha</i>
Acac kar	<i>Acacia karroo</i>	Indi neb	<i>Indigofera nebrowiana</i>
Acac lue lue	<i>Acacia luederitzii</i> var. <i>luederitzii</i>	Indi sp.	<i>Indigofera</i> species
Acac mel	<i>Acacia mellifera</i>	Ipom sin	<i>Ipomoea sinensis</i>
Acac nig	<i>Acacia nigrescens</i>	Jaca mim	<i>Jacaranda mimosifolia</i>
Acac nil	<i>Acacia nilotica</i>	Just fla	<i>Justica flava</i>
Acac sen lei	<i>Acacia senegal</i> var. <i>leiorachis</i>	Koha ama	<i>Kohautia amatymbica</i>
Acac tor	<i>Acacia tortilis</i>	Kyph ang	<i>Kyphocarpa angustifolia</i>
Acal ang	<i>Acalypha angolensis</i>	Lant cam	<i>Lantana camara</i>
Acal ind	<i>Acalypha indica</i>	Lant rug	<i>Lantana rugosa</i>
Acan his	<i>Acanthospermum hispidum</i>	Leon dys	<i>Leonotis dysophylla</i>
Achy asp	<i>Achyranthes aspera</i>	Leuc gla	<i>Leucas glabrata</i>
Acro inf	<i>Acrotome inflata</i>	Leuc neu	<i>Leucas neulizeana</i>
Albi ant	<i>Albizia anthelmintica</i>	Leuc sp.	<i>Leucas</i> species
Aloe her	<i>Aloe hereroensis</i>	Lime vis	<i>Limeum viscosum</i>
Aloe mar	<i>Aloe marlothii</i>	Loph cor	<i>Lopholaena coriifolia</i>
Alte pun	<i>Alternanthera pungens</i>	Lyci cin	<i>Lycium cinereum</i>
Amar hyb	<i>Amaranthus hybridus</i>	Maer ang	<i>Maerua angolensis</i>
Anth pub	<i>Antheaphora pubescens</i>	Malv cor	<i>Malvastrum coromandelianum</i>
Apto sp.	<i>Aptosimum</i> species	Melh acu	<i>Melhania acuminata</i> var. <i>acuminata</i>
Arge och	<i>Argemone ochroleuca</i>	Melh pro	<i>Melhania prostrata</i>
Aris ads	<i>Aristida adscensionis</i>	Meli aze	<i>Melia azadarach</i>
Aris bip	<i>Aristida bipartita</i>	Meli ner	<i>Melinis nerviglumis</i>
Aris can	<i>Aristida canescens</i> subsp. <i>canescens</i>	Meli rep	<i>Melinis repens</i>
Aris con	<i>Aristida congesta</i>	Melo can	<i>Melolobium candicans</i>
Aris mer	<i>Aristida meridionalis</i>	Merr tri	<i>Merremia tridentata</i>
Aris rhi	<i>Aristida rhinochloa</i>	Momo bal	<i>Momordica balsamina</i>
Aris sca	<i>Aristida scabrivalvis</i>	Mone inc	<i>Monechma incanum</i>
Aris sp.	<i>Aristida</i> species	Mund ser	<i>Mundulea sericea</i>
Aris sti	<i>Aristida stipitata</i> subsp. <i>graciliflora</i>	Myrs afr	<i>Myrsine africana</i>
Aste sp.	<i>Aster</i> species	Nico gla	<i>Nicotiana glauca</i>
Bala mau	<i>Balanites maughamii</i>	Nido ano	<i>Nidorella anomala</i>
Barl sp.	<i>Barleria</i> species	Obet ten	<i>Obetia tenax</i>
Beci ang	<i>Becium angustifolia</i>	Ocym ame	<i>Ocimum americanum</i>
Bide bip	<i>Bidens bipinnata</i>	Opun fic	<i>Opuntia ficus-indica</i>
Blep sp.	<i>Blepharis</i> species	Opun str	<i>Opuntia stricta</i>
Blep sub	<i>Blepharis subvulubilis</i>	Pani col	<i>Panicum coloratum</i>
Blum gar	<i>Blumea gariepina</i>	Pani deu	<i>Panicum deustum</i>
Boer ere	<i>Boerhavia erecta</i>	Pani max	<i>Panicum maximum</i>
Bosc alb	<i>Boscia albitrunca</i>	Papp cap	<i>Pappaea capensis</i>
Both ins	<i>Bothriochloa insculpta</i>	Park acu	<i>Parkinsonia aculeata</i>
Budd salv	<i>Buddleja salviifolia</i>	Pavo bur	<i>Pavonia burchellii</i>
Bulb bur	<i>Bulbostylis burchellii</i>	Pavo tra	<i>Pavonia transvaalensis</i>
Bulb his	<i>Bulbostylis hispidula</i>	Pell cal	<i>Pellaea calomelanos</i>
Cada ter	<i>Cadaba termitaria</i>	Pelt afr	<i>Peltophorum africanum</i>
Cant ine	<i>Canthium inerme</i>	Pent ins	<i>Pentarrhinum inspidum</i>
Capp tom	<i>Capparis tomentosa</i>	Perg dae	<i>Pergularia daemia</i> var. <i>daemia</i>
Casi per	<i>Cassine peragua</i>	Peri sp.	<i>Peristrophe</i> species
Cath ros	<i>Catharanthus roseus</i>	Phil vio	<i>Philenoptera violacea</i>
Celt afr	<i>Celtis africana</i>	Plec arm	<i>Plectroniella armata</i>
Cenc cil	<i>Cenchrus ciliaris</i>	Plect sp.	<i>Plectranthus</i> species
Cera tri	<i>Ceratotheca triloba</i>	Plum zey	<i>Plumbago zeylanica</i>
Cere jam	<i>Cereus jamacaru</i>	Poll cam	<i>Pollichia campestris</i>
Cham sp.	<i>Chamaecyce</i> species	Poly hot	<i>Polygala hottentotta</i>
Chama mim	<i>Chamaecrista mimosoides</i>	Poly vir	<i>Polygala virgata</i>

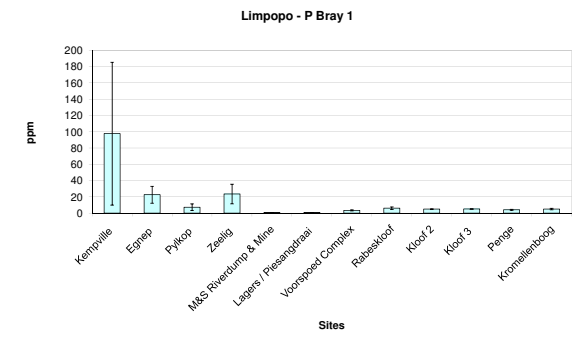
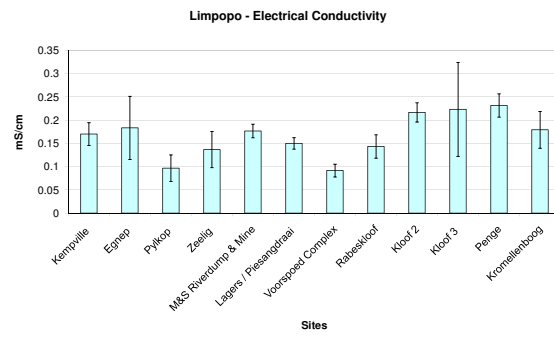
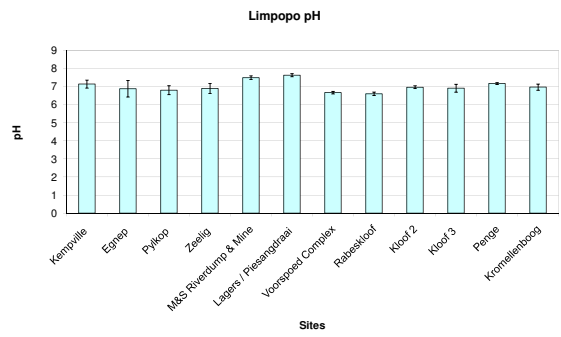
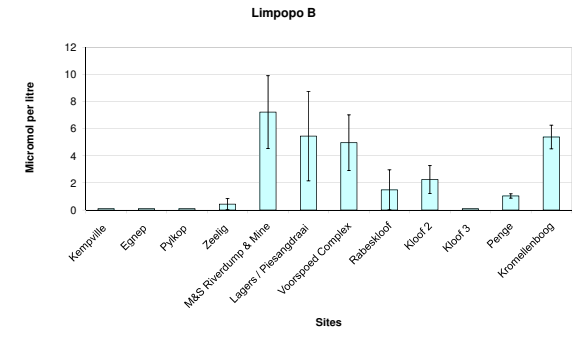
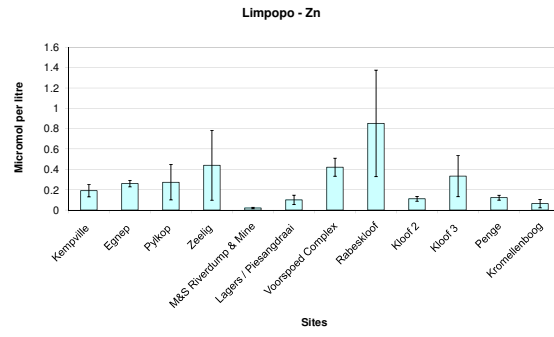
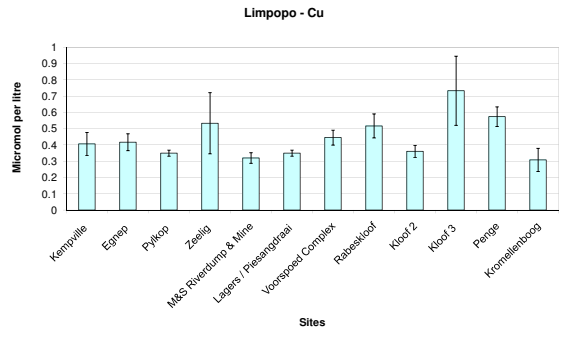
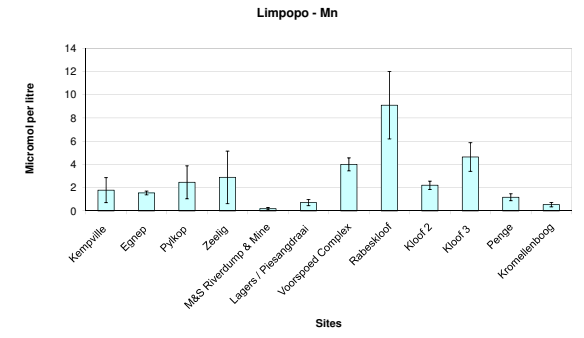
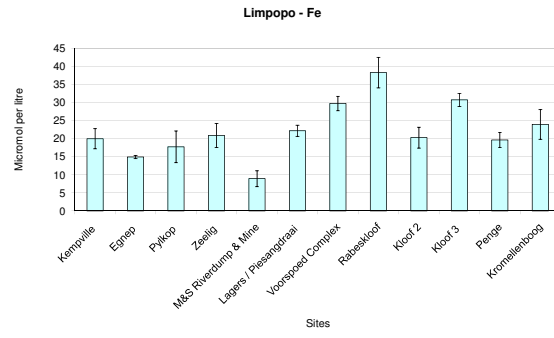
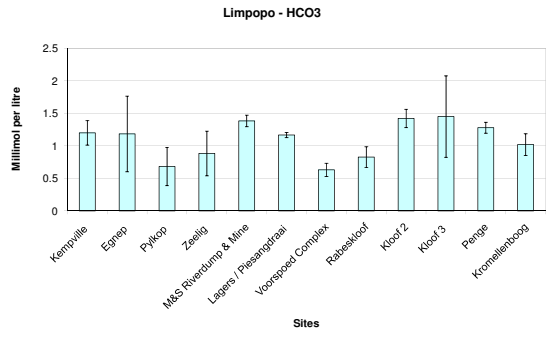
Abbreviation	Species name	Abbreviation	Species name
Chei sp.	<i>Cheilantes</i> species	Port qua	<i>Portulaca quadrifida</i>
Chen alb	<i>Chenopodium album</i>	Pros gla	<i>Prosopis glandulosa</i> var. <i>torreyana</i>
Chen car	<i>Chenopodium carinatum</i>	Pseu sp.	<i>Pseudoconyza</i> sp.
Chlo vir	<i>Chloris virgata</i>	Psia pun	<i>Psiadia punctulata</i>
Citr lan	<i>Citrullus lanatus</i>	Ptae obl	<i>Ptaeroxylon obliquum</i>
Cleo mon	<i>Cleome monophylla</i>	Pter spe	<i>Pterodiscus speciosus</i>
Cleo rub	<i>Cleome rubella</i>	Ptero vis	<i>Pteronia viscosa</i>
Cler gla	<i>Clerodendrum glabrum</i>	Pupa lap	<i>Pupalia lappacea</i> var. <i>lappacea</i>
Cocc ses	<i>Coccinia sessilifolia</i>	Pyro his	<i>Pyrostria hystrix</i>
Comb imb	<i>Combretum imberbe</i>	Rhig obo	<i>Rhigozum obovatum</i>
Comm gla	<i>Commiphora glandulosa</i>	Rhig tri	<i>Rhigozum trichotomum</i>
Comm pen	<i>Commicarpus pentandrus</i>	Rhus chi	<i>Rhus chirindensis</i>
Comm ten	<i>Commiphora tenuipetiolata</i>	Rhus gue	<i>Rhus gueinzii</i>
Conv sag	<i>Convolvulus sagittatus</i>	Rhus lep	<i>Rhus leptodictya</i>
Cony bon	<i>Conyza bonariensis</i>	Rhus pen	<i>Rhus pentheri</i>
Corc asp	<i>Corchorus asplenifolius</i>	Rhus pyr	<i>Rhus pyroides</i>
Corc con	<i>Corchorus confusus</i>	Rhus sp.	<i>Rhus</i> species
Corc kir	<i>Corchoris kirkii</i>	Rhus ten	<i>Rhus tenuinervis</i>
Crot men	<i>Croton menyhartii</i>	Rhyn min	<i>Rhynchosia minima</i>
Crot mon	<i>Crotalaria monteiroi</i>	Rhyn sp.	<i>Rhynchosia</i> species
Crota sp.	<i>Crotalaria</i> species	Rhyn tot	<i>Rhynchosia totta</i>
Cucu met	<i>Cucumis metuliferus</i>	Rici com	<i>Ricinus communis</i>
Cyat lan	<i>Cyathula lanceolata</i>	Sals kal	<i>Salsola kali</i>
Cyat sp.	<i>Cyathula</i> species	Sarc vim	<i>Sarcostemma viminale</i>
Cymb plu	<i>Cymbopogon plurinodis</i>	Schi mol	<i>Schinus molle</i>
Cymb val	<i>Cymbopogon validus</i>	Schk pin	<i>Schkuhria pinnata</i>
Cyno dac	<i>Cynodon dactylon</i>	Schm pap	<i>Schmidtia pappophoroides</i>
Dich inte	<i>Dichrocephala integrifolia</i> subsp. <i>integrifolia</i>	Scho bra	<i>Schottia brachypetala</i>
Dicl een	<i>Dicliptera eenii</i>	Scle bir	<i>Sclerocarya birrea</i> subsp. <i>caffra</i>
Digi eri	<i>Digitaria eriantha</i>	Sene sp.	<i>Senecio</i> species
Dihe amp	<i>Diheteropogon amplectens</i>	Senn ita	<i>Senna italica</i> subsp. <i>arachoides</i>
Dios lyc	<i>Diospyros lycioides</i>	Senn sp.	<i>Senna</i> species
Dodo ang	<i>Dodonaea angustifolia</i>	Sesa tri	<i>Sesamum triphyllum</i>
Domb aut	<i>Dombeya autumnalis</i>	Seta sph	<i>Setaria sphacelata</i>
Domb rot	<i>Dombeya rotundifolia</i>	Seta ver	<i>Setaria verticilata</i>
Ehre amo	<i>Ehretia amoena</i>	Sida cor	<i>Sida cordifolia</i>
Ehre rig	<i>Ehretia rigida</i>	Sida dre	<i>Sida dregei</i>
Elae tra	<i>Elaeodendron transvaalense</i>	Sida rho	<i>Sida rhombifolia</i>
Elep ele	<i>Elephantorrhiza elephantina</i>	Sida sp.	<i>Sida</i> species
Enne cen	<i>Enneapogon cenchroides</i>	Sola inc	<i>Solanum incanum</i>
Enne sco	<i>Enneapogon scoparius</i>	Sola nig	<i>Solanum nigrum</i>
Enne sco	<i>Enneapogon scoparius</i>	Sola pan	<i>Solanum panduriforme</i>
Ente mac	<i>Enteropogon macrostachyus</i>	Sola sp.	<i>Solanum</i> species
Erag chl	<i>Eragrostis chloromelas</i>	Sola tet	<i>Solanum tettense</i> var. <i>renschii</i>
Erag ech	<i>Eragrostis echinochloidea</i>	Sonc wil	<i>Sonchus wilmsii</i>
Erag leh	<i>Eragrostis lehmanniana</i>	Sorg hal	<i>Sorghum halepense</i>
Erag pal	<i>Eragrostis pallens</i>	Spir afr	<i>Spirostachys africana</i>
Erag rac	<i>Eragrostis racemosa</i>	Spor ioc	<i>Sporobolus ioclados</i>
Erag rig	<i>Eragrostis rigidior</i>	Spor nit	<i>Sporobolus nitens</i>
Erag sup	<i>Eragrostis superba</i>	Spor pan	<i>Sporobolus panicoides</i>
Erag tri	<i>Eragrostis trichophora</i>	Stac sp.	<i>Stachys</i> species
Eucl sp.	<i>Euclea</i> species	Stap sp.	<i>Stapelia</i> species
Eucl und	<i>Euclea undulata</i>	Stip obt	<i>Stipagrostis obtusa</i>
Euph ing	<i>Euphorbia ingens</i>	Stip uni	<i>Stipagrostis uinplumis</i>
Euph tir	<i>Euphorbia tirucali</i>	Suth sp.	<i>Sutherlandia</i> species
Eury ped	<i>Euryops pedunculatus</i>	Tage min	<i>Tagetes minuta</i>
Evol als	<i>Evolvulus alsinoides</i>	Tapi ole	<i>Tapinanthus oleifolius</i>
Feli mur	<i>Felicia muricata</i> subsp. <i>muricata</i>	Tarc cam	<i>Tarchonanthus camphoratus</i>
Ficu cor	<i>Ficus cordata</i>	Teco sta	<i>Tecoma stans</i>
Ficu sur	<i>Ficus sur</i>	Teph cap	<i>Tephrosia capensis</i>
Fing afr	<i>Fingerhuthia africana</i>	Teph pur	<i>Tephrosia purpurea</i>
Flav bid	<i>Flaveria bidentis</i>	Teph rho	<i>Tephrosia rhodesica</i>
Flue vir	<i>Flueggea virosa</i>	Term pru	<i>Terminalia prunioides</i>
Gard vol	<i>Gardenia volkensii</i>	Term ser	<i>Terminalia sericea</i>

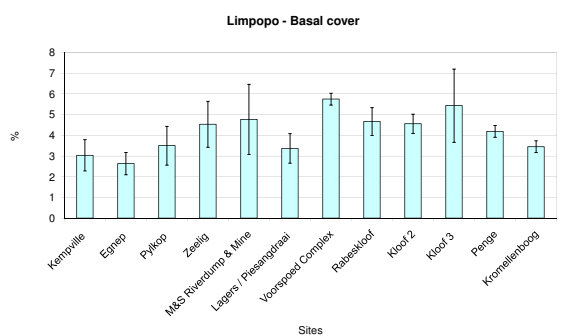
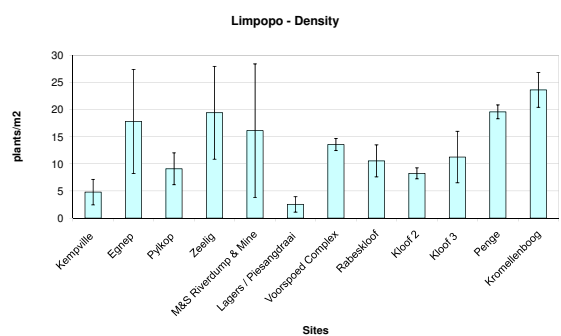
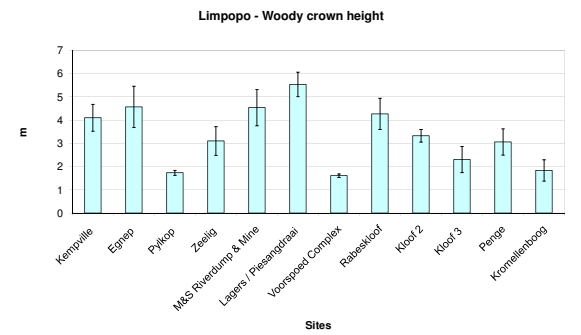
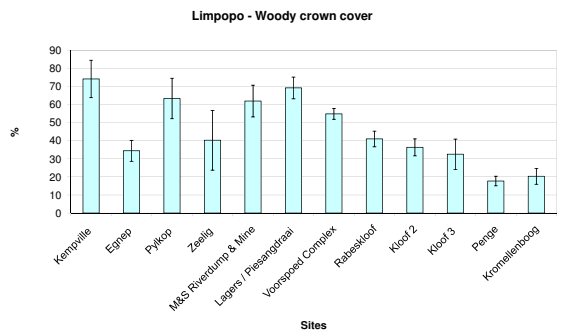
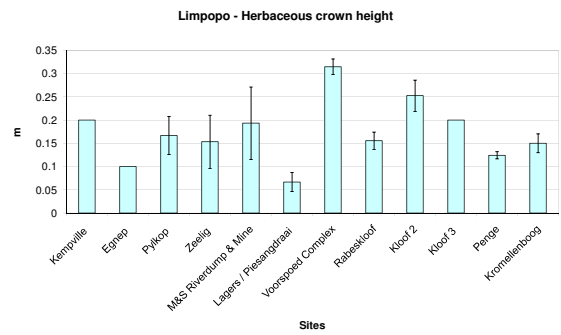
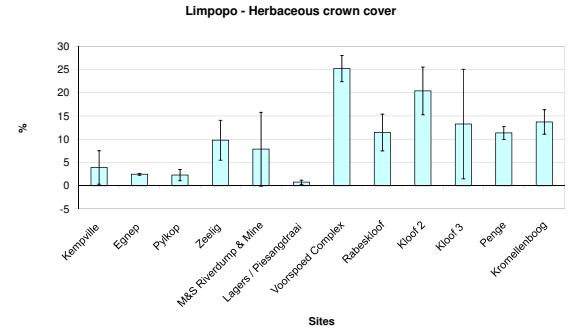
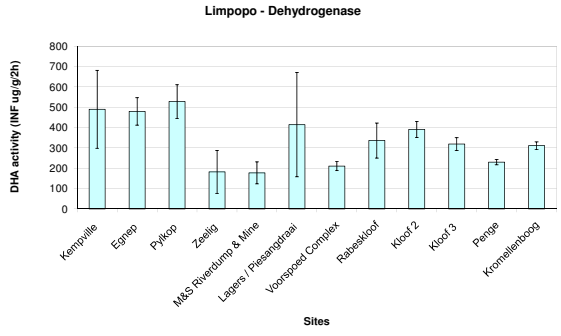
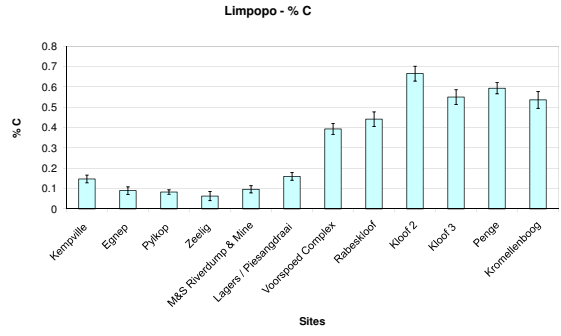
Abbreviation	Species name	Abbreviation	Species name
Gaza kre	<i>Gazania krebsiana</i>	Teuc tri	<i>Teucrium trifidum</i>
Geig bur	<i>Geigeria burkei</i>	Thes sp.	<i>Thesium species</i>
Gesi pha	<i>Gisekia pharmacioides</i>	Trag ber	<i>Tragus berteronianus</i>
Gomp fru	<i>Gomphocarpus fruticosus</i>	Trag sp.	<i>Tragia species</i>
Gomph cel	<i>Gomphrena celosioides</i>	Trem ori	<i>Trema orientalis</i>
Goss her	<i>Gossypium herbaceum</i>	Trib ter	<i>Tribulus terrestris</i>
Grew bic	<i>Grewia bicolor</i>	Trib zey	<i>Tribulus zeyheri subsp. zeyheri</i>
Grew flava	<i>Grewia flava</i>	Tric mon	<i>Tricholaena monachne</i>
Grew flave	<i>Grewia flavescens</i>	Uroc mos	<i>Urochloa mosambicensis</i>
Grew gra	<i>Grewia gracillima</i>	Uroc pan	<i>Urochloa panicoides</i>
Grew occ	<i>Grewia occidentalis</i>	Verb enc	<i>Verbesina encelioides</i>
Grew vil	<i>Grewia villosa</i>	Vern sp.	<i>Vernonia species</i>
Gymn bux	<i>Gymnosporia buxifolia</i>	Vign fru	<i>Vigna frutescens</i>
Gymn pol	<i>Gymnosporia polyacantha</i>	Vign vex	<i>Vigna vexillata</i>
Gymn sen	<i>Gymnosporia senegalensis</i>	Vite reh	<i>Vitex rhemannii</i>
Heli sp.	<i>Helichrysum species</i>	Walt ind	<i>Walteria indica</i>
Helio ova	<i>Heliotropium ovalifolium</i>	With som	<i>Withania somnifera</i>
Herm gla	<i>Hermannia glanduligera</i>	Xime ame	<i>Ximania americana</i>
Herm sp.	<i>Hermannia species</i>	Xime caf	<i>Ximania caffra</i>
Herm tom	<i>Hermannia tomentosa</i>	Zinn per	<i>Zinnia peruviana</i>
Hermb odo	<i>Hermbstaedtia odorata var. odorata</i>	Zizi muc	<i>Ziziphus mucronata</i>
		Zorn sp.	<i>Zornia species</i>

## **APPENDIX B.2. OTHER QUANTITATIVE RESULTS**

### B.2.1. Limpopo Province



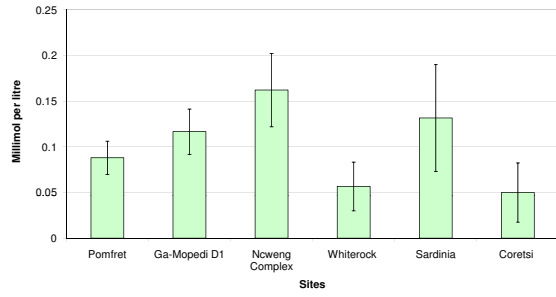




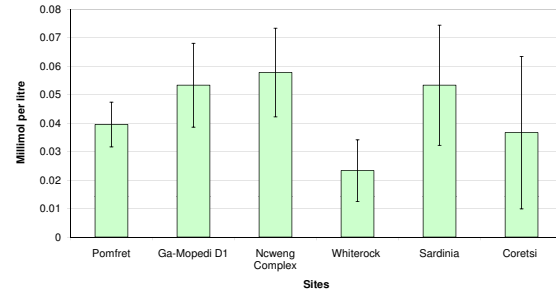
## **APPENDIX B.2. OTHER QUANTITATIVE RESULTS**

### **B.2.2. North-West Province**

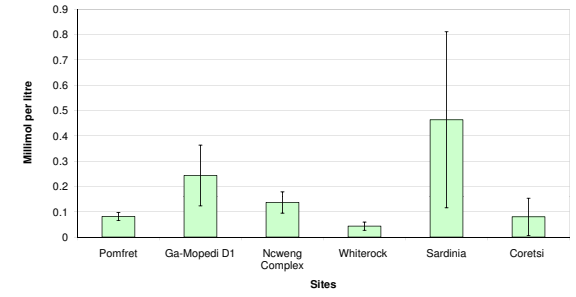
North-West - Ca



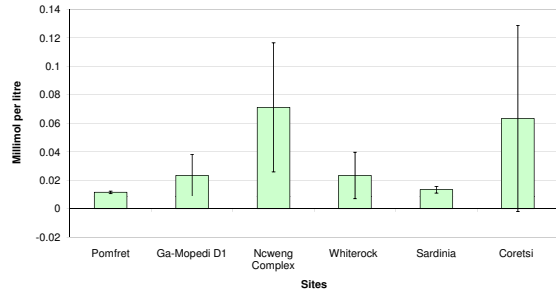
North-West - Mg



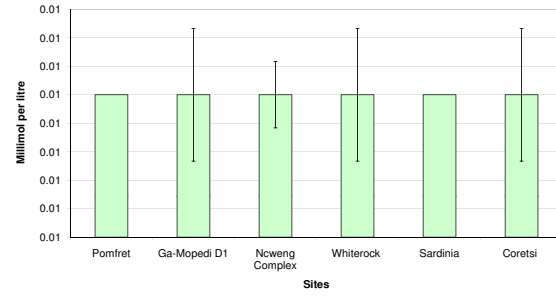
North-West - K



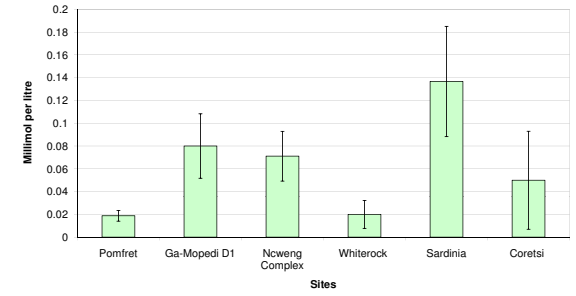
North-West - Na



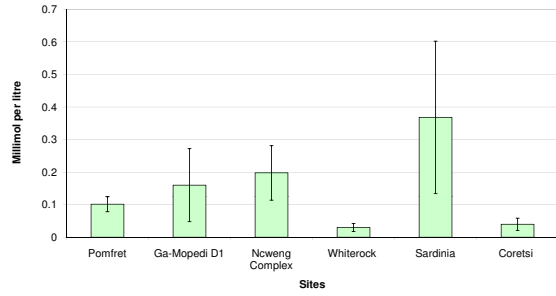
North-West - PO4



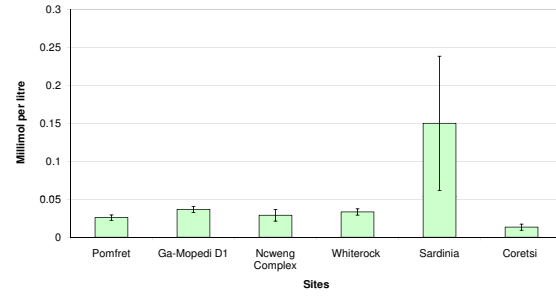
North-West - SO4



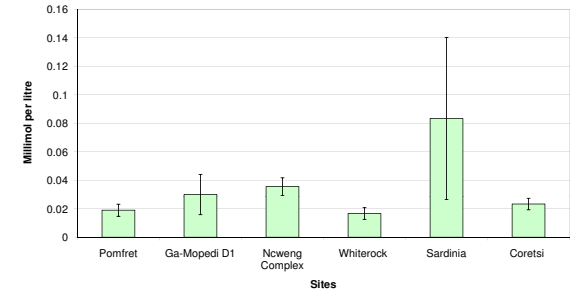
North-West NO3

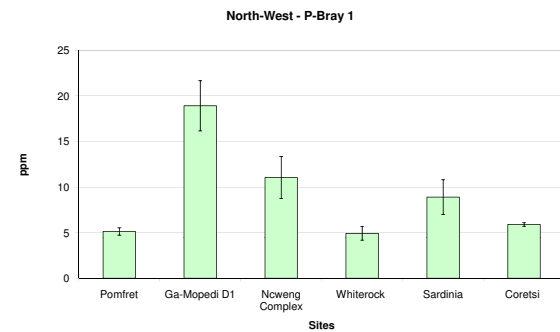
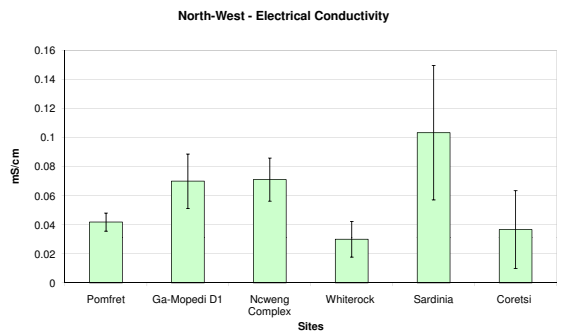
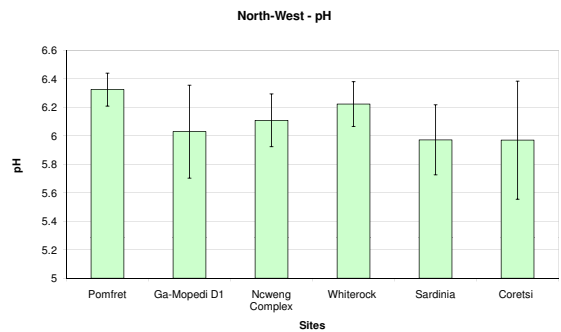
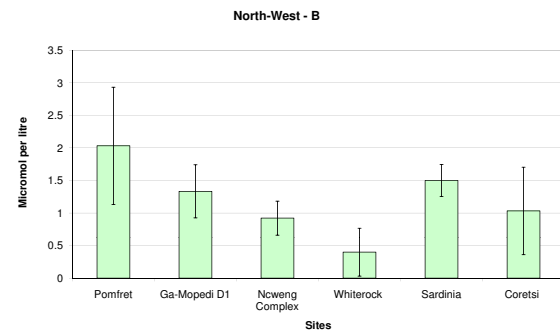
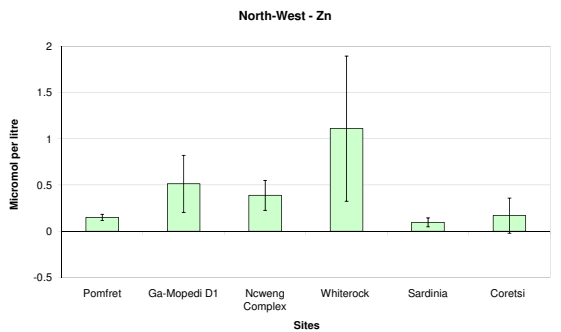
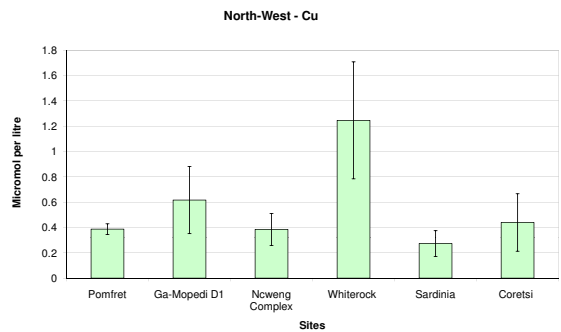
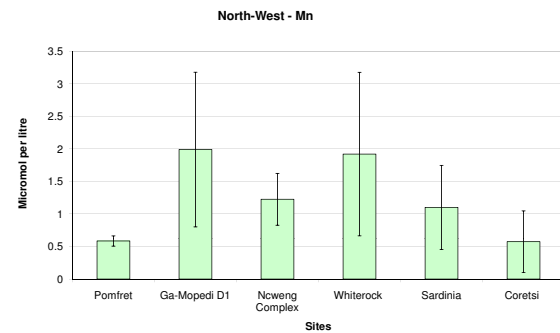
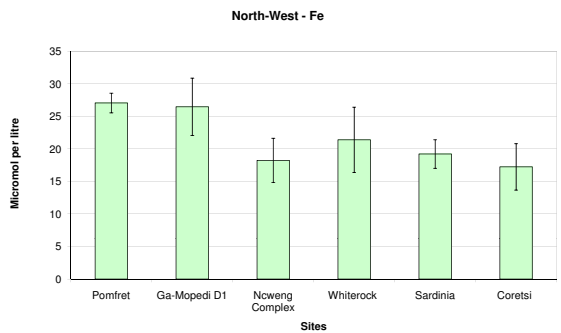
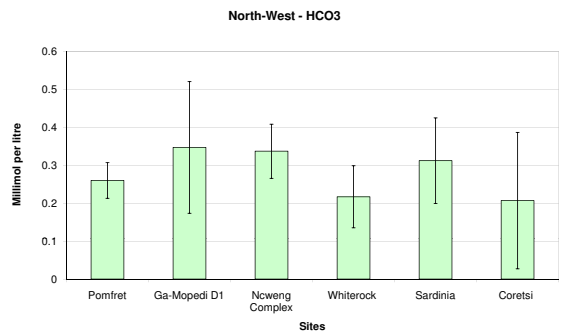


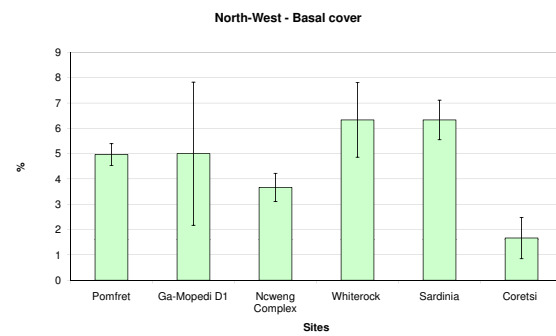
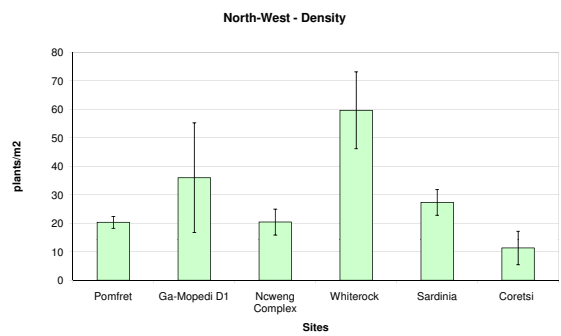
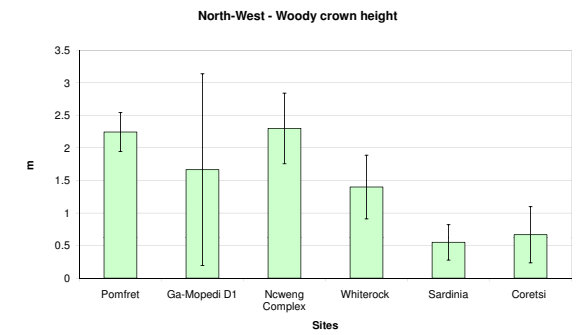
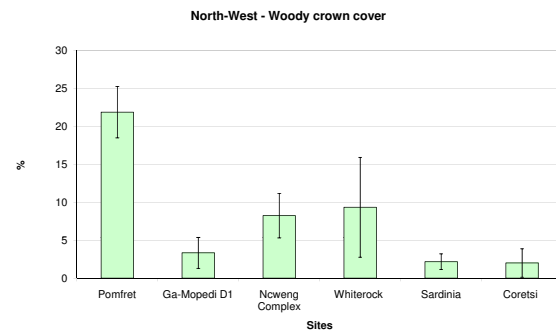
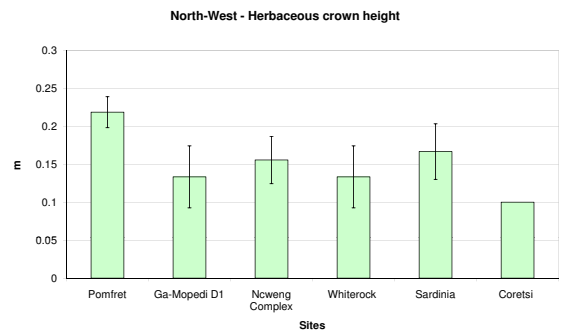
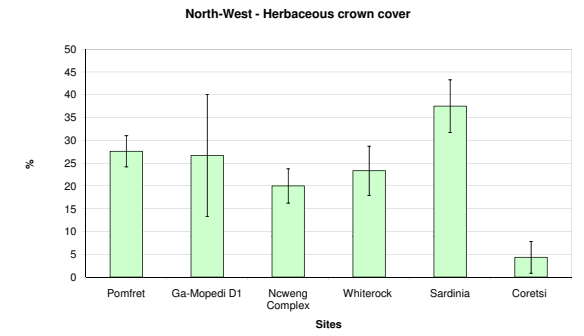
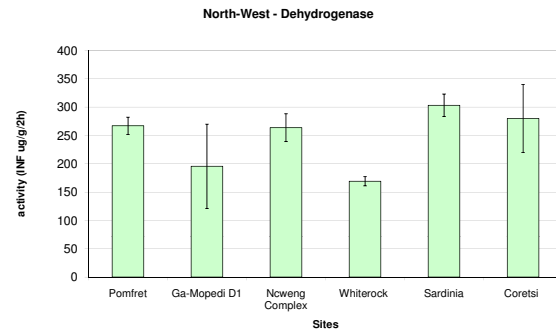
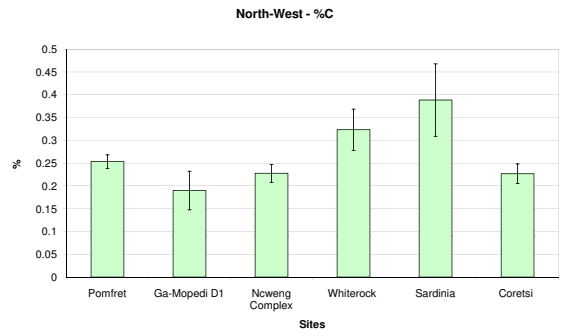
North-West - NH4



North-West - Cl



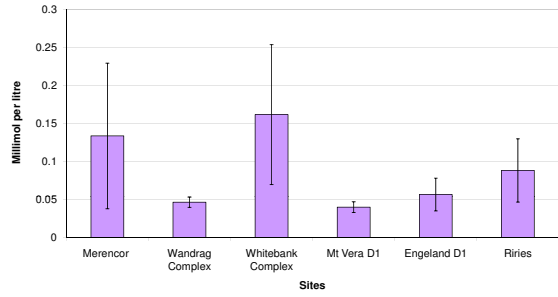




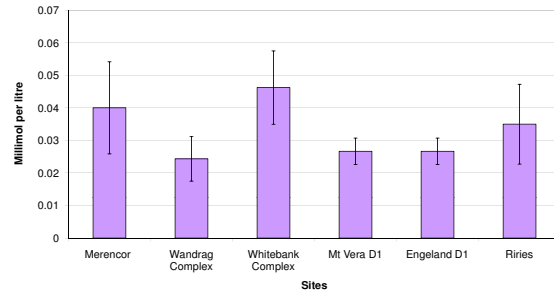
## **APPENDIX B.2. OTHER QUANTITATIVE RESULTS**

### **B.2.3. Northern Cape Province**

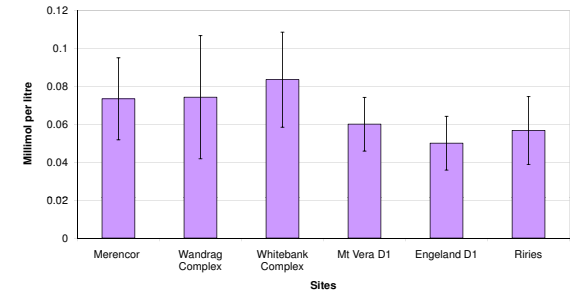
Northern Cape - Ca



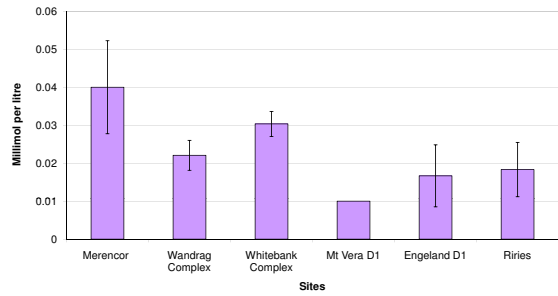
Northern Cape - Mg



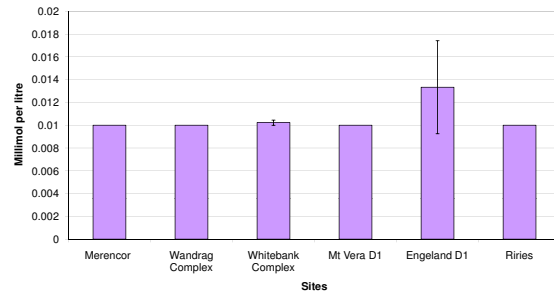
Northern Cape - K



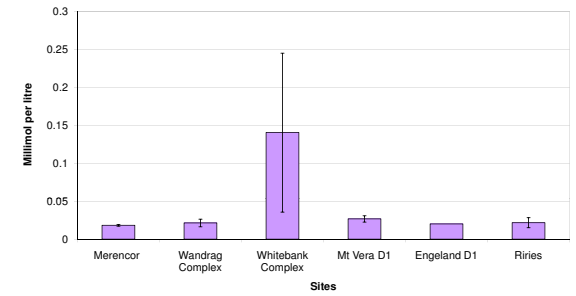
Northern Cape - Na



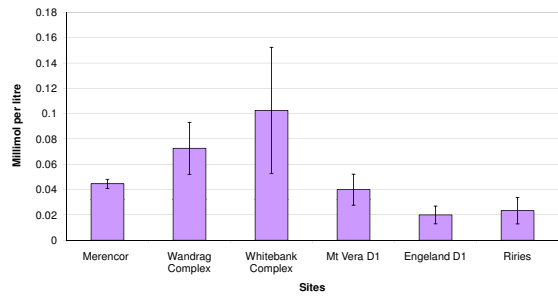
Northern Cape - PO4



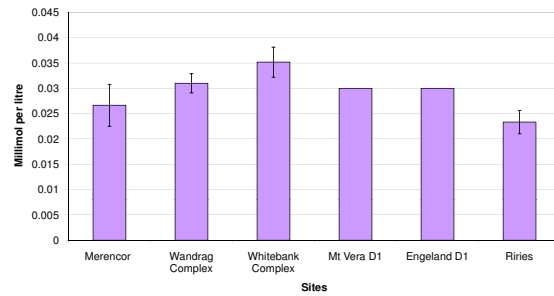
Northern Cape - SO4



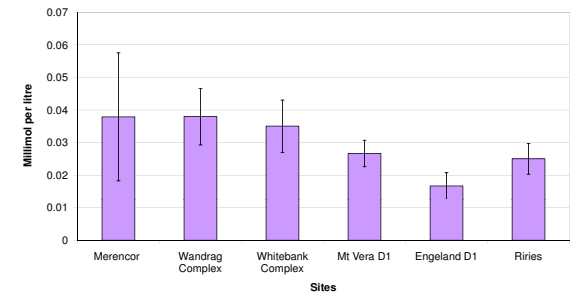
Northern Cape - NO3



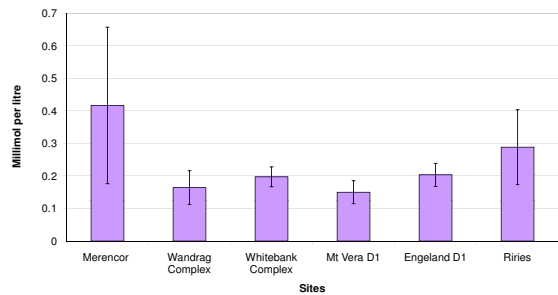
Northern Cape - NH4



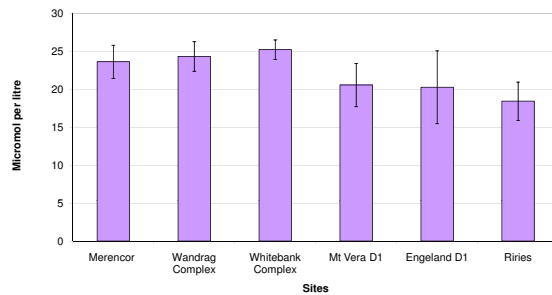
Northern Cape - Cl



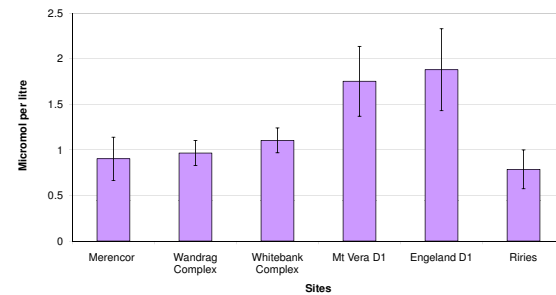
Northern Cape - HCO3



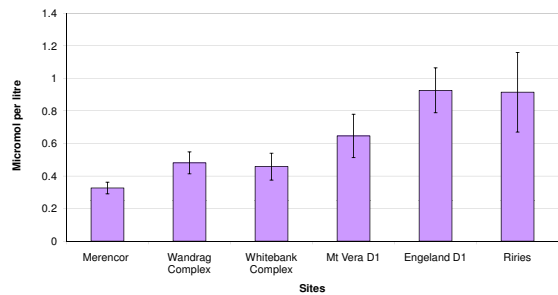
Northern Cape - Fe



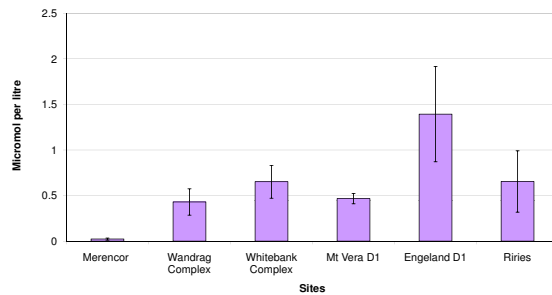
Northern Cape - Mn



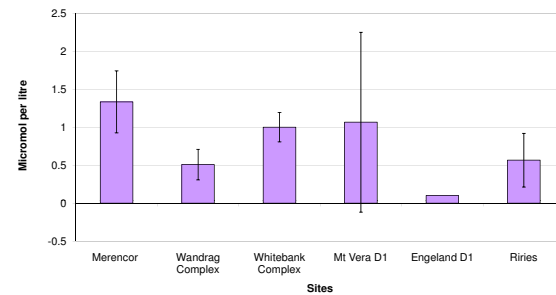
Northern Cape - Cu



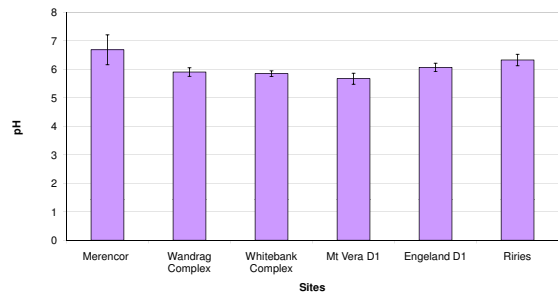
Northern Cape - Zn



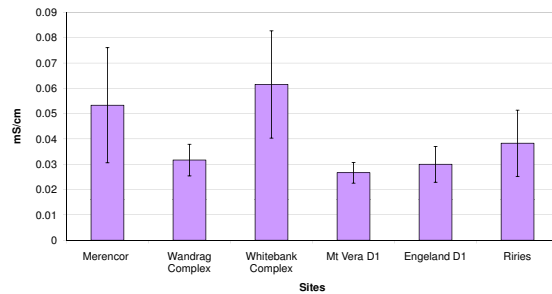
Northern Cape - B



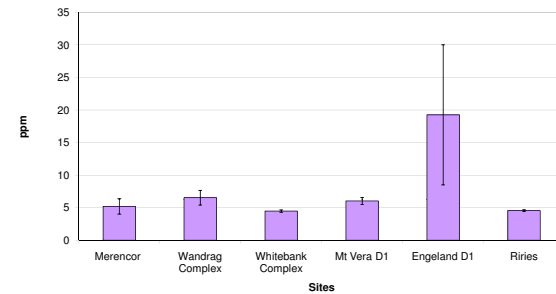
Northern Cape - pH



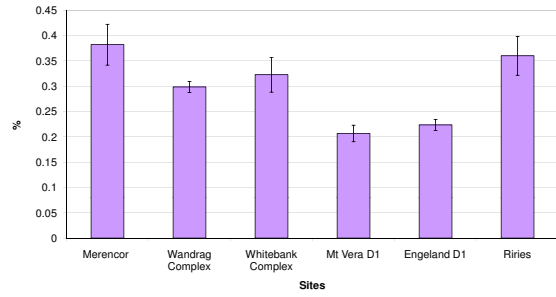
Northern Cape - Electrical conductivity



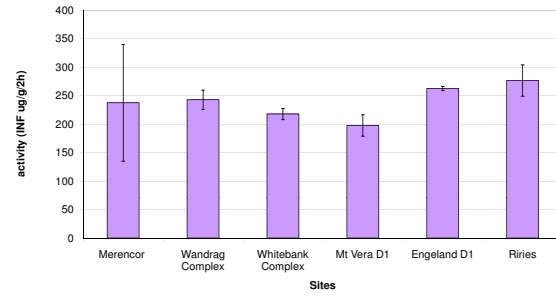
Northern Cape - P-Bray 1



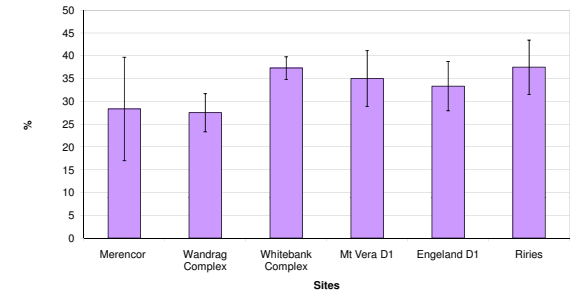
Northern Cape - % C



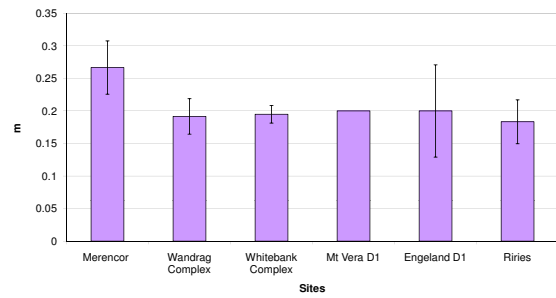
Northern Cape - Dehydrogenase



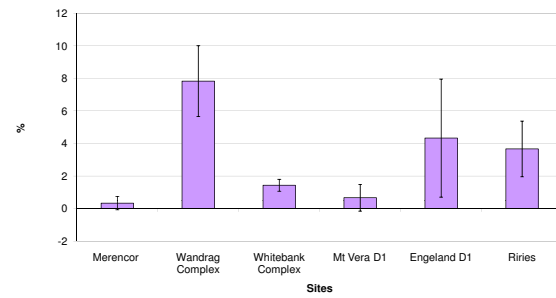
Northern Cape - Herbaceous crown cover



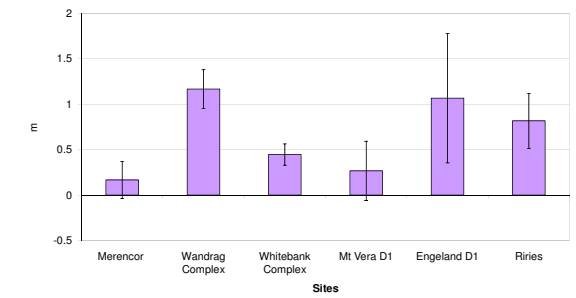
Northern Cape - Herbaceous crown height



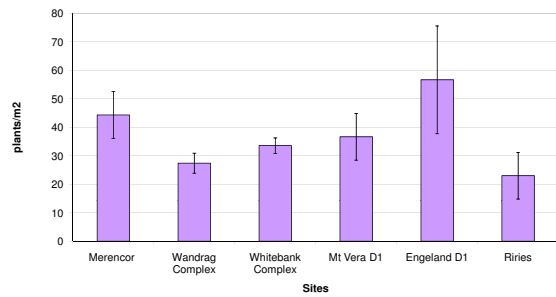
Northern Cape - Woody crown cover



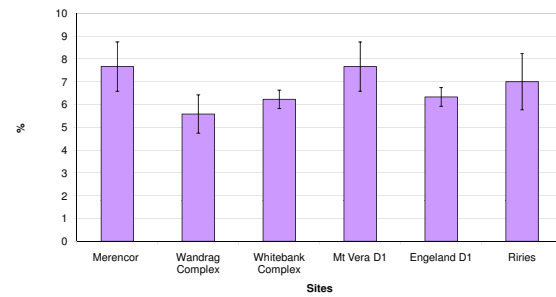
Northern Cape - Woody crown height



Northern Cape - Density



Northern Cape - Basal Cover



**APPENDIX C QUALITATIVE RESULTS**  
**APPENDIX C.1. LIMPOPO PROVINCE**  
C.1.1. Erosion

PROVINCE	DUMP_NAME	EROSION_TYPE	VISIBLE_SECPOL	IN_FLOODLINE
Limpopo	Egnep	Gully	No	Yes
Limpopo	Voorspoed3	Gully	No	Yes
Limpopo	Voorspoed7	Gully	No	No
Limpopo	Voorspoed7	Gully	No	Yes
Limpopo	Voorspoed7	Gully	No	No
Limpopo	Kloof2.7	Donga	Yes	Yes
Limpopo	Kloof2.10	Donga	Yes	Yes
Limpopo	Kloof2.10	Gully	No	Yes
Limpopo	Kloof3.1	Donga	Yes	Yes
Limpopo	Kloof3.1	Donga	No	Yes
Limpopo	Kloof3.1	Donga	No	Yes
Limpopo	Kloof3.2	Gully	No	No
Limpopo	Penge10	Gully	Yes	Yes
Limpopo	Penge12	Donga	Yes	Yes
Limpopo	Penge14	Gully	Yes	Yes
Limpopo	Penge14	Gully	No	Yes
Limpopo	Penge14	Donga	Yes	Yes
Limpopo	Penge17	Donga	Yes	Yes
Limpopo	Kromellenboog1	Gully	Yes	Yes
Limpopo	Kromellenboog1	Gully	No	Yes
Limpopo	Kromellenboog3	Gully	Yes	No

## **Appendix C.1. Limpopo Province**

### C.1.2. Secondary pollution

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
Limpopo	Kempville	Road	Yes	No
Limpopo	Egnep	Veldt	Yes	No
Limpopo	Egnep	Veldt	Yes	No
Limpopo	Egnep	Dump	Yes	No
Limpopo	M&S	Dump	Yes	Yes
Limpopo	Lagersdraai	Veldt	Yes	No
Limpopo	Pylkop	Veldt	Yes	Yes
Limpopo	Pylkop	Veldt	Yes	No
Limpopo	Pylkop	Veldt	Yes	No
Limpopo	Zeelig	Veldt	Yes	No
Limpopo	Zeelig	Veldt	Yes	No
Limpopo	Zeelig	Veldt	Yes	No
Limpopo	Zeelig	Veldt	Yes	Yes
Limpopo	Zeelig	Veldt	Yes	No
Limpopo	Voorspoed1	Veldt	Yes	No
Limpopo	Voorspoed1	Veldt	Yes	No
Limpopo	Voorspoed1	Veldt	Yes	No
Limpopo	Voorspoed1	Road	Yes	No
Limpopo	Voorspoed1	Road	Yes	No
Limpopo	Voorspoed2	Veldt	Yes	No
Limpopo	Voorspoed2	Veldt	Yes	No
Limpopo	Voorspoed4	Veldt	Yes	No
Limpopo	Voorspoed4	Road	Yes	No
Limpopo	Voorspoed5	Veldt	Yes	No
Limpopo	Voorspoed5	Veldt	Yes	No
Limpopo	Voorspoed5	Veldt	Yes	No
Limpopo	Voorspoed5	Road	Yes	No
Limpopo	Voorspoed6	Road	Yes	No
Limpopo	Voorspoed7	Dump	Yes	No
Limpopo	Voorspoed7	Road	Yes	No
Limpopo	Voorspoed7	Dump	Yes	No
Limpopo	Voorspoed7	Road	Yes	No
Limpopo	Voorspoed7	Dump	Yes	No
Limpopo	Voorspoed7	Stream	Yes	Yes
Limpopo	Voorspoed7	Stream	Yes	Yes
Limpopo	Voorspoed7	Road	Yes	No
Limpopo	Voorspoed7	Road	Yes	No
Limpopo	Voorspoed8	Veldt	Yes	No
Limpopo	Voorspoed8	Veldt	Yes	No
Limpopo	RabesKloof1	Veldt	Yes	Yes
Limpopo	RabesKloof1	Veldt	Yes	Yes
Limpopo	RabesKloof1	Dump	Yes	Yes
Limpopo	RabesKloof1	Veldt	Yes	Yes
Limpopo	RabesKloof2	Veldt	Yes	No
Limpopo	RabesKloof2	Veldt	Yes	No
Limpopo	RabesKloof2	Veldt	Yes	No
Limpopo	RabesKloof3	Dump	No	Yes
Limpopo	RabesKloof3	Veldt	No	Yes

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
Limpopo	RabesKloof3	Veldt	No	Yes
Limpopo	RabesKloof3	Veldt	No	Yes
Limpopo	RabesKloof3	Dump	Yes	No
Limpopo	RabesKloof3	Dump	Yes	Yes
Limpopo	RabesKloof3	Veldt	No	No
Limpopo	RabesKloof3	Dump	No	No
Limpopo	Kloof2.1	Veldt	Yes	Yes
Limpopo	Kloof2.3	Veldt	Yes	No
Limpopo	Kloof2.3	Veldt	No	No
Limpopo	Kloof2.3	Veldt	No	No
Limpopo	Kloof2.3	Veldt	No	No
Limpopo	Kloof2.4	Veldt	Yes	No
Limpopo	Kloof2.4	Veldt	Yes	No
Limpopo	Kloof2.4	Veldt	Yes	No
Limpopo	Kloof2.4	Veldt	Yes	No
Limpopo	Kloof2.4	Veldt	Yes	No
Limpopo	Kloof2.4	Veldt	Yes	No
Limpopo	Kloof2.4	Veldt	No	No
Limpopo	Kloof2.4	Veldt	No	No
Limpopo	Kloof2.4	Veldt	No	No
Limpopo	Kloof2.4	Veldt	No	No
Limpopo	Kloof2.5	Dump	Yes	No
Limpopo	Kloof2.6	Veldt	Yes	No
Limpopo	Kloof2.6	Veldt	Yes	Yes
Limpopo	Kloof2.6	Veldt	Yes	No
Limpopo	Kloof2.7	Dump	Yes	No
Limpopo	Kloof2.7	Dump	No	No
Limpopo	Kloof2.9	Veldt	Yes	No
Limpopo	Kloof2.9	Veldt	Yes	No
Limpopo	Kloof2.9	Veldt	Yes	No
Limpopo	Kloof2.9	Veldt	Yes	No
Limpopo	Kloof2.9	Veldt	Yes	No
Limpopo	Kloof2.9	Veldt	Yes	No
Limpopo	Kloof2.10	Veldt	Yes	No
Limpopo	Kloof2.10	Dump	Yes	No
Limpopo	Kloof2.11	Veldt	No	No
Limpopo	Kloof2.11	Veldt	No	No
Limpopo	Kloof3.1	Veldt	Yes	No
Limpopo	Kloof3.2	Dump	Yes	Yes
Limpopo	Kloof3.2	Dump	Yes	Yes
Limpopo	Kloof3.2	Dump	Yes	Yes
Limpopo	Penge1	Veldt	Yes	No
Limpopo	Penge3	Veldt	No	No
Limpopo	Penge4	Veldt	Yes	No
Limpopo	Penge4	Veldt	Yes	No
Limpopo	Penge4	Veldt	Yes	Yes
Limpopo	Penge6	Veldt	Yes	Yes
Limpopo	Penge6	Veldt	No	Yes
Limpopo	Penge6	Veldt	No	Yes
Limpopo	Penge6	Veldt	Yes	Yes
Limpopo	Penge6	Veldt	No	No
Limpopo	Penge6	Veldt	Yes	Yes
Limpopo	Penge6	Dump	Yes	Yes
Limpopo	Penge9	Dump	Yes	No

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
Limpopo	Penge9	Dump	Yes	Yes
Limpopo	Penge10	Veldt	No	No
Limpopo	Penge10	Veldt	No	No
Limpopo	Penge10	Road	No	No
Limpopo	Penge10	Road	Yes	Yes
Limpopo	Penge10	Veldt	No	Yes
Limpopo	Penge10	Veldt	No	Yes
Limpopo	Penge10	Veldt	No	Yes
Limpopo	Penge10	Veldt	No	Yes
Limpopo	Penge10	Road	Yes	Yes
Limpopo	Penge10	Dump	Yes	Yes
Limpopo	Penge10	Dump	Yes	Yes
Limpopo	Penge10	Building	Yes	Yes
Limpopo	Penge11	Dump	Yes	No
Limpopo	Penge11	Dump	No	No
Limpopo	Penge11	Dump	Yes	No
Limpopo	Penge12	Dump	Yes	No
Limpopo	Penge12	Dump	Yes	No
Limpopo	Penge12	Veldt	No	Yes
Limpopo	Penge12	Veldt	No	Yes
Limpopo	Penge12	Dump	Yes	Yes
Limpopo	Penge14	Dump	Yes	No
Limpopo	Penge14	Road	Yes	No
Limpopo	Penge17	Dump	Yes	Yes
Limpopo	Penge18	Dump	Yes	No
Limpopo	Penge18	Dump	Yes	No
Limpopo	Penge18	Dump	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Dump	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Dump	Yes	No
Limpopo	Kromellenboog1	Veldt	Yes	No
Limpopo	Kromellenboog1	Veldt	No	No
Limpopo	Kromellenboog1	Veldt	No	No
Limpopo	Kromellenboog1	Veldt	Yes	Yes
Limpopo	Kromellenboog2	Veldt	Yes	Yes
Limpopo	Kromellenboog2	Dump	Yes	Yes
Limpopo	Kromellenboog2	Dump	Yes	Yes
Limpopo	Kromellenboog2	Dump	Yes	Yes
Limpopo	Kromellenboog2	Dump	Yes	Yes
Limpopo	Kromellenboog2	Veldt	No	Yes
Limpopo	Kromellenboog2	Veldt	No	Yes

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
Limpopo	Kromellenboog2	Veldt	No	Yes
Limpopo	Kromellenboog2	Veldt	Yes	Yes
Limpopo	Kromellenboog2	Veldt	No	Yes
Limpopo	Kromellenboog2	Veldt	No	Yes
Limpopo	Kromellenboog2	Veldt	Yes	Yes
Limpopo	Kromellenboog3	Dump	Yes	No
Limpopo	Kromellenboog3	Veldt	Yes	No
Limpopo	Kromellenboog3	Veldt	Yes	No
Limpopo	Kromellenboog3	Veldt	Yes	No
Limpopo	Kromellenboog3	Veldt	Yes	No
Limpopo	Kromellenboog3	Veldt	Yes	No
Limpopo	Kromellenboog3	Veldt	Yes	No
Limpopo	Kromellenboog4	Dump	Yes	No
Limpopo	Kromellenboog4	Dump	Yes	No
Limpopo	Kromellenboog4	Dump	Yes	No
Limpopo	Kromellenboog4	Dump	Yes	No
Limpopo	Kromellenboog4	Dump	Yes	No
Limpopo	Kromellenboog4	Dump	Yes	No
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	
Limpopo	KromAccRoad	Road	No	

## **Appendix C.1. Limpopo Province**

### C.1.3. Water control structures

PROVINCE	DUMP_NAME	WCS_TYPE	VISIBLE_SECPOL	IN_FLOODLINE
Limpopo	Kempville	Contour wall	No	
Limpopo	Egnep	Contour wall	No	Yes
Limpopo	Egnep	Waterway	Yes	Yes
Limpopo	Egnep	Waterway	Yes	Yes
Limpopo	Egnep	Speed reducer	No	Yes
Limpopo	Egnep	Waterway	No	Yes
Limpopo	Egnep	Retaining wall	Yes	Yes
Limpopo	M&S	Retaining wall	Yes	Yes
Limpopo	Voorspoed1	Waterway	No	Yes
Limpopo	Voorspoed1	Contour wall	No	Yes
Limpopo	Voorspoed1	Contour wall	No	Yes
Limpopo	Voorspoed5	Gabions	No	Yes
Limpopo	Voorspoed5	Gabions	No	Yes
Limpopo	Voorspoed5	Gabions	No	Yes
Limpopo	Voorspoed5	Gabions	No	Yes
Limpopo	Voorspoed5	Gabions	No	Yes
Limpopo	Voorspoed5	Gabions	No	Yes
Limpopo	Voorspoed7	Contour wall	Yes	Yes
Limpopo	Voorspoed7	Contour wall	No	Yes
Limpopo	Voorspoed7	Contour wall	No	Yes
Limpopo	Voorspoed7	Contour wall	No	Yes
Limpopo	Voorspoed7	Contour wall	No	Yes
Limpopo	Voorspoed7	Contour wall	No	Yes
Limpopo	Voorspoed7	Waterway	No	Yes
Limpopo	RabesKloof1	Gabions	No	Yes
Limpopo	RabesKloof1	Retaining wall	No	Yes
Limpopo	RabesKloof1	Contour wall	No	No
Limpopo	RabesKloof1	Contour wall	No	No
Limpopo	RabesKloof1	Contour wall	No	No
Limpopo	RabesKloof2	Gabions	No	No
Limpopo	RabesKloof2	Retaining wall	No	No
Limpopo	RabesKloof3	Weir	No	Yes
Limpopo	RabesKloof3	Channel	No	Yes
Limpopo	RabesKloof3	Retaining wall	No	Yes
Limpopo	RabesKloof3	Contour wall	Yes	No
Limpopo	RabesKloof3	Retaining wall	Yes	Yes
Limpopo	RabesKloof3	Retaining wall	No	Yes
Limpopo	RabesKloof3	Retaining wall	No	Yes
Limpopo	RabesKloof3	Retaining wall	No	Yes
Limpopo	RabesKloof3	Retaining wall	No	Yes
Limpopo	RabesKloof3	Retaining wall	No	No
Limpopo	Kloof2.1	Retaining wall	No	No
Limpopo	Kloof2.1	Contour wall	No	No
Limpopo	Kloof2.2	Retaining wall	Yes	No
Limpopo	Kloof2.2	Retaining wall	No	Yes
Limpopo	Kloof2.2	Contour wall	No	Yes
Limpopo	Kloof2.2	Contour wall	No	Yes
Limpopo	Kloof2.3	Retaining wall	No	No
Limpopo	Kloof2.4	Retaining wall	No	Yes

PROVINCE	DUMP_NAME	WCS_TYPE	VISIBLE_SECPOL	IN_FLOODLINE
Limpopo	Kloof2.4	Contour wall	Yes	Yes
Limpopo	Kloof2.4	Contour wall	Yes	Yes
Limpopo	Kloof2.4	Contour wall	No	Yes
Limpopo	Kloof2.6	Contour wall	No	No
Limpopo	Kloof2.10	Contour wall	No	No
Limpopo	Kloof2.10	Contour wall	No	No
Limpopo	Kloof3.1	Retaining wall	No	No
Limpopo	Penge1	Contour wall	No	No
Limpopo	Penge1	Contour wall	No	No
Limpopo	Penge1	Contour wall	No	No
Limpopo	Penge1	Contour wall	No	No
Limpopo	Penge6	Retaining wall	No	No
Limpopo	Penge6	Contour wall	No	No
Limpopo	Penge8	Retaining wall	Yes	No
Limpopo	Penge8	Retaining wall	Yes	Yes
Limpopo	Penge9	Retaining wall	No	Yes
Limpopo	Penge9	Retaining wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	Yes	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge10	Contour wall	No	No
Limpopo	Penge11	Contour wall	No	No
Limpopo	Penge12	Contour wall	No	Yes
Limpopo	Penge12	Contour wall	No	Yes
Limpopo	Penge12	Contour wall	Yes	Yes
Limpopo	Penge14	Contour wall	Yes	Yes
Limpopo	Penge14	Contour wall	Yes	No
Limpopo	Penge14	Contour wall	Yes	Yes
Limpopo	Penge14	Contour wall	Yes	Yes
Limpopo	Penge14	Contour wall	Yes	Yes
Limpopo	Penge15	Contour wall	No	No
Limpopo	Penge15	Contour wall	No	No
Limpopo	Penge18	Contour wall	No	No
Limpopo	Penge18	Contour wall	No	No
Limpopo	Penge18	Contour wall	Yes	Yes
Limpopo	Kromellenboog1	Retaining wall	No	No
Limpopo	Kromellenboog1	Retaining wall	No	No
Limpopo	Kromellenboog1	Retaining wall	No	No
Limpopo	Kromellenboog1	Retaining wall	No	No
Limpopo	Kromellenboog1	Retaining wall	No	No
Limpopo	Kromellenboog2	Contour wall	No	Yes

## **Appendix C.2. North-West Province**

### C.2.1. Erosion

<b>PROVINCE</b>	<b>DUMP_NAME</b>	<b>EROSION_TYPE</b>	<b>VISIBLE_SECPOL</b>	<b>IN_FLOODLINE</b>
North-West	Pomfret 7	Gully	No	Yes
North-West	Whiterock	Gully	Yes	Yes

## **Appendix C.2. North-West Province**

### C.2.2. Secondary pollution

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
North-West	Pomfret 2	On dump	Yes	No
North-West	Pomfret 2	On dump	Yes	No
North-West	Pomfret 2	Road	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 3	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 4	On dump	Yes	No
North-West	Pomfret 5	On dump	Yes	No
North-West	Pomfret 6	On dump	Yes	No
North-West	Pomfret 6	Road	Yes	No
North-West	Pomfret 7	Road	Yes	No
North-West	Pomfret 7	On dump	Yes	No
North-West	Pomfret 7	On dump	Yes	No
North-West	Pomfret 7	Veldt/building	Yes	No
North-West	Pomfret 8	On dump	Yes	No
North-West	Pomfret 8	Road	Yes	No
North-West	Pomfret 8	On dump	Yes	No
North-West	Coretsi 1_South	On dump	Yes	No
North-West	Coretsi 1_South	On dump	Yes	No
North-West	Coretsi 1_South	Road	Yes	No
North-West	Coretsi 1_South	Road	Yes	No
North-West	Coretsi 1_South	Road	Yes	No
North-West	Coretsi 1_South	Road	Yes	No
North-West	Coretsi 2_West	On dump	Yes	No
North-West	Coretsi 2_West	Road on dump	Yes	No
North-West	Gamopedi	On dump	?	No
North-West	Gamopedi	On dump	?	No
North-West	Gamopedi	On dump	?	No
North-West	Gamopedi	On dump	?	No
North-West	Gamopedi	Road	?	?
North-West	Ncweng North 1	On dump	?	No
North-West	Ncweng North 1	On dump	?	No
North-West	Ncweng North 1	Veldt	?	No
North-West	Ncweng North 1	Road	?	No
North-West	Ncweng North 2	On dump	?	No
North-West	Ncweng North 2	Road	?	?
North-West	Ncweng North 3	On dump	?	No
North-West	Ncweng North 3	On dump	?	No
North-West	Ncweng North 4	On dump	?	No

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
North-West	Ncweng North 4	On dump	?	No
North-West	Ncweng North 4	On dump	?	No
North-West	Ncweng North 4	On dump	?	No
North-West	Ncweng North 4	?	?	?
North-West	Ncweng South 1.1	On dump	?	No
North-West	Ncweng South 1.1	On dump	?	No
North-West	Ncweng South 1.1	On dump	?	No
North-West	Ncweng South 1.1	On dump	?	No
North-West	Ncweng South 1.1	Veldt	?	No
North-West	Ncweng South 1.2	On dump	?	No
North-West	Ncweng South 1.2	On dump	?	No
North-West	Ncweng South 1.2	On dump	?	No
North-West	Ncweng South 1.2	On dump	?	No
North-West	Ncweng South 2.1	On dump	?	No
North-West	Ncweng South 2.2	On dump	?	No
North-West	Ncweng South 2.4	On dump	?	No
North-West	Ncweng South 2.4	On dump	?	No
North-West	Ncweng South 2.4	Road on dump	?	No
North-West	Ncweng South 2.4	Road	?	?
North-West	Bloubank	On dump	?	No
North-West	Bloubank	On dump	?	No
North-West	Bloubank	On dump	?	No
North-West	Bloubank	On dump	?	No
North-West	Bloubank	On dump	?	No
North-West	Bloubank	Veldt	?	?
North-West	Whiterock	On dump	Yes	No
North-West	Whiterock	On dump	Yes	No
North-West	Whiterock	On dump	Yes	No
North-West	Whiterock	On dump	Yes	No
North-West	Whiterock	On dump	Yes	No
North-West	Whiterock	Road on dump	Yes	No
North-West	Whiterock	On dump	Yes	No
North-West	Sardinia 1	On dump	Yes	No
North-West	Sardinia 1	On dump	Yes	No
North-West	Sardinia 1	On dump	Yes	No
North-West	Sardinia 2	On dump	?	No
North-West	Bruinkol 1	On dump	?	No
North-West	Bruinkol 1	On dump	?	No
North-West	Bruinkol 1	On dump	?	No
North-West	Bruinkol 1	On dump	?	No
North-West	Bruinkol 1	Veldt	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No
North-West	Bruinkol 2	On dump	?	No

## **Appendix C.2. North-West Province**

### C.2.3. Water control structures

<b>PROVINCE</b>	<b>DUMP_NAME</b>	<b>WCS_TYPE</b>	<b>VISIBLE_SECPOL</b>	<b>IN_FLOODLINE</b>
North-West	Pomfret 2	Weir	No	No
North-West	Pomfret 2	Retainingwall	No	No
North-West	Pomfret 3	Retainingwall	No	No
North-West	Pomfret 3	Retainingwall	No	No
North-West	Pomfret 3	Retainingwall	No	No
North-West	Pomfret 3	Retainingwall	No	No
North-West	Pomfret 6	Retainingwall	?	No
North-West	Pomfret 6	Retainingwall	?	No
North-West	Pomfret 6	Retainingwall	?	No
North-West	Pomfret 6	Retainingwall	?	No
North-West	Pomfret 6	Retainingwall	No	No
North-West	Pomfret 7	Retainingwall	No	No
North-West	Pomfret 8	Retainingwall	No	No
North-West	Pomfret 9	Retainingwall	No	No
North-West	Coretsi 2_West	Contour wall	No	?
North-West	Ncweng North 3	Contour wall	No	?

## **Appendix C.3. Northern Cape Province**

### **C.3.1. Erosion**

<b>PROVINCE</b>	<b>DUMP_NAME</b>	<b>EROSION_TYPE</b>	<b>VISIBLE_SECPOL</b>	<b>IN_FLOODLINE</b>
Northern Cape	Ettriks	Sinkhole	No	No
Northern Cape	Mt Vera	Gully	Yes	?
Northern Cape	Kuruman East	Donga	Yes	Yes
Northern Cape	Kuruman East	Donga	No	Yes
Northern Cape	Kuruman East	Donga	Yes	Yes
Northern Cape	Kuruman East	Donga	Yes	Yes
Northern Cape	Kuruman East	Donga	Yes	Yes
Northern Cape	Kuruman East	Donga	No	Yes
Northern Cape	Kuruman East	Donga	No	Yes
Northern Cape	Central Mill	Donga	No	No
Northern Cape	Central Mill	Donga	No	Yes
Northern Cape	Whitedale 1	Gully	No	Yes
Northern Cape	Whitekloof 1	Donga	No	Yes
Northern Cape	Groenwater 1	Gully	No	No
Northern Cape	Groenwater 1	Rill	No	No
Northern Cape	Groenwater 1	Gully	No	No
Northern Cape	Groenwater 1	Gully	No	?
Northern Cape	Groenwater 1	Gully	No	?
Northern Cape	Groenwater 2	Gully	No	No

## **Appendix C.3. Northern Cape Province**

### C.3.2. Secondary pollution

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
Nothern Cape	Exit 1	On dump	Yes	No
Nothern Cape	Exit 1	Road on dump	Yes	No
Nothern Cape	Exit 1	Dump/building	Yes	No
Nothern Cape	Exit 1	Road	Yes	No
Nothern Cape	Exit 2	Road	No	?
Nothern Cape	Ettriks	On dump	Yes	No
Nothern Cape	Wandrag 1	On dump	Yes	No
Nothern Cape	Wandrag 1	Veldt	Yes	No
Nothern Cape	Wandrag 1	On dump	Yes	No
Nothern Cape	Wandrag 1	On dump	Yes	No
Nothern Cape	Wandrag 1	On dump/veldt	Yes	No
Nothern Cape	Wandrag 1	On dump	Yes	No
Nothern Cape	Wandrag 1	On dump/veldt	Yes	No
Nothern Cape	Wandrag 1	On dump	Yes	No
Nothern Cape	Wandrag 2	On dump	Yes	No
Nothern Cape	Wandrag 2	Dump/building	Yes	No
Nothern Cape	Wandrag 2	On dump/veldt	Yes	No
Nothern Cape	Mt Vera	On dump	Yes	No
Nothern Cape	Mt Vera	On dump	Yes	No
Nothern Cape	Mt Vera	On dump	Yes	No
Nothern Cape	Mt Vera	On dump	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Mt Vera	Road	Yes	No
Nothern Cape	Riries 1	On dump	Yes	?
Nothern Cape	Riries 1	On dump	Yes	?
Nothern Cape	Riries 1	On dump	Yes	?
Nothern Cape	Riries 2	On dump	Yes	No
Nothern Cape	Riries 2	On dump	Yes	No
Nothern Cape	Riries 2	On dump	Yes	No
Nothern Cape	Riries 2	On dump	Yes	No
Nothern Cape	Riries 4	On dump	Yes	No
Nothern Cape	Riries 4	On dump	Yes	No
Nothern Cape	Riries 4	On dump	Yes	No
Nothern Cape	Riries 4	On dump	Yes	No
Nothern Cape	Merencor	Veldt	Yes	No
Nothern Cape	Merencor	Veldt	Yes	No
Nothern Cape	Merencor	Veldt	Yes	No
Nothern Cape	Merencor	Veldt	Yes	No
Nothern Cape	Merencor	Veldt	Yes	No
Nothern Cape	Merencor	Veldt	Yes	No
Nothern Cape	Merencor	On dump	Yes	No
Nothern Cape	Merencor	On dump	Yes	No
Nothern Cape	Merencor	On dump	Yes	No
Nothern Cape	Merencor	On dump	Yes	No

PROVINCE	DUMP_NAME	AREA_TYPE	PREVIOUSLY_REHAB	IN_FLOODLINE
Nothern Cape	Merencor	On dump	Yes	No
Nothern Cape	Merencor	Road	Yes	No
Nothern Cape	England	On dump	Yes	No
Nothern Cape	England	On dump	Yes	No
Nothern Cape	England	On dump	Yes	No
Nothern Cape	England	On dump	Yes	No
Nothern Cape	England	On dump	Yes	No
Nothern Cape	England	On dump	Yes	No
Nothern Cape	England	Road	Yes	No
Nothern Cape	Kuruman East	On dump	Yes	No
Nothern Cape	Kuruman East	Veldt	Yes	No
Nothern Cape	Kuruman East	Road	?	?
Nothern Cape	Central Mill	On dump	Yes	No
Nothern Cape	Central Mill	On dump	Yes	No
Nothern Cape	Central Mill	On dump	Yes	No
Nothern Cape	Central Mill	On dump	Yes	No
Nothern Cape	Central Mill	On dump	?	?
Nothern Cape	Central Mill	Road	Yes	No
Nothern Cape	Whitedale 1	On dump	Yes	No
Nothern Cape	Whitedale 1	On dump	Yes	No
Nothern Cape	Whitedale 1	Veldt	No	No
Nothern Cape	Whitedale 2	On dump	Yes	No
Nothern Cape	Whitedale 2	On dump	Yes	No
Nothern Cape	Whitedale 2	On dump	Yes	No
Nothern Cape	Whitedale 2	Road on dump	Yes	No
Nothern Cape	Whitebank 1	On dump	Yes	No
Nothern Cape	Whitebank 1	Veldt	?	No
Nothern Cape	Whitebank 1	On dump	?	?
Nothern Cape	Whitebank 2	On dump	Yes	No
Nothern Cape	Whitebank 2	On dump	Yes	No
Nothern Cape	Whitebank 2	Veldt	?	?
Nothern Cape	Whitekloof 1	On dump	Yes	No
Nothern Cape	Whitekloof 1	On dump	Yes	No
Nothern Cape	Whitekloof 1	On dump	Yes	?
Nothern Cape	Groenwater 2	Veldt/ dump	No	No
Nothern Cape	Groenwater 2	On dump	Yes	No
Nothern Cape	Groenwater 2	On dump	Yes	No
Nothern Cape	Groenwater 2	Road	No	Yes
Nothern Cape	Groenwater 1	Road	No	Yes
Nothern Cape	Groenwater 1	?	?	?
Nothern Cape	Groenwater 1	?	?	?

## **Appendix C.3. Northern Cape Province**

### C.3.3. Water control structures

PROVINCE	DUMP_NAME	WCS_TYPE	VISIBLE_SECPOL	IN_FLOODLINE
Northern Cape	Exit 2	Retaining wall	No	No
Northern Cape	Exit 2	Contour wall	No	?
Northern Cape	Exit 2	Contour wall	No	?
Northern Cape	Exit 2	Contour wall	No	?
Northern Cape	Wandrag 1	Contour wall	No	?
Northern Cape	Wandrag 2	Retaining wall	No	No
Northern Cape	Merencor	Contour wall	No	?
Northern Cape	England	Contour wall	No	No
Northern Cape	Kuruman East	Retaining wall	No	No
Northern Cape	Kuruman East	?	No	Yes
Northern Cape	Kuruman East	?	No	Yes
Northern Cape	Kuruman East	?	No	Yes
Northern Cape	Kuruman East	Retaining wall	No	Yes
Northern Cape	Kuruman East	Waterway	No	Yes
Northern Cape	Kuruman East	Weirs	No	Yes
Northern Cape	Kuruman East	Weirs	No	Yes
Northern Cape	Kuruman East	Weirs	No	Yes
Northern Cape	Certral Mill	Waterway	No	No
Northern Cape	Certral Mill	Contour wall	No	No
Northern Cape	Certral Mill	Contour wall	No	?
Northern Cape	Certral Mill	Contour wall	No	?
Northern Cape	Certral Mill	Contour wall	No	?
Northern Cape	Certral Mill	Contour wall	No	?
Northern Cape	Whitebank 1	Waterway	No	No
Northern Cape	Whitebank 2	Retaining wall	No	Yes
Northern Cape	Whitekloof 1	Contour wall	No	No
Northern Cape	Whitekloof 2	Contour wall	No	No
Northern Cape	Whitekloof 3	Contour wall	No	No
Northern Cape	Whitedale 1	Contour wall	No	No
Northern Cape	Whitedale 2	Contour wall	No	No
Northern Cape	Whitedale 2	Contour wall	No	No
Northern Cape	Whitedale 2	Contour wall	No	No
Northern Cape	Whitedale 2	Contour wall	No	No
Northern Cape	Groenwater 1	Contour wall	No	No
Northern Cape	Groenwater 2	Contour wall	No	No
Northern Cape	Groenwater 3	Contour wall	No	No