

**THE IMPACT OF ALIEN PLANT INVASIONS ON BIODIVERSITY IN SOUTH
AFRICA. THE CASE OF ALIEN ACACIA SPECIES IN THE GAUTENG AND
CHROMOLAENA ODORATA IN THE KWAZULU NATAL PROVINCES.**

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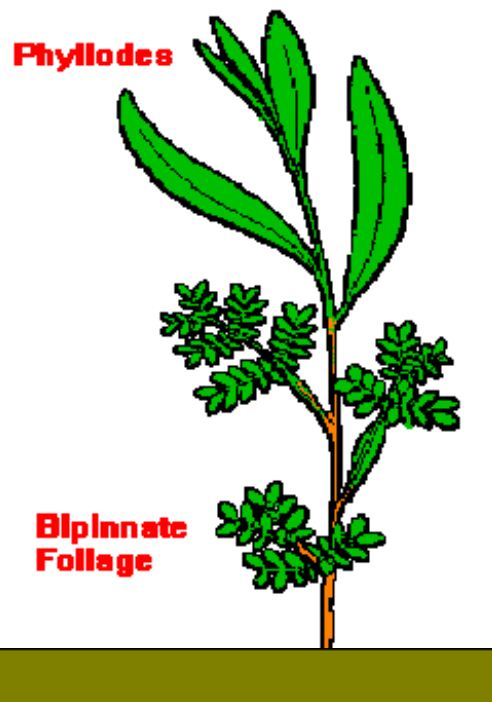
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**DEDICATED TO MY DEAREST MUM & DAD,
BROTHERS AND SISTERS NOT LEAVING OUT MY BOSOM
FRIENDS.**



Chromolaena odorata

Acacia specie

ABSTRACT

The research is aimed at:

- Measuring the impact of Acacia species on biodiversity in the Gauteng province of South Africa,
- Assessing the impact of Chromolaena odorata on the biodiversity of the KwaZulu Natal province,
- Looking at links between the *root structures* of these alien invasive species, their effects on *soil and water systems* (the environment being an important water user), and their abilities to spread widely,
- Predicting the spread of Acacia species and Chromolaena odorata across Africa (South Africa, Cameroon and Ghana) based on geological and climatological data,
- Looking at control methods aimed at curbing the spread of alien invasive species (particularly Acacia species and Chromolaena odorata),
- Checking out the ramifications of chemical control methods on the environment at large, and,
- Suggesting alternate approaches to control the spread of these alien species across the African continent.

In this research work, the causes and solutions to the loss of biodiversity in South Africa especially along river-banks is dealt with significantly. Attempts are made to point out issues tied to the prevailing water crisis and ecosystem fragmentation for scientists and policy-makers. Its recommendations are laid down in simple and plain terms, and in a manner that draws attention to even the non – science community, thus finding its way into living rooms and classrooms. The recommendations in a way propels the call for succinct efforts by way of environmental education programs and many other approaches in both rural and non – rural areas in South Africa on how to deal with the prevailing impacts of the identified invasive alien plants on the biodiversity of the region as well as water systems. The results further prove and stress the point that indigenous as well as useful species in Southern Africa are fast becoming extinct and most of these extinctions have been tied to: human activity (such as over exploitation of water resources), and worst of all some exotic species such as the ones this study focuses on; Acacia species and Chromolaena odorata.

The study proves that water is vital in maintaining natural ecosystems which sustain biodiversity, and help to regulate the hydrological cycle, hence bringing value to people in the form of goods and services derived from activities in these ecosystems. Thus, for biodiversity to be sustainable, water must be saved. In effecting this research project, the author relied on structured questionnaires, postal and also interview schedules utilized by way of interviews, and also on fieldwork carried out along the Mid Elands River and other major rivers of the two provinces. These sample sites (mainly along river banks) were instrumental for data generation and useful for scientific judgements on the magnitude (level attained) of the conservation status within the riparian and grassland (mainly coastal) vegetations of the Gauteng and KwaZulu Natal provinces respectively.

The research approach (a combination of several methods) employed for the purpose of the study is known as the *paradigm of choices* as expressed in today's present educational jargon (educational terminology). Some of the instruments which were used apart from interview schedules and questionnaires, included field monitoring tools, and a couple of vegetation survey techniques. Useful to the research work were climatic data on the continent and the availability of CLIMEX software which eased assessments.

Documentary analysis was also resourceful to this study as it served in giving impetus to the literature review and entire thesis build-up. In this respect, up to date official government documents, research reports, and handbooks pertaining to this field of biodiversity were closely but critically analysed and used.

Evidence from the analysis of the data obtained from the field exercises and interview schedules is crystal clear of the fact that the vivid spread of these invasive plant species has got an adverse effect on both the ecology of South Africa and the people that inhabit it. At the present rate of spread, the research study concludes that, if much is not done to curb these alien invasive plant species; their spread as well to the rest of the African continent remains unavoidable. The thesis (research report) is divided into 5 chapters, outlined as follows:

Chapter 1: General Introduction

Chapter 2: Research Materials and Methods

Chapter 3: Results

Chapter 4: Discussion

Chapter 5: Conclusions and Recommendations

Based on the empirical field work done the writer succinctly has come up with some recommendations on the issues per se. In sum, the recommendations suggest the best ways to deal with the alien invasive species which is nothing short of the integrative approach, nonetheless designed to function at its maximum and in conjunction with locally available materials, manpower, *will* and on the spot expertise. Also, the study depicts the rapid spread of Acacia species and Chromolaena odorata across the African continent could lead to an environmental catastrophe should appropriate measures not be taken henceforth.

The findings also bring to light the necessity of co – ordination of all key players in this fight against alien invasive plant species and giving clues (suggestions or hints) on how concrete environmental policies can be designed in order to match with the objectives of ecologists and other concerned experts alike. Taking this route the study unfolds with compounding suggestions on what the African governments and experts (ecologists, conservationists, and hydrologists) on the field should inter alia do to avert this looming disaster.

ABSTRACT OF THESIS IN GERMAN

Zusammenfassung

Ziele der Forschungsarbeit:

- Messung des Einflusses von Acacia-Arten auf die Biodiversität in der Provinz Gauteng/ Republik Südafrika
- Einschätzung des Einflusses von Chromolaena odorata auf die Biodiversität in der Provinz KwaZulu Natal/ Republik Südafrika
- Betrachtung der Zusammenhänge zwischen den *Wurzelstrukturen* der oben genannten exotischer Arten, ihrer Auswirkung auf die *Boden- und Wassersysteme* (mit der Umwelt als wichtigem Wasserverbraucher) und ihrer Fähigkeit zur weiten Ausbreitung
- Vorhersage der Ausbreitung von Acacia-Arten und Chromolaena odorata in Afrika (Republik Südafrika, Kamerun und Ghana) anhand geologischer und klimatologischer Daten
- Analyse der Kontrollmethoden zur Reduzierung der Ausbreitung exotischer Arten (speziell Acacia-Arten und Chromolaena odorata)
- Erforschung der Effekte chemischer Kontrollmethoden auf die Umwelt als Ganzes
- Unterbreitung alternativer Vorschläge zur Kontrolle der Ausbreitung exotischer Arten über den afrikanischen Kontinent

Hauptziel dieser Forschungsarbeit ist die Auseinandersetzung mit den Ursachen der Verringerung von Biodiversität (v.a. an Flussufern) in Südafrika und der Entwurf von Interventionsmöglichkeiten, die diesen Prozess aufhalten können. Mit dieser Arbeit werden die herrschende Wasserkrise sowie die Zerstörung des Ökosystems Wissenschaftlern und Politikern nahegebracht. Die hier entwickelten Empfehlungen sind in einer einfachen und klaren Weise dargestellt und somit auch der nichtwissenschaftlichen Gesellschaft (Schulen, Privatpersonen) zugänglich. Diese Empfehlungen bestätigen und unterstützen den Bedarf an konkreten Anstrengungen durch Umwelt-Bildungsprogramme sowie weiteren Aktivitäten in ländlichen und urbanen Regionen, um Handlungsstrategien zum Umgang mit der Problematik andauernder Folgen exotischer Arten auf die Biodiversität und Wassersysteme der Region zu entwickeln. Des weiteren beweisen die Ergebnisse der Forschung, dass das rasante Aussterben (schneller als je zuvor in der Geschichte) einheimischer nützlicher Arten im Südlichen Afrika in enger Verbindung mit menschlicher Aktivität (wie Übernutzung von Wasserressourcen) und dem Eindringen exotischer Spezien wie den hier studierten Acacia-Arten und Chromolaena odorata stehen.

Die Studie beweist, dass Wasser von überragender Bedeutung für den Erhalt natürlicher Ökosysteme ist. Für eine nachhaltige Biodiversität ist es deswegen wichtig, sparsam mit der Ressource Wasser umzugehen.

Bei der Durchführung der für diese Arbeit notwendigen Forschungen benutzte der Autor strukturierte Fragebögen und Interviews, sowie selbst erhobenes empirisches Datenmaterial vom Mid Elands River und weiteren wichtigen Flüssen der zwei Provinzen. Diese Feldstudien (v.a. an Flussufern) waren von fundamentaler Bedeutung für die Datengewinnung und nützlich im Hinblick auf möglich wissenschaftliche Urteile bezüglich des erreichten Niveaus der Maßnahmen zum Arterhalt der Ufer- und Grasslandvegetation der Provinzen KwaZulu Natal und Gauteng.

Die für diese Studie gewählte Herangehensweise (eine Kombination mehrerer Methoden) wird in den Sozialwissenschaften als „Paradigm of choices“ bezeichnet. Während der Feldstudien kamen Monitoring Tools und mehrere Vegetations-Survey-Techniken zur Anwendung. Hilfreich war auch die Verfügbarkeit klimatischer Daten des Kontinents sowie die Anwendung der CLIMEX-Software, welche die Auswertung der erhobenen Daten erleichterte. Die Analyse von Dokumenten bereicherte und ergänzte den Überblick über den aktuellen Forschungsstand. Offizielle Regierungsdokumente, Forschungsberichte und Handbücher wurden hierfür ausführlich und kritisch analysiert und einbezogen.

Die Ergebnisse der Datenanalyse aus den Feldstudien und Fragebögen beweisen eindeutig, dass die weite Verbreitung exotischer Arten einen ungünstigen Effekt sowohl auf die Ökologie der Republik Südafrika als auch seiner Einwohner hat. Die Arbeit zeigt, dass bei dem derzeitigen Ausdehnungstempo – sollten keine Maßnahmen getroffen werden – eine weitere Verbreitung der exotischen Arten über den gesamten afrikanischen Kontinent unvermeidlich ist.

Die Arbeit gliedert sich in folgende fünf Kapitel:

1. Einleitung
2. Forschungsmaterialien und Methoden
3. Forschungsergebnisse
4. Diskussion
5. Schlüsse und Empfehlungen

Auf Basis seiner empirischen Forschungen entwickelt der Autor einige knappe Empfehlungen. Dabei handelt es sich um Vorschläge zum Umgang mit exotischen Arten im Rahmen eines integrativen Ansatzes, welcher ein maximales Ergebnis bei Einsatz lokal verfügbarer Materialien, Arbeitskräfte, einheimischer Experten und dem notwendigen Willen erzielen kann. Des Weiteren beschreibt diese Studie, wie eine Verbreitung von exotischen Acacia-Arten und *Chromolaena odorata* über den afrikanischen Kontinent zu einer Umweltkatastrophe führen können, sollten angemessene Maßnahmen ausbleiben. Die Ergebnisse betonen die Notwendigkeit der Koordination aller Beteiligten in Schlüsselpositionen im Kampf gegen exotische Arten und geben Hinweise, wie konkrete umweltpolitische Programme gestaltet werden können, die den Anforderungen von Ökologen und anderen beteiligten Experten gerecht werden. Letztendlich führt die Studie zu übergreifenden Vorschlägen, was afrikanische Regierungen und Experten (Ökologen, Artenschützer und Hydrologen) tun können, um gemeinsam diese herannahende Katastrophe zu verhindern.

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CONTENTS

	PAGE
DEDICATION	ii
ABSTRACTiv
ACKNOWLEDGEMENTS	viii
LIST OF ABBREVIATIONS	xiii
LIST OF FIGURES	xiv
LIST OF TABLES	xv
CHAPTER ONE	1
General Introduction	1
1.1 Introduction.....	1
1.2 Research methods and plan.....	2
1.2.1 The aim.....	3
1.2.2 Hypothesis.....	3
1.2.3 Thesis outline.....	3
1.3 Justification for the research.....	3
1.3.1 Contribution of the research	4
1.3.2 Relation to previous research.....	5
1.4 Evaluation.....	5
1.5 Decision making.....	5
CHAPTER TWO	6
Research Materials & Methods	6
2.1 Research procedures followed in this study.....	7
2.1.1 Research design.....	7
2.1.2 Methods.....	8

2.1.3	Limitations.....	8
2.1.4	Field data Collection.....	9
2.2	Location of South Africa.....	10
2.2.1	Population of South Africa.....	11
2.2.2	Area and population density.....	11
2.3	Geography of South Africa.....	12
2.3.1	Soil Types.....	13
2.3.2	Climate.....	14
2.3.3	Description of sites.....	14
2.4	Significance of the sampling exercise.....	15
2.5	The Research Instruments.....	17
2.6	The main study.....	31
2.6.1	The Participants involved.....	31
2.6.2	Validity and reliability of the questionnaires (postal questionnaires) and interview Schedules.....	32
2.6.3	The interviews.....	34
2.6.4	Questions used for interview schedules.....	35
2.7	Fieldwork and measuring techniques.....	36
2.8	Organizations concerned.....	50
2.9	Public involvement.....	50
2.9.1	Ethical concerns.....	50
2.10	Remarks.....	52
CHAPTER THREE		53
Results		53
3.1	Research findings.....	53

3.1.1 Findings from postal questionnaires distributed in South Africa, Cameroon and Ghana.....	53
3.1.2 Findings from interviews.....	63
3.2 Results of documentary analysis.....	68
3.2.1 Further background information on South Africa viz a viz the Environment....	71
3.3 Results of field survey.....	77
3.3.1 Approach towards the interpretation and analysis of field findings.....	88
3.4 Comparison of results	89
CHAPTER FOUR.....	90
Discussion	90
4.1 Literature review and theoretical framework.....	90
4.1.1 The situation of invasive species in South Africa’s biomes.....	93
4.1.2 Uses and importance of biodiversity.....	93
4.2 Current distribution of alien invasive species in South Africa.....	107
4.2.1 Exotics and their rates of spread	108
4.2.2 Vegetations invaded by Acacia species and Chromolaena in South Africa.....	110
4.3 Conservation and Management of Ecosystems and Biodiversity.....	111
4.3.1 The importance of biodiversity in ecosystem function.....	113
4.3.2 The causes and consequences of the disappearance of species.....	115
4.3.3 Ecological effects of invasive species.....	116
4.3.4 Impacts of alien invasive plant species on biodiversity.....	117
4.4 Control measures for invasive plant species.....	119
4.5 Ecology of the Grasslands and Savannah areas.....	121
4.6 Geography of the Gauteng and KwaZulu Natal Provinces.....	125
4.7 Thrust of the research study.....	128

4.8 Alien invasive species, Biodiversity management and the Ecological theory.....	131
4.9 South Africa and International engagements on environment.....	144
CHAPTER FIVE.....	157
Conclusions and Recommendations.....	157
5.1 Summary.....	157
5.2 Managing biodiversity.....	161
5.2.1 Threats to sustainable biodiversity management	161
5.3 Critical review of research methods used in the field.....	162
5.3.1 Strengths of instruments and methods utilized in this study.....	163
5.3.2 Weaknesses of instruments and methods utilized in this study.....	165
5.4 Proposed Control Methods for Alien Invasive Species	166
5.5 Conclusions.....	183
5.6 General Recommendations on the control of alien invasive species.....	188
REFERENCES.....	191
APPENDICES.....	205

LIST OF ABBREVIATIONS

<u>ABBREVIATIONS</u>	<u>MEANING</u>
ARC	Agricultural Research Council
BTU	Brandenburg Technical University of Cottbus.
CBD	Convention on Biological Diversity.
CITES	Convention on Trade in Endangered Species of Wild Fauna and Flora.
DEAT	Department of Environmental Affairs and Tourism.
DWAF	Department of Water Affairs and Forestry.
ETC	Meaning that there are a host of others, or and so on.
Et al.	Meaning and others, or there exist other members.
E.G	For example.
GPS	Global Positioning System.
GSM	Global Systems for Mobile Communications.
IAS	Invasive Alien Species
N.E	North East.
NGO	Non Governmental Organisation.
p	Page.
pp	Pages.
PCQ	Point Center Quadrat method.
PPRI	Plant Protection Research Institute.
RHP	River Health Programme.
Sp (Spp)	Specie(s).
UN	United Nations.
WWP	Working for water Project.
WfW	Working for Water Programme.
%	Percentage.

LIST OF FIGURES

	PAGE
FIGURE 1: Map of South Africa showing the Gauteng and KwaZulu Natal provinces.	10
FIGURE 2: Flowchart showing steps taken when designing, using and analysing the questionnaire.	20
FIGURE 3: Diagram illustrating the application of the Point Centre Quadrant Method in the field	43
FIGURE 4: Budget Allocation - Department of Environmental Affairs and Tourism	72
FIGURE 5: Programmes funded by Donor Agencies (DEAT, National Botanical Institute & South African National Parks).	73
FIGURE 6: Programmes funded by Donor Agencies (only amounts > R5 000 000 shown).	74
FIGURE 7: Funds provided by Government, Private Sector and Non - Governmental Organisations for environmental research	75
FIGURE 8: Steps in the policy formulation process	158
FIGURE 9: Control of alien invasive species	178
FIGURE 10: Strategies aimed at curbing the spread of alien invasive tree species (initial option)	179
FIGURE 11: Alternative control routes for wattles, gum or pine trees (general)	179
FIGURE 12: Steps followed for the control of stumps	180
FIGURE 13: Planning control of invasive alien species (integral control option)	181
FIGURE 14: Planning toward implementation and final stages	181
FIGURE 15: Integrative control approach in the control of <i>Chromolaena odorata</i>	182

LIST OF TABLES

	PAGE
TABLE 1: Showing some geographical facts about South Africa.	12 - 13
TABLE 2: Statistical data for South Africa's climate in GP & KZN	14
TABLE 3: Analysis of responses expressed in percentages (A)	54 - 55
TABLE 4: Analysis of responses expressed in percentages (B)	57 - 58
TABLE 5: Analysis of responses expressed in percentages (C)	60 - 61
TABLE 6: Some characteristics of the various control methods	70
TABLE 7: NRF Funding for Environmentally Sustainable Development Projects	76
TABLE 8: Survey results of site 1	77
TABLE 9: Survey results of site 2	77
TABLE 10: Survey results of site 3	78
TABLE 11: Survey results of site 4	78
TABLE 12: Survey results of site 5	79
TABLE 13: Survey results of site 6	80
TABLE 14: A Point-Centered Quarter Analysis using values obtained from site six along Elands River. (Along this transect, five sampling points, one at every 5m along about 25 – 30°).	81
TABLE 15: Invasive species number per quarter	82
TABLE 16: Determining density, dominance and frequency of species.	83
TABLE 17: Survey results of site 7	84
TABLE 18: Survey results of site 8	84
TABLE 19: Survey results of site 9	85
TABLE 20: Survey results of site 1	86
TABLE 21: Survey results of site 2	86

TABLE 22: Survey results of site 3	87
TABLE 23: Survey results of site 4	88
TABLE 24: Signatories to the CBD	92
TABLE 25: The Species Richness of South Africa's Terrestrial Areas	97
TABLE 26: The Impacts of invading alien plants on the amount of water in river Systems (surface runoff) in each Province of South Africa, and Lesotho.	98
TABLE 27: Estimated mean annual volumes of water used by the top 25 invader species for the whole of South Africa, ranked according to the volume of water used	98 - 99
TABLE 28: Distribution of Acacia Species and Chromolaena odorata in South Africa	107 - 108
TABLE 29: Seed numbers of Acacia species in the soil under different densities	109
TABLE 30: Number of grassland bird species affected negatively or positively by afforestation	136
TABLE 31: Actual and Potential Plant Biodiversity Loss	156
TABLE 32: Initial control options for wattle	170
TABLE 33: Follow-up and maintenance control options for wattle	171
TABLE 34: Estimated number of Wattle Seeds in the soil	174
TABLE 35: Control strategy	183

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

The present degree of spread of alien plant species is taking its toll on the biodiversity of South Africa and the African continent at large. Today, control by way of the varying approaches; mechanical, cultural, chemical, and biological approaches are still being evaluated for their effectiveness to a limited extent. Delineating the rate of recovery in most of the areas where biological control has been used will serve as a major signpost to the way forward.

Assessment of the extent of alien plant invasions and impacts on biodiversity in the **savannah** and **grassland biomes** of South Africa has been a pending issue which this writer finds it necessary to trash by way of contributing via this research work. Several schools of thought have indicated that using remote sensing and spatial modelling, much could be achieved in this approach to solve the problem. When this writer was doing a research on the *impact of alien flora species along the mid Elands River (riparian vegetation) in the N.E of Gauteng* a few months ago, he developed a deep appetite in seeking for answers to questions that the work (literature) raised, viz `a viz the impact of these exotic species on biodiversity, and ways to harness proper recovery. Nevertheless, as time elapsed and with due consultations here and there this writer has come to identify that there are major controversies or gaps in the literature which leads to the research problem that has to be unravelled.

Globally, problems facing our planets biodiversity are numerous. Biodiversity related issues are fast becoming more and more complicated today. One may not fail to note that the problem stems from several spheres; be it socio – economically oriented, scientific in nature (which is obvious) or / and a spill - off from poor managerial practices by those concerned not leaving out the haphazard implementation of addressed policies deemed satisfiably fit to make a land mark.

Not even at the time of running through the initial preparatory phases of this work that this writer could with certainty pinpoint areas whose biodiversity has not been damaged in the provinces of Gauteng and even KwaZulu Natal, in South Africa. A dilemma one could often refer to.

The rate of recovery of the biodiversity of certain identified areas need to be clearly mapped out. This is a problem area, marked with the controversial loss of land to urbanisation in South Africa. Could we succinctly weigh the threat to biodiversity in the chosen areas? To what degree of precision would be the results of our findings?

What percentage of plants and animals are left in the provinces of Gauteng and KwaZulu Natal? What has been their population statistics over the past years? Does it make a great difference?

Much land has been converted for agricultural uses and other needs, hence a threat to the biodiversity owing to habitat disturbance from road building to a host of things that will be further investigated. The spread of invaders seem to bring to the society at large challenges from the view point of lack of enough education (sensitisation) and from managerial frontlines, land tenure in such a multi-culturally blessed country and equity.

1.2 RESEARCH METHODS AND PLAN

1.2.1 THE AIM

The operational aim of this work knowing fully well the areas concerned has as its reference state of biodiversity; a grassland and savannah type is to succinctly measure the impact of alien plants on species diversity. The specific aims include:

- Measuring the impact of Acacia species on biodiversity in the Gauteng province of South Africa.
- Assessing the impact of *Chromolaena odorata* on the biodiversity of the KwaZulu Natal province.
- Looking at links between the root structures of these alien invasive species, their effects on soil and water systems, hence the biodiversity of the country and the abilities of this species to spread widely.
- Predicting the spread of Acacia species and *Chromolaena odorata* specifically across Africa (South Africa, Cameroon and Ghana) based on geological and climatological data.
- Looking at control methods aimed at curbing the spread of alien invasive species (particularly Acacia species and *Chromolaena odorata*).
- Checking out the ramifications of chemical and other control methods on the environment at large,

- Suggesting alternate approaches to control the spread of these alien species across the African continent.

1.2.2 HYPOTHESES

1. Chromolaena odorata, Acacia spp are some of the existing alien plants that negatively affect the biodiversity of the KwaZulu Natal and Gauteng provinces respectively,
2. The negative ecological implications of the impact of alien flora on biodiversity outweigh those of the positive one if any,
3. Recovery of biodiversity after successful bio-control projects has not been successful within most areas of South Africa,
4. The integrated approach is best suited in these provinces as opposed to the use of single methods.

1.2.3 THESIS OUTLINE

The structural organisation of this thesis is divided into 5 chapters:

Chapter 1: General Introduction

Chapter 2: Research Materials and Methods

Chapter 3: Results

Chapter 4: Discussion

Chapter 5: Conclusions and Recommendations

1.3 JUSTIFICATION FOR THE RESEARCH

To justify this research work, the researcher has taken four dimensions to arrive at a precise and substantive justification.

Talking about the **size** of the **area involved** in the research will also be important. The Gauteng Province covers an area of about 18.810 Sq Km which gives us a 1.6% of the total surface area of South Africa. The inhabitants number seven million plus. Nearby this province is the KwaZulu Natal province which has as number of inhabitants, exceeding eight million and covers an area of about **92.100 km²**. The coastal grassland areas of this province are significantly invaded by alien species as in the grassland / savannah areas of Gauteng. These statistical revelations are premedial for comparatively coming to terms with an idea of how vast the influence / pressure this inhabitants have on the biodiversity of the provinces and the notorious spread of alien species like Chromolaena Odorata and Acacia that threaten it. Even

at this point we all know that there are gaps that exist **in the literature**. To date, literature has not come up with a clear cut trace of what and how this problem of infestation of alien species and the ramifications on biodiversity as a whole could be successfully dealt with. The threat to our biodiversity is not just a regional thing, or a South African case – it is global and this means researchers have to coherce for the common good of all of us.

As concerns the **methodology** to be used, one will not fail to highlight here some major issues to be considered. The methods or approach to tackling this inquiry will zoom from a survey type (which incorporates interviews, distribution of questionnaires to a selected number of participants) and also field work (observations) will be effected in several sites of the provinces. Such observations and the scientific measurements that go with it will be instrumental to making comparatively but precise findings which tally with the rationale of the work and in cognissance of the fact that the theoretical survey served as a booster to amplify or pave the way for an umbrella shade of ideas on what has been done indepth and what needs to be added. (More about the methods in the coming chapter - Research materials and methods).

1.3.1 CONTRIBUTION OF THE RESEARCH

The research will be found to contribute in several directions:

- Change in ways of approaching the problem of land infestations by aliens such as Chromolaena Spp and other alien invasive species whilst paying attention to the focus and meaning of the interpretations of every step taken in the given localities,
- It will contribute to a change in the body of knowledge in this line of situation analysis. How? Its findings and recommendations emanating from the work will be original and contributive to follow up research projects.

The scientific outcomes will be put in simple and easily discerned English language with a German translated copy made available for the ease of dissemination of its findings by and large. Owing from the fact that little has been done in this line of the research; the work will be valuable and contributive to the scientific community not only in South Africa but in a much broader and larger spectrum spinning right across the African continent, Europe, USA and beyond. This of course for its importance and resourcefulness and for the advancement of science and research. Within the framework of the study, a checklist / and or model will be developed to assist nature conservationists and resource managers who have no guides at present.

1.3.2 RELATION TO PREVIOUS RESEARCH

It is but obvious that this research is related to the previous research carried out by Florentin (2000). Looking at the impact of alien flora invasions on the soil and water system in the Gauteng Province of South Africa, some few months back served as a stepping stone or spin off point for looking at the overall impact of alien plants on the biodiversity of this 'lovely' country.

1.4 EVALUATION

This research project was monitored and evaluated by two supervisors from BTU COTTBUS (one of whom will be responsible for the overall assessment exercise). The research was monitored through out by way of meetings with the supervisor(s) and at regular thesis-in-progress seminars.

1.5 DECISION MAKING

This researcher also overlook on the amount of money the Government of South Africa has spent so far in fighting the spread of invasive species. Equally, other threats to landscape and wildlife (population growth, intensification to agriculture, and inappropriate water management) will be critically analysed, as it will be based on this and more that policy makers with the aid of researchers in the field will be able to come up with appropriate decisions to combat the problems faced in this region of Africa. Definitely the work tended to have weighed what measures best suited in this fight to control the impact of *Chromolaena* spp and other invasive alien plants (mainly *Acacia* species) in the region: Could it be;

- √ The introduction of natural enemies,
- √ Mechanical destruction of invasive alien flora,
- √ A change in forestry practice, or
- √ A quick overhaul of agricultural practices in the region that will go a long way to resolve this problem is a matter to be dealt with in the next chapters.

CHAPTER TWO

RESEARCH MATERIALS AND METHODS

This chapter with focus on research materials and methods covers the location of the study, the population, the sample, and research instruments and the research instruments were administered.

The research approach (a combination of several methods) employed for the purpose of the study is known as the ‘paradigm of choices’ as expressed in today’s present educational jargon. Some of the instruments that were used included interview schedules and questionnaires. The research study involved field officers, specialized weed inspectors, agricultural / land resource managers, nature conservation officers, nature conservation park officers, and working for water officers, seasoned environmentalists and researchers in the two provinces of South Africa that were of direct concern to this work. Equally other experts positioned in renowned research institutes and other prestigious institutions such as Universities and Technikons around the country were regularly consulted. Not left out are research students in this discipline who also formed the bulk of the participants in this study. Postal questionnaires similar to those developed for the South Africans (see appendix) were equally distributed to similar groups in Cameroon and Ghana. This measure was aimed at getting a clue as to the spread of *Chromolaena odorata* across the African continent. This was cardinal to this research as it aimed at also predicting the spread of invasive alien species in Africa. The author thought it wise coupled with consent from other experts to equally disseminate questionnaires to field officers, specialized weed inspectors, agricultural / land resource managers, nature conservation officers, nature conservation park officers, and other concerned, in Ghana and Cameroon so as to get a substantial basis for his claims on the imminent and future impacts of these invasive species in Africa.

Documentary research was also resourceful to this study. In this respect, official government documents, research reports, and handbooks pertaining to this field of biodiversity were closely studied and their contents compared, and put into context.

The content of this present chapter in no small way unravels the complexity of the research approach used. This no doubt includes the precise location of the fieldwork sites, the population sizes of the locations, sample (area), and the research parameters considered.

Seemingly one may take the approach to be more or less of a survey type at one time and in another find it tilting to be a kind of monitoring exercise as it assumed along the field sites, monitoring techniques. i.e., mostly where measurements were done. These measurements and distribution of questionnaires, interviews and documentary analysis carried out were scientifically oriented.

Further the measurements taken from the field were aimed at generating adequate but reliable data, gathered for assessment together with the relevant information deduced as a result of interviewing / questioning experts, scientists and others concerned.

Prior to approaching the respondents and also going to the field, some elementary / preparatory routine planning as in any proper research work had to be done. The writer had to look into issues of logistics and precautionary measures to be taken well in advance. Clearance from the state and private landowners had to be agreed far in advance before entering the respective zones, some of which are familiar to this writer. As is the case, researching in a zone which is not yours, all necessary health concerns have to be given, information on the weather and other hazards like fire especially in the zones around the sites where lots of data had to be sorted out and compared to those earlier obtained.

Additionally, follow up meetings had to be held successively with field supervisors to ensure smooth running of the study from the beginning to the end.

2.1 RESEARCH PROCEDURES FOLLOWED IN THIS STUDY

This chapter describes the research design; the research questions, the type of data required to answer the questions, and how the data were obtained. The chapter also describes the procedures that were followed when developing the interview schedules and questionnaires used to measure mainly the social impacts of alien invasive species and other aspects related to the knowledge on conservation and biodiversity in South Africa.

2.1.1 RESEARCH DESIGN

A survey research design was adapted and followed in the present study. Surveys serve to describe characteristics of a population, Schumacher and McMillan (1993), and can either be descriptive or analytical. Descriptive surveys use samples to get an accurate account of the

characteristics of a particular population regarding a certain phenomenon. In this study, the type of survey used was more than just analytic and descriptive in style, and the “phenomenon” being investigated was the impact of alien invasive plants (Acacia species and Chromolaena Odorata) in the Gauteng and KwaZulu Natal provinces of South Africa.

2.1.2 METHODS

The research methods of the study followed both a practical and a theoretical approach. A survey was conducted of past and present biodiversity management programmes and environmental policies, including native and alien plant species and their impacts on biodiversity. The rates of biodiversity recovery could be attained by systematically carrying out the necessary field observations. This will require active fieldwork as well as the study of official and unofficial statistics and other data.

2.1.3 LIMITATIONS

The major limitation(s) that this writer placed on the research work include;

- Sites visited (in Gauteng and KZN Provinces) were those approved by the responsible ministries / departments of the government of South Africa.

The research further concentrated on the following areas:

- Links between alien flora infestations, its causes, effects on the environment and its socio- economic impact on biodiversity and the lives of the inhabitants of the Gauteng province of South Africa;
- Existing forest management practices and their impacts on the biodiversity and the rate of its recovery in the Provinces;
- Other contributory factors to soil degradation, especially agricultural practices (past and present) that strikes the biodiversity of the region;
- Conflicting cultural and ethnic interests in current forest, biodiversity and soil use;
- National environmental law and policy, implementation mechanisms and structures at local level;
- Local and regional efforts on various levels in the past to establish sustainable biodiversity management schemes in the Provinces, an analysis of the reasons for their long-term failure;
- Infrastructural weaknesses as obstacles to the establishment of effective biodiversity

- management programmes;
- The role of public education;
 - The role of the international community in conserving the area's biodiversity.

2.1.4 FIELD DATA COLLECTION

Reliable figures generally, speaking related to a chosen population tends to be obtained with relative ease from the sample of a population. The other way round or a combination of the following that will be adopted for use in the research work, Harper (1971).

1. Direct observation. Certainly this writer had gone to the field for observations of acceptable scientific standards. This, even if they are of a rudimentary sort to facilitate proper data collection. Courtesy of Dixon and Massey (1983). Observing, counting, and also identifying the alien specie(s) under investigation in the specified areas of the Provinces was imperative.
2. Interviewing – Asking personally for the required information. This meant interviewing renowned researchers across the board doing similar tasks or with sound opinions of the terrain in question. Officials in the department of environmental affairs were extensively interviewed and also they were required to fill questionnaires (not compulsory). A selected few number of inspectors and technicians of the department of agriculture and those of other ministries were also interviewed for a thorough fact verification attempt by this writer.
3. The use of questionnaires was identified by this researcher to be valuable in generating most of the data being sought.

The analyses of data made good use of modern and recent software that could also be valuable to predict future invasions of alien plants – especially *Chromolaena Odorata* in other parts of Africa.

2.2 LOCATION OF SOUTH AFRICA

This study was conducted in the Gauteng and KwaZulu Natal provinces of South Africa. The Republic of South Africa covers an area of about 1,219,912 sq Km, and contains exceptionally diverse physical features. The following figure is a map of South Africa showing the various provinces in which this writer carried out this study.

FIGURE NO. 1: MAP OF SOUTH AFRICA SHOWING THE GAUTENG AND KWAZULU NATAL PROVINCES.



Explanation: Figure 1 shows map of South Africa and its neighboring countries of the SADC.

This rainbow nation is more than a land of sunshine, flowers, a diverse biodiversity and beautiful beaches. Interestingly it is also a land of diverse cultures and people who have over the years been eye witness to the arrival of strange species, uniquely not of their kind.

South of the globe lies South Africa. Bound by the Atlantic Ocean on the West and in the East by the Indian Ocean. To the North lies Botswana, Namibia, and Zimbabwe, to the North – East lies Mozambique and to the east Swaziland. For Lesotho, South Africa totally surrounds it on the other hand. South Africa is made of 9 provinces. Gauteng the smallest of the nine provinces shares boundaries with the Free State which in turn borders KwaZulu Natal to the

East. This is clearly visible in the map found in the previous page. It is worth adding that the Vaal River forms the Southern boundary of Gauteng with the Free State.

2.2.1 POPULATION OF SOUTH AFRICA

As of this moment the population of South Africa stands at roughly 38, 000, 000. The country's ethnic division is 75.2 % black, 13.6 % white, 8.6 % colored and 2.6 % Indian. The colored population lives mostly in the Cape and the Indians in Kwa Zulu – Natal. The Zulus form the largest ethnic group followed by the Xhosa. The smallest is the Venda.

The population of Gauteng on the other hand is made up of the other numerous African groups, as well as the Europeans, Asians and Indians. According to Du Plessis & Theron (1999, 29) there is also a fairly large colored population.

The population was officially estimated to have been on the rise over the recent years but the death toll as a result of AIDS, Tuberculosis, and other killer diseases have played up the death rates. Poverty and the rising exodus of knowledgeable individuals over the post apartheid era have had an effect on the statistical values made known today. Overall population growth has not been rapid as anticipated by statisticians. It is clear that the composition and distribution are extremely diverse.

The population has a very uneven distribution, with more people concentrated in the cities, whilst the poor and most of the uneducated in the rural areas of the countryside.

2.2.2 AREA AND POPULATION DENSITY

The population of Gauteng is about 7, 048 300 according to the 1995 statistical records. This gives a total of 17.1 % of the National population. The area sums up to about 18.810 Km² (1.6 % total surface area of the country). Statistics show that the rate of urbanization stands at 82.4%. The population density of Gauteng will thus give us a good picture of the situation, and equally that of KwaZulu Natal.

The span of cities and population has lots of effects on biodiversity and the environment as a whole. Including development, habitat fragmentation comes to the lamb light and all these issues have an impact on the environment, let alone the spread of alien invasive species. Knowledge on the cultural diversity of South Africa (as illuminated earlier on) portrays the

dimension to which the magnitude of response to management of the country's biodiversity in terms of approach aimed at controlling the spread of alien invasive species by the different groups will have to toe.

2.3 GEOGRAPHY OF SOUTH AFRICA

South Africa is at the southern tip of the continent of Africa. Its Geographic co-ordinates are 29 00 S, 24 00 E, Courtesy of the CIA world fact internet site. Below is a table constructed based on information collected from the CIA website.

TABLE 1: SHOWING SOME GEOGRAPHICAL FACTS ABOUT SOUTH AFRICA

Area:	Total: 1,219,912 sq km Land: 1,219,912 sq km Water: 0 sq km
Land boundaries:	Total: 4,750 km Border countries: Botswana 1,840 km, Lesotho 909 km, Mozambique 491 km, Namibia 855 km, Swaziland 430 km, Zimbabwe 225 km
Coastline:	2,798 km
Maritime claims:	Contiguous zone: 24 nm Continental shelf: 200-m depth or to the depth of exploitation Exclusive economic zone: 200 nm Territorial sea: 12 nm
Climate:	Mostly semiarid; subtropical along east coast; sunny days, cool nights
Terrain:	Vast interior plateau rimmed by rugged hills and narrow coastal plain
Elevation extremes:	Elevation extremes: Lowest point: Atlantic Ocean 0 m Highest point: Njesuthi 3,408 m
Natural resources:	Gold, chromium, antimony, coal, iron ore, manganese, nickel, phosphates, tin, uranium, gem diamonds, platinum, copper, vanadium, salt, natural gas
Irrigated land:	12,700 sq km (1993 est.)
Natural hazards:	Prolonged droughts
Environment - current issues:	Lack of important arterial rivers or lakes requires extensive water conservation and control measures; growth in water usage threatens to outpace supply; pollution of rivers from agricultural runoff and urban discharge; air pollution resulting in acid rain; soil erosion; desertification

<p>Environment - international agreements:</p>	<p>Environment - international agreements: Party to: Antarctic-Environmental Protocol, Antarctic Treaty, Biodiversity, Climate Change, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Marine Dumping, Marine Life Conservation, Nuclear Test Ban, Ozone Layer Protection, Ship Pollution, Wetlands, Whaling signed, but not ratified: none of the selected agreements</p>
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Explanation: Table 1 highlights certain geographical facts about South Africa ranging from area, natural resources, and the climate. South Africa completely surrounds Lesotho and almost completely surrounds Swaziland. (Source: Author's own)

The country occupies a fairly strategic position at the Southern tip of the African continent, and has a very wide coastline stretching from the West to the East. It shares borders with Zimbabwe to the north, the Indian Ocean to the east, Mozambique, Swaziland, Lesotho, and Namibia respectively.

Its environmental diversity, including the country's position astride the great lakes amidst its numerous natural riches, its latitudinal extent in degrees between the South and North, its altitudinal range from sea – level to several hundreds of metres, and its spread from the coast to the remote continental interior of the Zulu land makes it unique.

The Gauteng and KwaZulu Natal provinces constitute a great proportion of South Africa's population, and cover a substantive amount of the country's total surface area brought together. In both the rural and urban zones of South Africa, there lies a vast beauty, the vegetations (velds).

This researcher chose this area for the study mainly because of his amazement of the beauty at stake, meaning the natural landscape; biodiversity of the land which is being threatened by exotics. His sound knowledge of the current impasse it has on us all today and tomorrow has drawn his curiosity and interest in giving a hand to the speedy contribution to the resolution of the current dilemma.

2.3.1 SOIL TYPES

In the *Gauteng province* which is mainly savanna, the soil type ranges from Oxisols, alfisols, to entisols. This accounts for the plants: scattered trees such as acacia, baobab, euphorbia, palm, grasses visible in the region. In this part of South Africa there is a pronounced dry season w/frequent fires and a well-defined winter season.

In the *KwaZulu Natal province* the soil types include: mollisols and aridisols. The climate is dry-humid boundary; with annual precipitation and temperature the *measuring rod*, lots of animals: burrowing rodents, ungulates, mule deer, wood rat, chipmunk, lizards, wrenit, towhee, small reptiles, and mammals.

Plants include short (grasses), sparse xerophytes: cacti, shrubs. Annuals are dormant during the driest seasons, succulents (cactus, euphorbia), shrubs; creosote bush, sagebrush, prickly pear, saguaro, palo verde amongst others; mosses, lichens, blue-green algae dormant in soil but active during rain.

2.3.2 CLIMATE

South Africa's climate varies from place to place. For the purpose of this study, below is a summary of the climate of the provincial capitals of Gauteng and KwaZulu Natal, as outlined in the (Government publication; Statistics South Africa 2000, 2) table 2.

TABLE 2: STATISTICAL DATA FOR SOUTH AFRICA'S CLIMATE IN GP & KZN

	JOHANESBURG – GAUTENG PROVINCE	DURBAN – KWAZULU NATAL PROVINCE
Average temperature (°C)	January – 20.1 July – 10.4	22.9 12.9
Average hours of sunshine / month	January – 250 July – 284	185 251
Average rainfall (mm)	January – 125 July – 4	141 11
Average number of rainy days	January – 16 July – 1	18 3
Average annual rainfall (mm)	713	844

Explanation: Table 2 shows statistical data on South Africa's climate. Though mainly for Gauteng and KZN provinces, it however gives a general clue on the country's climate. (Source: **Author's own**)

2.3.3 DESCRIPTION OF SITES

Bio – control in restoring the biodiversity of certain sites have not proven that successful. This researcher in his recent visits especially to several sites in the NE of Gauteng observed that much has not changed between then and now. Rather, the infestation of the riparian area seems to gather more strength, hence the spread. In KwaZulu Natal, the sites visited,

especially in the coastal grasslands are seriously infested by *Chromolaena odorata*. Even the threats of fires have not been strong enough to wipe them out.

2.4 SIGNIFICANCE OF THE SAMPLING EXERCISE

Sampling here simply implies taking a small part that represents a whole. It is equally known as the reduced number of participants (conservationists, environmentalists, policy makers, experts, researchers, the list is endless) and organizations (governmental departments, NGO's etc) extrapolated from a wider population for the current scientific inquiry, Florentin (2000). This is because collecting data from everyone is particularly impossible.

However attention must equally be given to ensure that the sample is not only representative but void of bias. In this study, the various participants (for interview and answering of questionnaires) were randomly selected across Gauteng and KwaZulu Natal province except for a few whose views were sampled from other provinces. The principle on which the sampling procedure was based is a unique and important factor to reckon with in this study.

One may ask what sampling is and above all its essence? However the essence of sampling as pointed out by L.R Gay (1976), L. Cohen and L. Manion (1985) is that it must accurately reflect the population under study.

To a large extent this was the main principle observed in the sampling procedure adopted in this study.

2.4.1 THE ORGANIZATIONS INVOLVED

For this study, those organizations, and research institutions in the Gauteng and KwaZulu Natal provinces that are concerned with programs were identified with the help of the ministries and with due consultation with some leading experts in this field of research. It was however important to recognize the fact that the environment had an influence on science, thus, a major reason why sampling of respondents to questionnaires from all these organizations concerned (both urban and rural) was not ignored.

2.4.2 THE PARTICIPANTS INVOLVED

2.4.2.1 RESEARCH STUDENTS

They were merely asked questions as to their opinion to the biodiversity management situation in South Africa and specifically pertaining to the two concerned provinces, hence sampling their views on this. More other issues were also probed into as a result of the discussions that pursued, (see appendix for questionnaires). Those research students interviewed were of a wide range of abilities.

2.4.2.2 EXPERTS

This set of participants contributed immensely to this research (study). The total number of participants who contributed to the study by way of filling the given questionnaires came up to 100.

Of this only 80 returned their answered questionnaires. Quite a good number of the respondents answered questions posed to them verbally, by way of ‘structured interviews’.

Research experts in the field of biodiversity and alien plant control are however included in this category of participants, since their experience and views to this area of research very much counts.

These experts are found at the national, provincial and divisional levels in the organizational set up of South Africa.

The number of organizations, key researchers, field officers, specialized weed inspectors, agricultural / land resource managers, nature conservation officers, nature conservation park officers, and working for water officers, and research students summed up to about 10. The ages of these experts (both males and females) ranged from 25-60.

As concerns the standard of education received by these teachers, I found out that most had atleast a minimum of an M.Sc and for a few with degrees lower than that, they had a wide range of experience with many years of service to their respective organizations, thus fit as qualified seasoned researchers. Quite a handful of them had obtained masters and postdoctorate degrees in related disciplines of nature conservation and applied environmental sciences.

Those of age close to 60 and above irrespective of their standard of education were found to have acquired lots of experience in the domain of environmental research and more specifically alien plant control over several years.

2.5 THE RESEARCH INSTRUMENTS

It is worthwhile to discuss the instruments used and their treatment. In terms of the field work which demanded accurate measurements for generation of data, the following were found useful in fulfilling the objectives of the study; GPS equipments, a one hundred meter long chains, photo Cameras, musking tapes, measuring tapes, area maps, reference textbooks, compass equipment, plastic bags for collection of unidentified species, and a stand by vehicle for facilitation of movements in and out of the sites. The above were helpful to this writer in ensuring appropriate data collection at precise locations of the intended areas within the different zones of the two provinces.

In view of the multifaceted nature of the research approach, interviews were carried out, questionnaires distributed, and documentary studies effected to succinctly come out with the necessary information to pave the way for adequate recommendations. A set of structured questions for interviews and a data sheet in preference to an audio tape was used in the field for data collection. These and more and their employment is discussed in the subsequent paragraphs.

2.5.1 QUESTIONNAIRE

The questionnaire was designed by this writer, pilot tested and corrected. It was designed in a manner deemed absolutely useful in fulfilling the objectives of the study. It however took a structured form, with most of the items in the instrument varying and comprising of open ended and close-ended questions.

The open-ended questions allowed respondents to express themselves and thus gave room for the writer to get to the bits of issues and at greater depths.

Borrowing the conceptions of Isaac and Michael (1983), which emphasizes the importance of pilot testing research instruments prior to their being used, the questionnaires were pilot tested twice at different times. This in no small way enabled a further revision and refinement of the instrument as vague items were systematically identified and modified. At the end, all the modifications were made to suit the main research question under investigation. With this exercise carried out twice, it resulted to a scaling down of items to 20, which was meant to perfect the investigations, and at the same time to minimize the respondents fatigue.

Designing good questionnaires is often a problem to many new comers in research. This is a fundamental basis for gathering valuable and acceptable data. Sanders (1995) is of the opinion that, designing an effective questionnaire involves more than just listing a number of appropriate questions. This is true of course. Sanders (1995, 1) goes ahead in her article by stating that:

“ ...many researchers ignore the fact that their findings are affected by problems with their instruments ...”

But then what really are questionnaires? There are several definitions. That of Galfo (1975) as quoted by Sanders (1995, 1): “...data – gathering instruments used to obtain factual data. [CIS] opinions and attitudes in such a way that the respondents and the data gatherer need not come into contact with each other.” In this respect, Sanders (1995, 1) adds by saying that, **questionnaires** differ from **structured interviews**, where the two parties do meet in order that the respondent may answer a set of questions.

There are several advantages and disadvantages for all of this, but one must always negotiate what tail end is most suitable when constructing questionnaires. Again, these instruments are just one of the most used and abused methods of gathering information in research today.

The problems inherent with questionnaires and peculiar to all these studies are those of *questionnaire design*. Formats of questionnaires if put together will attract more respondents, hence a high response rate. This is not all, but getting acquainted to what these problems of questionnaire design are, is one of the best ways of getting things right.

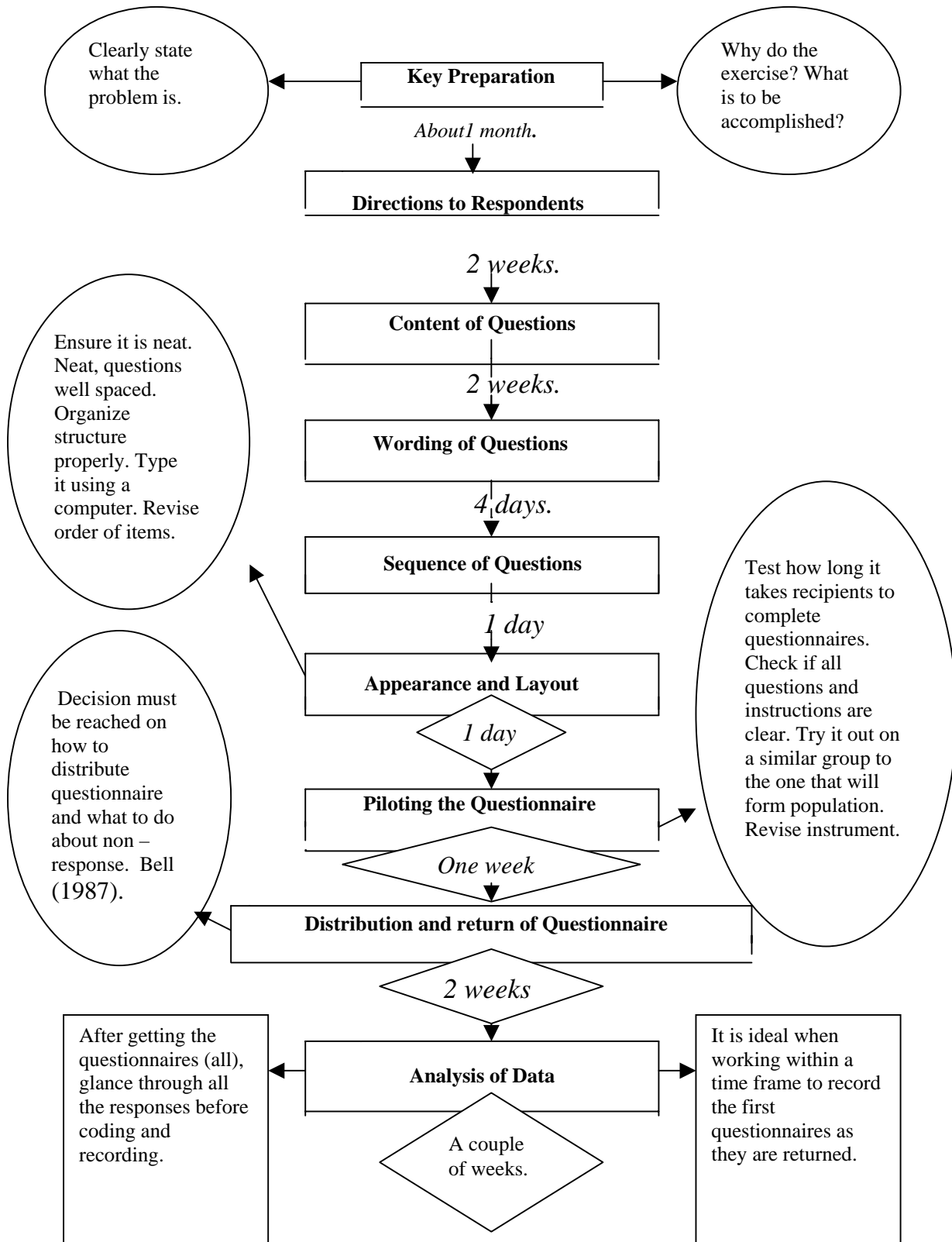
Why right? Why a right direction? But why not? Definitely, constructing or designing a questionnaire rightly is actually the primary stage of effecting proper research surveys. This similar view is widely shared amongst researchers today. Some researchers have gone ahead to support such claims by waging the opinion that long durations of ‘planning, reading, design, and exploratory pilot work is needed before any sort of specification for a questionnaire can be determined. This is not a re-invention on my part nor that of some ‘schools of thoughts’, but a mere share of the truth. Real findings in themselves.

ADMINISTRATION OF THE QUESTIONNAIRE

This writer in designing or formulating his own questionnaire bore certain modalities in mind; Administration, arranging the questions, writing the questions, then testing them just to list a few. Courtesy of the Internet site; <http://www.longman.net/keypoint/tna/tips.html>.

This writer saw the need to provide a cover letter to the questionnaire which explains its purpose, and gives an indication of the confidentiality of responses. Also this researcher provided a conclusion to the questionnaire, which thanked the respondents for their participation and good will (though most researchers neglect this). Equally one cannot distribute such an instrument without giving clear instructions on what should be done with the questionnaire upon completion, especially in the case where questionnaires need to be posted back to one. Definitely no one will be that willing to return one's filled instrument should a researcher fail to provide stamped addressed envelopes for that purpose. For the few questionnaires that this writer went around from the respondents this writer made sure they were informed about his coming in advance as sometimes the respondents needed to be clarified on certain issues. The flow chart that follows highlights the steps taken by the writer from the planning stage to analyzing the data within the questionnaires.

FIGURE 2: FLOWCHART SHOWING STEPS TAKEN WHEN DESIGNING, USING AND ANALYSING THE QUESTIONNAIRE. (Source: Author's own)



Arrangements of the questions

This very much encourages participation. The questions were placed in a logical order, first placing the simple, easy-to-answer questions towards the beginning of the questionnaire generally made sense as experience has shown this writer. This was done despite the writers knowledge of the fact that it is also acceptable for background questions to be placed about the respondent at the beginning or end of the questionnaire. Sensitive questions as thought by this author were deemed best suited towards the end of the questionnaire. In anticipation for maximum co-operation, this writer decided to minimize branching in the questionnaire as this was to introduce complexity in the face of the respondents.

Writing the questions

Questions were not directly preceded by instructions on how to answer the question. This was all dealt with in the pre-liminary paragraphs of the questionnaire. In addition instructions for the questions were made complete and unambiguous. This is very important in every research instrument of this nature. With all these, respondents were able to answer all questions. In writing the questions the author made sure the chosen words used could be understood by all respondents. In all, attention was given to the notion that asking more questions than were needed could tend to mar the good work in progress of the research survey. However, in this respect this writer sought advice and considered adequately covering all the key areas. The principle of only one idea with each question makes life simple for researchers, this was moderately adopted by this writer. It was necessary to put in place types of questions that determined and matched the statistical analyses that were planned to be performed on it. For question types that needed a particular kind of analysis, adjustments were done after the pilot test in view to that effect.

Testing the questionnaire

Testing the questionnaire(s) on a subset of a target group was deemed vital to ironing out any problems prior distribution. This came true as some questions were rephrased and others deleted completely to:

- Avoid overburdening the participants. A survey with ten to fifteen questions is ample,
- Avoid using terms that contain words or phrases that would have been found to be unfamiliar to most readers of the question,

- Avoid “double-barreled” questions,
- Avoid “loaded” questions, and
- Avoid questions for which there are no clear answers.

BRIEF LITERATURE SURVEY ON QUESTIONNAIRES

Conducting useful research is gathering reliable information. And the basis for doing that is designing questions and questionnaires that get the kind of information from which the researcher can draw valid conclusions. When one looks at a complete questionnaire or the results of a valid study, he or she is often tempted to say, “it is not difficult a thing to do,” but that temptation quickly passes moments after a closer analysis. That’s about all it takes to realize that designing good questions and a good questionnaire requires more thought and time than one might originally think. There are an almost infinite variety of things to think about and to do correctly to avoid the kinds of errors that can make scores of hours of work worthless. This writer in designing his research instrument looked at some of the basic building blocks of questionnaires, sorting out potential pitfalls, and indicating through out, all the ways he avoided them, in order to produce a set of questions that have the best possibility of generating reliable, accurate data on the topics of interest.

Bell (19??, 58) says, “*you will only reach the stage of designing a questionnaire after you have done all the preliminary work on planning, consulting and deciding exactly what you need to find out*”.

But then, it is the duty of a researcher to decipher on what he or she exactly wants to find out, it is clear that this key starting point becomes a link to a chain of other related aspects of the discipline, which is useful for an individual to handle cautiously. With a clearly articulated layout of what the problem to be addressed is, forms a basis for gathering the precise information by use of concise questions. A second thought on the *raison d’etre* for the investigation, survey or evaluation serves as a prerequisite to explaining what one hopes to accomplish by the use of the questionnaire. Such a focus serves as a guide, and ultimately, a direction on what choice of questions remain ideal for use. Directions to respondents are a primary and instrumental part of any questionnaire designer that seeks to capture the attention of all concerned with great respect and admiration. Definitely there is that need to share with the respondents the aims and objectives of the work and why their participation is most

welcomed. This writer did not fail in this endeavour. The content of questions also counts. He did all for the questions to be clear and concise. Getting respondents participate fully required that this writer pose questions that the respondents had a chance to answer, which in fact he did. This called on me to be able to judge profoundly by way of foreseeing how much can the target group be able to offer and their limits. This took this writer to the issue of inappropriateness in the terminology used in most questionnaires. In this direction this writer did all in his best not to try to show how much difficult words (big sounding words) he knew as this does not help the research in anyway. The diction in setting up the question is also a key factor that researchers sometimes do not pay attention to.

A good and well-planned questionnaire may just be marred overnight by the use of slangs, technical words, and this becomes a problem. Research also proves that the use of strong words often influence respondents to answer questions in a certain manner; this is a thing this researcher was so conscious about, and had to avoid at all cost.

Finally the sequence of the questions was of great concern to this writer. So many questions bring confusion to respondents, this writer has often noted. Thus it is ideal to start with simple but fact based questions to those which demand the sole opinion and perspectives of the respondent(s).

Assessing the straightforwardness of one's questionnaire is this writer did not shy away from as he understood the importance of it. This could be a terrible mistake ('to shy away...') to commit. Learning is a lifelong experience and it is not at this stage that one will have to think that one has become perfect. Thus, verifying the form of one's own questions, reviewing them if necessary (often reviewed), and as a task end up to say, 'yes, this is going to provide what you wish to obtain or know about'.

This researcher could finalize the format of his questionnaire entirely on the results of the pilot study.

2.5.2 INTERVIEW SCHEDULES

For interviews, several questions were posed to the participants, research students, and other experts in applied environmental sciences. Also policy makers, and executives of the concerned ministries were reached for reasons concerning their stands viz à viz the South Africa's way forward in dealing with its biodiversity.

The interviews were structured for all the participants concerned and used equally for assessing the aspirations and the socio-cultural impacts of alien plant invasions.

For the research questions to have suited the investigations several modifications had to be made time and again. Also the numbers of items were significantly reduced to the minimum in an effort to minimize **respondent fatigue** since the aim was to obtain a one to one interview rather than a questionnaire.

Equally the reduction in number of items significantly saved time for both the researcher and the respondents.

Pilot testing which was aimed at:

- Identifying vague items, hence leading to modification by this writer, and
- Helping to determine the amount of time needed for carrying out each interview session, thus determining the sample population.

Items in the instrument were quite varied and open ended as well. The responses probed were aimed to give a clue to the real picture of the potentials of the local researchers. In this light the issue of verifying the consistency between the national environmental policy and regional and global environmental policies as employed by South Africa was definite as it showed the degree of commitment to this nation.

HOW THE RESEARCH QUESTIONS WERE ANSWERED

There were **twenty - seven** research questions in the interview schedule and **twenty** questions in the postal questionnaire meant for this study. These two types of instruments were used during the study for the simple reason that, one; the interview schedule was valuable in order to validate the other instrument (questionnaire). The questionnaire was not out to test the prior knowledge of the respondents but merely to generate useful information needed by this writer. The structured interviews were part of the process necessary to develop the postal questionnaires. Firstly a selected group of experts in the field of biodiversity research were interviewed as a step in defining the content boundary of the questionnaire to be developed. A semi-structured interview was used to access this information. Semi-structured interviews allow researchers to prepare the questions beforehand, to ensure that they do not forget to cover all the questions. However, they have the flexibility to permit researchers to follow up on leads, and thus obtain more data and greater clarity.

HOW THE DATA WERE OBTAINED TO ANSWER QUESTIONS ASKED

In making out the reason for every question to be asked, this writer therefore could decipher what type of data was required, thus had to work out how the data were to be obtained. This was methodically done.

DEVELOPING THE INTERVIEW SCHEDULE

At this stage it was relatively easier to proceed with the development of the interview schedule. But then, even with the limitations that are known in this method, this writer developed the interview schedule. This is because part of the aim of the study was to develop an acceptable instrument, such as this on which a checklist could be formulated in the near future for researchers to diagnose problems quickly and easily in the field. The development of the interview schedule involved these main phases: the preparatory and the piloting phases.

THE PREPARATORY PHASE

This involved three steps:

- drawing up of a list of scientifically acceptable *propositional knowledge statements* about biodiversity and alien plants.
- compiling a list of common ideas about biodiversity management, conservation and environmental concepts, explicitly discussed in the research literature.
- defining the content boundaries of the instrument.

These steps are further dealt with in more detail in the up coming sections.

- **Step1: Correct propositional knowledge statements about biodiversity and alien plants**

The purpose of this step was to draw up a list of acceptable scientific views about biodiversity and alien plants, which was to be used as a guide for this writer when constructing the interview items and when treating the answers.

Linkonyane (1997) explains the term *propositional knowledge statement* as referring to statements that are currently considered to be scientifically correct. In this study, the propositional knowledge statements were those statements about biodiversity and related

environmental concepts, which are currently considered to be acceptable by the scientific community.

A list of correct statements about the concept *biodiversity* was drawn up after interviewing the participants and then consulting encyclopaedias and other reference documents (including environmental and nature conservation science textbooks) to obtain a list of scientifically correct statements which covered the work to be dealt with.

The specific content areas to be covered in the list of propositional knowledge statements were defined by interviewing three leading research experts about what they thought was the state of South Africa's biodiversity. Two environmental science "experts" were asked by this writer to validate the list, when it had been developed, by checking if the statements were scientifically correct. These "experts" involved one environmental science consultant, and one lecturer of applied environmental sciences involved in teaching biodiversity management in a South African university.

- **Step 2: Compiling a list of common ideas about biodiversity management, conservation and environmental concepts**

The main aim of this step was to compile a list of common ideas about biodiversity management, conservation and environmental science concepts held by researchers in previous research studies, so these could be included in the research instruments (interview schedule) to be developed. In South Africa, researchers ideas about the concept of *biodiversity management and alien plant infestations* have been very well documented in relevant research findings, as well as recorded in State archives.

This writer conducted a comprehensive and in-depth analysis of research findings from previous research reports on the topic *biodiversity* in order to identify and compile a list of common ideas held by researchers and the people of South Africa alike on biodiversity management, the impact of alien plant invasions on biodiversity and other related concepts around the region and in the world. This was done because there has been no single research paper that deals with the impact of alien invasive plants on the biodiversity of these two provinces in South Africa as such in a conservationist context. Therefore such a list was deemed essential by this author for future use and this was aimed at improving designs for research instruments that will investigate aspects of this kind.

- **Step 3: Defining the content boundaries of the instrument.**

The third step was meant to define the boundary of the test so that aspects which participants were expected to know would be included in the interview schedule. In this way, the instrument was useful in testing not only what they had as experience but also their prior knowledge. Hence, with this the instrument was purported to have evaluated the extent of the biodiversity situation per se.

THE PILOTING PHASE

The interview schedule being designed by the researcher for the study was aimed at fulfilling certain basic criteria. The researcher ensured the interview schedule was to be easy to administer; to check basic knowledge about biodiversity and the crisis brought about by alien plant invasions and to seek **understanding** of biodiversity-related concepts and expertise in dealing with the problems faced with alien species (exotics) which would have been difficult to obtain from simply consulting text materials or distributing questionnaires. Above all, it was ideal to validate the questionnaires to be used in the research study.

Developing the questions

In developing the questions proper, one was cautious of not making grammatical errors and also ensuring that the whole set of questions was in context and toed the line of the objectives for the study. The questions for the research were treated and the number shrunk considerably after pilot testing them and seeking advice from research experts in the field.

The question format and purpose(s) of each question in the initial draft

In formulating the questions for the various research instruments care was given that the questions remained detailed where relevant and equally there was a need to insert in the instruments open ended items which permitted the respondents to offer profound responses, in some cases giving useful examples that profited this research study enormously.

FACE VALIDATION OF THE QUESTIONS

The complete instrument was given to five “experts” to check for face validity. Sanders and Mokuku (1994) explained face validity in the context of scientific research as follows:

“...face validity of an instrument is established when ‘on first impression it appears to measure the intended content or trait’. It is usually established by

referring the test to expert judgement, often that of university scientists or science educators”.

The five experts were asked to check if, in their opinion, the test questions would measure students’ understanding and if there were possible problems of question wording and language which might affect the validity of the interviews. The experts included three environmental science researchers in the PPRI (Plant Protection Research Institute) and **two** conservationists (who have read widely in the area of biodiversity management and alien plant control). Constructive criticism was received, and a number of changes were effected to the questions in the interview schedule.

Notable criticisms in the instrument relating to Questions 4, 10, 11 and 24 are discussed below.

Test question 4: Initially, question 4 read as follows; “Why is biodiversity protected in South Africa”. Two of the experts (the conservationists and the environmental science researcher) were concerned about the view of protection and biodiversity underpinning the statement. In summary, the criticism was based on the argument that, scientifically, there was basically a need to protect the country’s biodiversity. In the discussion that pursued there was the warning that emerged that, the question was more of a replica of the present question **two**, which goes thus: (Why is biodiversity important for South Africa?). The two experts even provided this with relevant research papers which highlighted the weaknesses of formulating ‘questionnaires’ on the part of young researchers. In the environmental sciences there are widely held beliefs that strongly contrast as concerns how biodiversity can be protected. Thus, there was that suggestion to introduce either of such questions (2 and 4) with a lead – in sentences, which need to be “contextualised” to everyday life situation. The criticisms made by the experts prompted the researcher to modify the questions and bear in mind the importance of an introductory statement. The question finally read as:

How is biodiversity protected in South Africa?

Test question 10: This question involved getting the respondent bringing forth the techniques in conservation management, be it traditional (local). Such biodiversity management-related concepts could give us clues as to how South Africa as a nation has evolved in this domain of alien control and crisis management, as the spread of alien invasive species is alarming as one

expert puts it. The initial question was; ‘How should we conserve biodiversity in Africa’. The major criticisms were based on the wording of the question and on the sequencing of the logic programmed (planned) for the interview schedule to assume. For instance, one expert suggested that broadening the question to cover Africa, obviously could bring about conflicting ideas that may “confuse” the respondent and the interviewer at one stage. Limiting it to South Africa was the best thing to do. Also the same expert suggested the following;

- that some changes in the wording be effected such that the question does not seem to search for technical clues as similar to that of question four. The final version of this question read as:

Why should we conserve biodiversity in South Africa?

Test question 11: The initial question read as follows; ‘What are the rural masses of South Africa doing to conserve biodiversity?’ Consequently, the question gave the impression to the experts as though biodiversity management was an issue of the rural peoples. This writer realised that it was not fair to sectionalise. This could be a form of intervention and irrational an approach in scientific research. Definitely the question was made to reflect the entire populations. In addition to this change, other modifications were made to the wording of the question in order to make it clearer. The final wording read:

What could ordinary South Africans do to help conserve biodiversity?

Test question 24: The initial question was; Is *Chromolaena Odorata* likely to grow in other parts of Africa? To all the five experts this question looked naïve and really needed to be rephrased in a manner that tied to the one of the aims of the research. With this in mind, the question was now re-structured to take the following format. Do you in anyway envisage or predict the spread of say, *chromolaena Odorata* across Africa. If yes, why?

THE PILOT PHASE

The instruments were then piloted with a group of **ten** volunteers. Six of them were research students at the University of Witwatersrand. Two experts came from the Department of Environmental Affairs in Durban, KwaZulu Natal province. There were four females and six males. These volunteers (participants) did not take part in the main study. This group of students and experts were similar to those who participated in the main study, in that they

were all within the same field of study having enormous experiences in this field of research and at virtually the same levels at the time. Ward (1981) points out that a pilot group needs to be similar to a research group for the simple reason that the researcher can be fairly sure that problems likely to occur in the main study are likely to be detected in the pilot study.

It is evident now that, piloting has several advantages. It enables the researcher to check on the suitability of individual test items (Ward, 1981); to gain feedback on how well subjects understood the questions, response procedures and instructions (Evans, 1968; Bell, 1987); to establish the duration of the test so that the researcher(s) can have an idea of how long the test will take to administer and can make appropriate arrangements for the main study (Evans, 1968; Ward, 1981); to eliminate all test items that do not yield usable data (Bell, 1987); and to practice how to administer the test (Evans, 1968).

In this study the main purpose of piloting was to check if the questions and instructions were clear and unambiguous. This was done by providing respondents with clear instructions in the questionnaire (both the postal and interview questionnaires). For the interview schedules instructions were delivered and further elucidated verbally. The respondents were permitted at any point to indicate whether they had any problems understanding what they were required of in each question. If the respondents did not understand what was demanded in a question, they were further requested to indicate the words or phrases which were not clear to them for clarification. Moletsane and Sanders (1996) suggest that asking respondents (especially students) to record problems encountered ensures that they do consider the problems, and also provides written feedback which allows the researcher to make certain modifications to the test.

RESULTS OF THE PILOT STUDY

The piloting was administered and completed within one hour. There were virtually no difficulties with regards to the administration of the test (pilot test). Some of the participants in the exercise, however, indicated that they had difficulties with certain questions. The exact figures of research students (post grads) and experts with and without difficulties, and some comments written by several students who had problems in individual tasks, were looked into

and evaluated for the purpose of seeing to it that the instruments were of an acceptable standard.

Many of the comments written by both the research students and experts with difficulties who took part in the pilot study showed that students did not have problems **understanding** the questions in the questionnaires. Instead, the comments from the research students suggested their inability to give answers due to lack of knowledge or careless reading of the questions. However, Questions 23, 25, and 27 proved to be problematic for 20% of the ‘volunteers’ (2 of the 10 volunteers). These questions had also been commented on by three of the five “experts” who had been asked to validate it (the other two simply made suggestions on how to further probe the respondents while asking question 21). The problems encountered by the research students in the pilot test for this question (21) were based on their not understanding the logic behind the quota system. They were not aware of its rationale and existence at all in South Africa. For example, one of the volunteers wrote as feedback: *“I do not understand exactly what was required in terms of quota specifications”*. Since question one was intended to derive some necessary data and facts not commonly found around, this writer still decided to maintain this question because no alternative could be found to generate the facts sought. Leaving out this question could have also made the test shorter, and not only that, but could have had a set back on the logical pathway planned for.

The final version of the instrument (interview schedule) which was administered in the main study consisted of 27 questions, that is the questions of the original instrument, despite the fact that the wording had been modified in several instances, as described earlier. A copy of the final version of the questionnaires used in the research is found at the appendix.

2.6 THE MAIN STUDY

2.6.1 THE PARTICIPANTS INVOLVED

Research students in the field of environmental sciences and several research experts in alien plant control, nature conservation and biodiversity management. This included all the experts, government officials and Conservationists with whom this writer had interview sessions.

Also, those who assisted this writer in the survey within the riparian vegetation along the Mid Elands River N.E of Gauteng and the grassland areas (mainly coastal) of KwaZulu Natal.

The research sample for the main study consisted of one hundred participants, mostly research students in Universities and Technikons within the Gauteng and KwaZulu Natal provinces. The ages of these students ranged from 17 - 30 years (this was obtained by asking the fellow research students verbally).

There were 48 females and 52 male participants. All the students contacted were taking part in either environmental science or nature conservation research projects ran by their various departments or for a very few cases running their master degree or doctoral degree research studies. The sample did not consist of a specific and whole class of the environmental science / nature conservation students in a particular institution, but a group of students who are at the cutting edge of research with trust in biodiversity management. This was a “convenient sample” to which the researcher had access because he interacted with most of the researchers and students in these institutions months back while doing his field work for the master degree research at Technikon Pretoria, in the year 2000. None of the research students and experts in the main study took part in the pilot study.

2.6.2 VALIDITY AND RELIABILITY OF THE QUESTIONNAIRES (POSTAL QUESTIONNAIRES) AND INTERVIEW SCHEDULES

It is imperative that a typical research write - up (report) must include an estimate of the confidence that can be placed in the results, Murphree (1974). However, the amount of confidence in the results of an evaluation/research report is proportional to the validity and reliability of the instruments employed.

Validity in simple terms is the extent to which an instrument actually measures what it was intended to measure.

The validity (construct and content) of the questionnaires was checked and ascertained to verify if the items in the questionnaire and interview schedules covered the various aspects under study by a panel of five research experts. They however confirmed that the items employed covered the topic satisfactorily. The concurrent validity of the instruments used in this study increased due to its consistency with the aims and objectives of the study.

Reliability on the other hand is another aspect of the instruments employed that had to be analyzed. It is the consistency of a test in yielding the same results given under the same

conditions, (Charles 1988). A better method of assessing the reliability of an instrument over a certain period of time is the test – retest method. As stated by Mthunzi (1992, 50); Campbell and Stanley in (1963) argue that although this method of ascertaining the reliability of a research instrument is certainly effective, changes in some responses might be a result of such factors as maturation, major events occurring which influences the respondents' decisions, new skills being learnt during the interval or changes occurring within the socio-economic and cultural environment of the respondents.

However, what was actually done was to compare the consistency of the responses given by the participants during and after the pilot test carried out on the sample. With a few modifications carried out, one may assume that the consistency in the responses might have slightly been affected. The comparison of the responses to the questions made, and opinions raised by the environmental scientist who participated to be part of the pilot test group, however serves as an estimate for consistency of the instruments used in the study.

Consequently reliability of the respondents had to be checked and this was done by analyzing the responses to some of the questions that were intentionally repeated in different words. The variables under study in the questionnaires were to sort out answers to questions posed by the researcher and in that way attain the objectives set aside.

The answered postal questionnaires were analyzed. Significant responses to the items above are summarized in the upcoming tables. For all this, the total relative frequency responses were recorded.

The responses the questionnaire required were “Strongly Agree (SA); Agree (A), Disagree (D), and Strongly Disagree (SD)”.

The scores obtained were computed to give an overall attitude score for each statement. The postal questionnaire was made up of twenty items. The number of questionnaires distributed was 100. These were distributed across research students in tertiary institutions, nature conservationists and environmentalists, not leaving out other experts in the field of biodiversity management. These participants came from the provinces of Gauteng and KwaZulu Natal where the bulk of alien invasive acacias and chromolaena are present. The questionnaire had no separate sections. There were two kinds of questions in the instrument.

Both open ended questions and close ended questions. The open-ended questions required the respondent to write and express him or herself freely, and for this spaces were provided. The close ended questions were those that required the respondent to select or tick in the appropriate box that answers the question best. The questionnaire was found to be easy to administer and easy to complete and analyze.

As for the interview schedules it had no close ended questions. All the questions needed the respondent to answer freely and there were 27 questions. It took averagely one hour to interview participants with these questions. Probing was vital here for clarification at times. The researcher carefully followed the respondent and took down important points while he or she responded to the questions.

Numerous steps were taken during the development of the instruments to check on face validity and content validity (checking that content was appropriately covered). However, it was planned that follow-up interviews with participants would be conducted in order to check for the consistency of the responses (reliability) and possible validity problems. As this was done, the researcher was able to check whether there were any ambiguities in the items of the instruments, to find out why some respondents did not give answers to certain questions, or to probe further and get insights into participants' understanding of the impacts of alien plant invasions, and biodiversity concepts.

Reliability refers to the consistency of the scores obtained from the administration of an instrument to the same group on different occasions, (Fraenkel and Wallen, 1993). In this study, little or no efforts were made to ensure reliability because the instruments were not administered more than once to the same sample. Furthermore it was not possible to split the instruments (postal questionnaires) into equal halves to do a split-half reliability test.

2.6.3 THE INTERVIEWS

The interviews were more or less interpersonal in approach. It was time consuming but necessary as it served to validate the responses gotten from the questionnaires. This was achieved as a result of the researchers careful planning and probing skills. These skills were instrumental in obtaining the information that was sought. The total number of individuals

this researcher interviewed numbered ten (10). The total number of questions attained 27 and covered entirely the aims of the research study, (See copy of questionnaire in appendix).

The participants were interviewed at convenient hours and at convenient places. With the interviews the interviewer could capture the individual's attention and interest for a longer time, (Botha's lecture notes, p10). Also with this method, the person's reaction can be observed. Reactions such as resistance to certain questions can be significant and thus, informative as well, (Florentin, 2001).

In this study, the method adopted for interviews was the composite method (Indirect and direct), (Botha) cited by Florentin (2001). This implies the writer listened to the respondent and at the same time orientated the trends of the interview session in an indirect manner in order to achieve the objectives targeted.

2.6.4 QUESTIONS USED FOR INTERVIEW SCHEDULES

This writer on his own constructed these questions and at most did ensure their face validity by having them thoroughly screened by a hand picked number of experts (five in number). This was to ensure originality of the work. Before this researcher carried on, the questions had to be tested and reviewed over and in conjunction with expert's advice and results of the pilot test. This took place in Gauteng and was geared towards putting them in line with the research problem therein (see copy of interviews schedules in appendix).

Review of the items in the schedule led to a number of them being rephrased and the items in it modified. The questions were open – ended and allowed respondents to freely express themselves and to greater depths while answering the questions.

To further ensure validity of the items, a language teacher from Swaziland was consulted to thoroughly look over them and make valuable comments about them. This after the face validation and piloting of the instrument. Confirmation by the language expert on the fact that the items chosen satisfactorily covered the broad area of the research and was properly worded, thus paved the way forward.

ANALYSIS OF PARTICIPANTS' RESPONSE

The analysis of the responses was timely. This was as soon as the interviews came to a close. And the aim was to ensure that no detail was forgotten or neglected. To ensure this, a line-by-line analysis of the scripts' of notes was made during the interview sessions. This involved, screening of the facts, open coding and frequency counts of the correct and incorrect responses.

DOCUMENTARY ANALYSIS

This involved scheming through research reports, data bases (e.g., SAPIA), and project research documents of several tertiary departments, official government gazettes, newsletters, and a lot of documents from all organizations concerned in biodiversity management within Southern Africa. The approach was both contingent and congruent in format.

2.7 FIELDWORK AND MEASURING TECHNIQUES

Fieldwork here implied carrying out some form of vegetation analysis. This required enormous plant ecological techniques within the riparian, grassland and savannah vegetations of the Gauteng and KwaZulu Natal provinces. The selected sites were located N.E of Gauteng, and to the Coastal grassland areas of the KwaZulu Natal. For the area to have been sampled as best suitable for the research studies, this writer had to ensure that it was:

- adequately large in land area and equally harboring the alien but invasive plants under study,
- uniform (homogenous), and
- partially dominated by the species subjected under the study. Also the distribution should not be sparse, but rather dense in nature.

For the selection of the sites, the above criteria were scrutinized by the researcher to have been met, and satisfactory to field supervisors. These are the routine but preliminary steps taken in every vegetation analysis exercise. The following equipments were vital to this writer in fulfilling the demands of the field study, and they include; GPS equipments, several one hundred meter chains, Photo Cameras, Musking tapes, Measuring tapes, area maps, a GSM mobile phones, one Compass equipment, Plastic bags, site photographs, a pick up truck - for transportation of equipment and field support team to and out of the sites along the Mid

Elands River (in the Gauteng) and coastal areas of the KwaZulu Natal province. Without these proper data collection at the pinpointed spots in the zones would have been a nightmare. As a re-visit, (especially at the Mid – Elands River sites), there was little or no strain in sorting out the plots as they had been marked in the earlier visits during the previous research study, in the Year – 2000. The emphasis with the analysis was not at this point and time to sample the quantitative variation of species within the area once more, but as a follow up to the initial field surveys. In this regard, the term monitoring best describes the present motives of this research. Nonetheless with additional sites covered at the riparian zone, made it more demanding a task.

The techniques used in the field were the quadrat or plot methods including (certain methodological aspects of the transect method), in combination with the point center quadrat method (PCQ) and simple monitoring techniques. The PCQ method was the main method used. The methods used for the fieldwork were slightly modified but the underlying principles still upheld. Results of the research have been drawn from interviews, documentary analysis and field surveys along the Elands River. The area along Mid Elands River where sampling was done harbors 3 veld types which are; the **Magaliesberg**, **Bankenveld**, and the sour **Bush veld**.

2.7.1 MEASURING / SURVEY TECHNIQUES IN PLANT ECOLOGY

There are several plant ecological techniques used around the world for vegetation analysis. Before carrying out the study, this author had the obligation to ensure that the technique(s) he was to employ in the field were the most appropriate methods. Thus, for this to be realized the author quickly reviewed all the methods available and taking into cognissance the advantages and disadvantages of using any. At the end a choice was made and concrete reasons advanced for making that choice. But before those general appraisals of why classify vegetation of an area and other issues concerning the survey approach are deemed necessary to look at.

REASONS FOR CLASSIFYING VEGETATION:

- To differentiate vegetation types;
- To identify habitats which can be considered as sensitive, threatened, worthy of conservation or as problem areas due to bush encroachment;
- To ease communication;

- Vital for wildlife management (veld condition, grazing capacity, water provision, and fire programmes);
- Essential for planning recreational facilities and necessary for monitoring programmes.

Generally speaking management practices which depend on an inventory type of the area include the following: fire programmes, determining grazing capacity, suitable game animals, conserving biodiversity and monitoring just to list a few, Rooyen (ND).

STEPS GENERALLY FOLLOWED DURING A VEGETATION SURVEY TO CLASSIFY PLANT COMMUNITIES

- Reconnaissance of area – maps of topography, soil, geology, land types and aerial photographs;
- Plant collection and identification;
- Mapping of aerial photographs and stratification of the area into homogenous habitat units;
- Determining plot size, shape and number;
- Location of plots (random);
- Vegetation survey and description of physical environmental factors;
- Data processing and analysis;
- Identifying vegetation types (classification) and confirmation of units in the study area;
- Naming and describing vegetation types; and
- Drawing vegetation maps, Rooyen (ND, 3).

Talking about the apparatus, several of them are used in vegetation surveys ranging from ropes of 100 m to data sheets, compass, clinometer, anemometer, GPS and so on. Analysis of aerial photographs are also important in that it gives a three dimensional image. The aim of this in plant ecology is to distinguish, describe and map the different plant communities, Rooyen (ND).

2.7.2 TYPES OF SURVEY TECHNIQUES

QUADRAT OR PLOT METHODS

This is the most frequently used technique to gather quantitative vegetation data. They are deemed by research experts as the most suitable since they can be modified and applied successfully in almost all vegetation types. Literature reveals that the size of plots can be

determined separately for woody (100 – 200 sq. m) and herbaceous stratum (15 – 100 sq. m), or perhaps for different communities. On the other hand experts advise that the number of sampling units must be large enough to include all the most important species. Also it is required that the number of quadrats should not be less than five.

Braun – Banquet method

This method as (Werger, 1974) puts it, makes use of representative homogenous plots with a minimum size to sample the vegetation of a particular area. All plant species within that plot are recorded and covered and / or abundance values accorded to each species after which a matrix is compiled of the raw data. An *analytical phase*, which considers aspects such as (choice of terrain, homogeneity, distribution and number of sampling units, size and shape of the sampling plots, floristic observations, and environmental factors), and a *synthetical phase* are often distinguished in this method.

In the synthetical phase, all the data collected in the field is compiled into a table with the columns representing *relevés* and the rows species. A matrix of the table is filled in with the cover and in some cases abundant values of the species in the relevés. Various computer programmes have been identified to group this species with similar distribution patterns, (Rooyen, ND). Other activities here will include distinguishing the characteristic floristic composition of groups of *relevés*, confirm their patterns by means of correlation between vegetation and specific habitat characteristics whereby specific species can be identified. It is often advised that this ecological interpretation be verified. There are some restrictions to this synthetical phase detailed in some science literature text materials.

Transect method

Dombois & Ellenberg (1974) state that this method can be used to classify vegetation types, describe relationships between the vegetation and environment and to illustrate the vertical structure of the vegetation. The method is used to calculate the frequency, density and dominance of woody plant species. Relative frequency, density and important values are also calculated.

Such a method is perfectly suitable to illustrate vegetation changes along a gradient, for example – changes in soil, a view shared by several vegetation analysts and ecologists alike.

Usually a line transect of atleast 50 m by 2m or 100 m by 5m is laid out. The former was the measurement strictly used along the Elands River. A tape is absolutely necessary here for measurement purposes, laid on a compass line. For a transect of 2 m wide, demarcating it is easier by walking along the tape with a 2 m measuring rod. In this manner, woody species (trees and shrubs) are identified within the transect, (see data sheet used for recording in appendix). For each individual in this case, the distance from the starting point is measured. Diameters of tree stems above the ground are measured immediately. Mueller – Dombois & Ellenberg (1974) are of the opinion that, if an individual has more than four stems at soil level, it is regarded as a clump and the diameter of the entire plant base is measured. Other measurements for each individual include: plant height, canopy diameter, height of the first branch, and so on. In the field, this writer decided to estimate heights for very tall plant species (*Chromolaena Odorata* and *Acacia* species), and made use of his class intervals to record plant heights, canopy diameter and so on.

As a rule measurements within 5 m sections on the tape; assuming we consider 5 x 2 m as a unit. Further more Mueller – Dombois & Ellenberg (1974) advise that at least two transects should be done in each community. With this said and done the upcoming calculations can be worked out:

$$\text{Relative \% frequency} = \frac{\text{Number of units where species occurred}}{\text{Total number of units}} \times 100$$

$$\text{Relative \% density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative \% tree height} = \frac{\text{Total tree height of a species}}{\text{Total tree height of all species}} \times 100$$

$$\text{Relative \% canopy diameter} = \frac{\text{Total canopy diameter of a species}}{\text{Total crown diameter of all species}} \times 100$$

$$\text{Relative \% dominance} = \frac{(2 \times \text{Rel \% canopy diameter}) + (\text{Rel \% tree height})}{3} \times 100$$

$$\text{Relative \% basal diameter} = \frac{\text{Total basal diameter of a species}}{\text{Total basal diameter of all species}} \times 100$$

$$\text{Importance value} = \frac{\text{Rel \% frequency} + \text{Rel \% density} + \text{Rel \% dominance}}{3}$$

Exclosure plots

They are used to exclude animals when the effect of grazing should be determined. Large exclosures (1 hectare) or smaller cages (1 sq. m) can be used. The species composition and biomass of the plant material in the cage (control), as well as of an adjacent unfenced plot of equal size is harvested. Cages should be set out at random within a homogenous vegetation type.

Comparative harvesting method

This method as suggested by (Haydock & Shaw, 1975) is suitable in determining the phytomass of the herbaceous stratum (grasses) and the results can be used to calculate the grazing capacity. In this method, it is required that five quadrats be placed in each vegetation type ranging from the above grounds production from very poor to very good. A five point scale is used where “1” is the quadrat with the lowest production and “5” the quadrat with the highest production. The other quadrats are ranked between 1 and 5. In each quadrat the grass layer is harvested and weighed. At the end a regression curve is drawn of dry mass against ranking.

Phytomass

This approach is widely used to determine the phytomass of the grass layer over a season or a year. The above ground plant material is harvested at four-week intervals in pre – selected plots, (not less than 30 of 0.5 sq. m are also harvested). The sum total of the mass is determined and basal mass of plants is also calculated.

Canopy – gap ratio

In this method, the ratio between the mean canopy diameter and mean distance between canopies is determined. As such the percentage cover is calculated using the following formulae:

$$\% \text{ cover} = 90.7 / (n + 1)$$

Where n = mean number of canopy diameters between canopies

$$\% \text{ cover} = 80 / (n + 1)$$

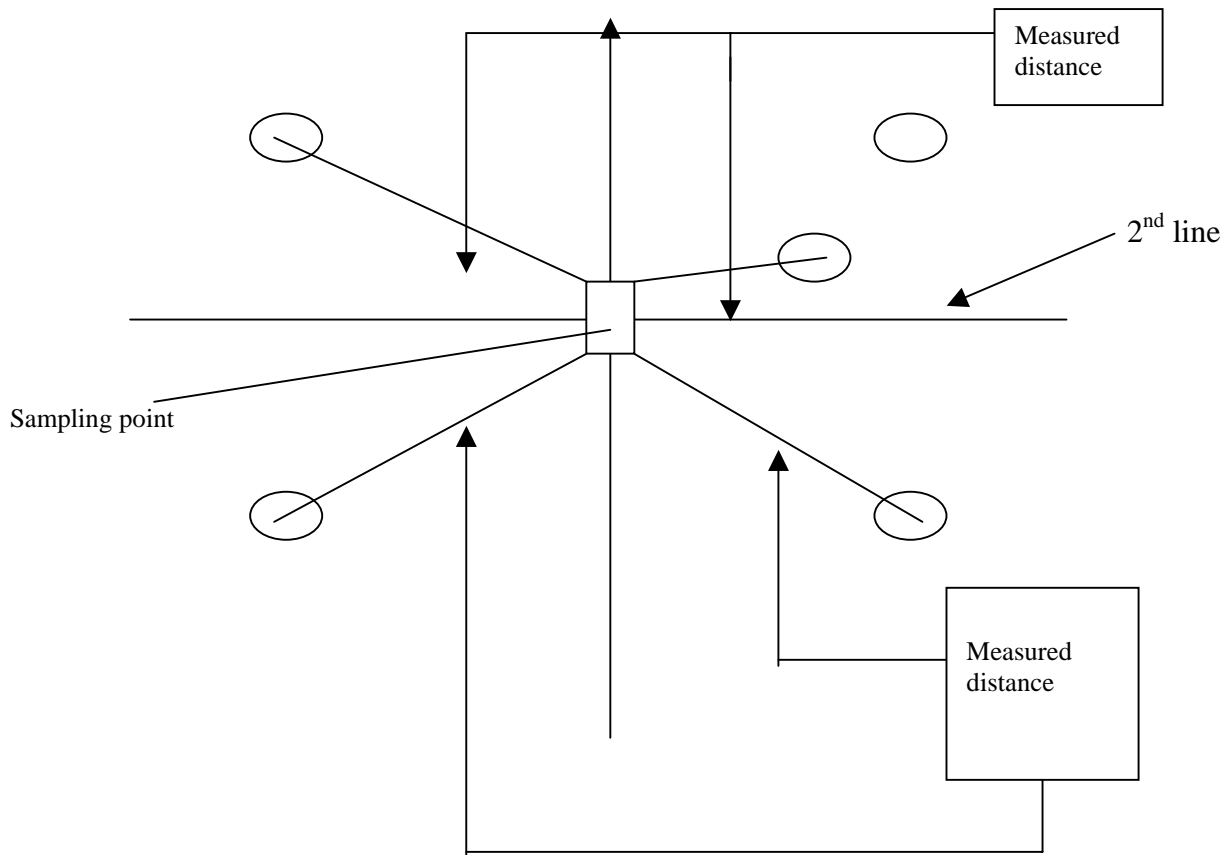
POINT OR PLOTLESS METHODS

Point centre quadrant (pcq) method

In this method, four distances are measured instead of one at each sampling point. Four quarters are established at the sampling point through a cross-formed by two lines. One line is the compass direction and the second a line running perpendicular to the compass direction through the sampling point, (Dombois & Ellenberg, 1974).

The distance of the mid point of the nearest tree from the sampling point is measured in each quarter. The following is a diagrammatic illustration – See next page.

FIGURE 3: DIAGRAM ILLUSTRATING THE APPLICATION OF THE POINT CENTRE QUADRANT METHOD IN THE FIELD



*Explanation: The diagram shows all the steps in applying the PCQ method for sampling a given point.
(Source: Author's own)*

There are no correction factors needed. This is so because the four distances of a sampling point if averaged and squared are found to be equal to the mean area occupied by each tree (Mueller-Dombois & Ellenberg, 1974). As a matter of fact, there is no correction factor needed when the four distances are averaged; and $MA = D^2$, where D = the mean distance of four points-to-nearest-tree distances taken in each of the four quarters. Morisita (1954) is quoted by (Dombois & Ellenberg, 1974) to have mathematical proof of the workability of this method.

LIMITATIONS OF THE PCQ METHOD FOR FIELD APPLICATIONS

- An individual must be located within each quarter, and
- An individual must not be measured twice.

For this reasons, this researcher did take time to select the sites where he did carry out his fieldwork. It is imperative that the chosen stands do not have wide spacing of individual species, for it presents a major problem using the PCQ method. Dombois & Ellenberg (1974, 111) suggest the following parameters likely to be obtained in the distance methods: Species, Density (from near distance), Diameter (and therefore basal area and dominance), and Frequency (as the occurrence of a species at a sampling point). Dombois & Ellenberg (1974) further state that, similar parameters are also obtained from plots.

MAJOR ADVANTAGES OF THE DISTANCE METHOD

- They do not require laying out of plot boundaries and this saves considerable amounts of time.
- It eliminates to a certain degree the personal error from judging whether boundary individuals are inside or outside the quadrat.

Further to this, a display on the results and how they are obtained for site six using the PCQ method is shown in Chapter 3 – section; Results of field survey.

Different applicable methods include the wheel point method, line intercept method (Dombois & Ellenberg (1974) agree that this method is helpful for woody as well as herbaceous vegetation analysis.), Disc pasture meter, and the ecological index method for determining range condition.

Other points or plotless methods include those that are aimed at determining plant density. McNeill et al. (1977) has compared and analyzed the following types:

- Nearest method (distance to nearest individuals).
- Nearest neighbour method.
- Random pair method.
- Third nearest neighbour in two sectors.
- Point center method (distance to nearest plant in each of the 4 quadrants)
- T – square, and
- Nearest individual in two sectors.

OTHER GENERAL METHODS

Stem count, palatability methods are some of a few known methods used in vegetation analysis.

Monitoring

In vegetation (ecology) based studies like this one, monitoring requires the formulation of common objectives between managers who are making decisions and the scientists (researchers) who are obtaining the information on which those decisions are to be made. Data collected for most of these cases must be suitable for use. It is agreed among researchers that this is the essence of triangulation. Maher and Norris (1990) state that, after objectives have been formulated, a number of testable hypotheses can be proposed and evaluated in terms of what information is needed for decision making.

The goals and objectives need to be clearly defined. It is also important to decide what one is monitoring for. Specific questions also need to be formulated that will be answered by monitoring in terms of the reason for the monitoring. In fact this researcher did ensure these aspects to an acceptable degree. In this research study, the manner in which information can be collected and used in making decisions was clearly outlined. The following questions were pondered upon by the researcher:

- What are the appropriate spatial and temporal boundaries of the study?
- What precision is required in the data?
- What accuracy is needed in the data?
- Will the data collected be compatible with existing data?
- What sort of biodiversity management options exists and what data might support the analysis of various options in decision – making?

For this study the following served as pointers that indicate the extent of the researchers considerations in the monitoring effort:

Defining the study areas

- Site visits before the actual fieldwork started was carried out.

- Proper understanding of the areas and associated problem areas were obtained as a result of the initial visits.
- Spatial boundaries were determined. Those of River Elands and others are the catchment areas.

Site selection

- Depended upon the study aims.
- *Reference sites (a site in its natural, unimpacted condition) and regular monitoring points were judiciously made.
- Data obtained was compared to the reference site data and inferences were then made concerning the ecological state of the monitoring sites.

Gathering new and integrating existing information (data)

- Biodiversity-related databases were found to be good sources of existing and useful information.
- Some of the literature was integrated into this current study as part of the literature review.

Establishing “baseline” conditions

- Current data depicts the extent, distribution of invasive alien species and present conditions of South Africa’s fragile ecosystems.
- The researcher is currently mapping the spread and intensity of *Chromolaena Odorata* and alien *Acacia* species within the two provinces.

Indicator selection

This was done with the notion in mind that:

- A number of elements could be used across a range of organizational levels, and
- Across a range of spatio-temporal scales.
- Ecological indicator was biologically relevant and easily measured.

- The indicator was integrative and able to maintain continuity in measurement over space, time and a wide degree of environmental impact (Cairns & McCormick, 1992).
- The indicator was sensitive to change, and
- Distributed over a broad geographical area.

Identity control areas

This was linked to each vegetation type in order to demarcate between control zones and those subjected to different kinds and intensities of stress and management practices.

Implementing a sampling scheme

Deciding the sample size was done at the design stage of the project proposal. Gauteng and KwaZulu Natal were clearly identified for the sampling sites. This was to avert imparting statistical analysis therein, hence the outcome of the study. Being an issue of scale, appropriate levels of resolution needs to be determined in order to answer the research questions posed.

Length of the study

- A time frame was decided upon for this study to be carried out in stipulation with the regulations governing higher degree research projects laid down and enforced by the BTU Cottbus.
- During this time (period) sufficient data is expected to have been collected to answer the research questions.

Statistical analysis of Data required

- The researcher selected appropriate statistical tools and this solely depended upon the magnitude of the information required to meeting the aims of the study.
- Decisions about the use of any statistical procedure had to be weighed, as different procedures demand different data requirements.
- Issues such as precision, accuracy and replication were dealt with at this level.

- After sample collection, description followed suit.

The Decision-making process

On this issue, (Roux et al., 1999) is of the opinion that there exist a link between data collected and derived information, with management actions. Care was exercised by the researcher for the results obtained to serve this purpose.

Quality assurance

- This was to identify, measure and control errors.
- Before measurements the researcher ensured that the instruments used were not faulty as it was going to mar results.

Cost effectiveness

- All was done by the author to minimize cost but meet the stated objectives.

It is clear that most of these methods have little to do with the specific aims of the research project. It is worth mentioning that, a few selected methods were instrumental for the research such as the transect methods, PCQ and other monitoring approaches as well. Combining or integrating the various approaches was not only as a result of 'convenience' but as a matter of fact aimed at triangulating the data obtained. Triangulation as (Mathison, 1988) describes is a strategy for increasing the validity of evaluation and research findings. Typically, through triangulation, it is expected that various data sources and methods lead to a singular proposition about the phenomenon being studied. This has been the case of this research study.

2.7.3 CHOICE OF SAMPLING METHODS.

Several methods had to be put together examined and those ideal were: 3 in number (monitoring, transect and PCQ methods, for field surveys and the other 3; interviews, questionnaires, documentary approaches) were those selected and used for the research. This was to have a three-dimensional kind of research finding - triangulation.

It has been established that most of these techniques used are more consistent and repeatable than other techniques in measuring the impact of species grassland and savanna vegetations. Walker (1976), Everson & Clarke (1987) and Panagos & Zacharias (1995) for example, have

all strongly argued and proven the consistency in the use of quadrats to record species composition in grasslands. Generally the sampling methods chosen for the study were critically analyzed and the advantages they carried outweighed the disadvantages, and thus, was beneficial to be used in this case.

2.7.4 STRATEGIES EMPLOYED IN THE FIELD

As a matter of fact, the considerations discussed above monitoring along the various sites in the field was relatively easier as the sizes of the sampling areas were within the scope of the researcher to carry out his measurements. The largeness in size of the quadrats was helpful in reducing excessive variances between quadrats, patchiness of the vegetation gradient being sampled and the boundary to area ratio of the quadrats (Greig – Smith, 1983). Transects varied according to the size (broadness) of each site. The standard length was set at 100 m though some exceptions really existed. Some sites served as benchmarks and others were monitored intensively in all the two provinces for the duration of the research study (they include in the Gauteng: sites 6 – 9 and in the KwaZulu Natal: sites 2 – 4).

2.7.5 STATISTICS INVOLVED

Much about the statistical approach and layout is discussed in the subsequent chapters. It stretches across the cardinal areas of the research and data generation tools used – such as questionnaires, interviews, field measuring and measuring apparatus.

ANALYSIS OF DATA

This was made easier using computer tools such as Excel and other software programmes such as SPSS. Values were obtained from data collected from the questionnaires, documentary and field surveys along the selected sites.

DESCRIPTION OF SITES

All sites investigated were selected using certain criteria. Some of them are that:

- The sites occurred within ancient grassland or savanna communities with history and evidence of recent habitat degradation.
- The sites were located within an altitude accessible enough.
- The sites must not be main grazing areas for farmers.

- The sites fall within zones, which have been earmarked for research by Government organizations and other research institutions.

In the Gauteng province the number of sites here numbered nine. All the sites were within the riparian vegetation.

In the KwaZulu Natal province the sites surveyed in this province were four in number. They held typical grassland features.

2.8 ORGANIZATIONS CONCERNED

Government Departments, such as the Department of Environmental Affairs and Tourism, Department of Water Affairs and Forestry, Agriculture, Agricultural Research Council; experts, scientists, and policy makers within these settings and Non Governmental Organizations, Tertiary institutions played a major role in delivering the necessary documentation used for the analysis carried out. The willingness of some of the experts from these administrative structures in taking part in the interviews and answering the provided questionnaires paved the way forward for the research study.

2.9 PUBLIC INVOLVEMENT

Public policy was reflected by the urge of governments and experts in quickly resolving the problems brought about by invasive flora species. Those interviewed were sampled from most if not all related departments of government ministries, NGO's and research organizations etc.

A target of about a dozen persons were primarily aimed but not all took part or turned up as such. The participants were chosen. As the interviews went along, those interviewed further referred this writer to other colleagues for detail or more relevant information to the study.

2.9.1 ETHICAL CONCERNS

Prior to interviews, this writer ensured that the respondent had grasped a clear picture of the inquiry. Also the writer did take time to explain the purpose of the inquiry and did well to “draw” the respondents’ interest into the process. This writer in all occasions restrained from acting thoughtlessly. During interview sessions “he – the writer” remained patient whilst observing and taking note of what the respondent was saying. The interviews carried out were

more or less personal. It is agreed amongst methodologists that in all well intended interviews, this not being an exception, certain principles were strictly conformed to. As in (Florentin (2001) they include:

- Taking into account that the physical environment is within a relaxed and eased atmosphere with privacy ensured;
- Confidentiality between the participants and the writer was upheld to this date and not only re-assured at the time of the inquiry;
- Avoidance of unnecessary criticism, arguments, and non – related problems;
- Taking down important points made during the course of the interview sequentially and;
- The length of each interview was quite concise and appropriate. In short, on average, each interview lasted for about an hour to an hour and a half.

Nevertheless, this writer equally upheld the feeling of positiveness. In all circumstances, the vocabulary employed during the conversations were simple and straightforward.

For all the interview sessions the writer stayed composed and polite in his language and actions whilst addressing questions to the respondents. The writer did not in any case rush to making any hasty conclusions as he observed the reactions of the participants wisely before arriving at any finite decisions. In sum, decisions on what was relevant and contributive were reached objectively from a broad spectrum of issues embedded in the work. Decisions arrived at, by the author were taken from a broad and objective base. Actually, the author in all circumstances avoided drawing rapid conclusions and forcing judgements when reliable and objective information was lacking. The Scientific attitude in the author can be visualized from the analysis and interpretation of the data collected. However, when collecting the data, an effort was made to collect it as quickly as possible in order to ensure validity and not to inconvenience the participants. Heads of institutions from which most of the participants (respondents) came from were appropriately informed of the purpose of the research when data collection involved their subordinates. This action was vital for ensuring collaboration from the respondents. Usually it is procedural to have a respondents immediate boss (hierarchy) to agree that he or she take off time during working hours to answer questionnaires and attend to interviews.

In collecting the data, the author ensured that the respondents were comfortable and relaxed. The data-gathering exercises allowed adequate time for the introduction, explanations of questions and brief discussions to allay any fears. It also allowed time for the distribution and collection of responses. Before gathering data, instructions on how participants were to proceed were given by the author. This writer however, anticipated changes and problems during the data-gathering process. For this and more, adequate measures were taken to guard against any odds emanating from the inquiries.

2.10 REMARKS

In this chapter, the writer has summarised the research procedures followed when developing the research instruments, and describes how the research was conducted and the analytic approach followed in analysing findings leading to the results. The results of the research are presented and discussed in chapter 3 and subsequent chapters.

CHAPTER THREE

RESULTS

This chapter is devoted to giving an insight on the issues that pertain to the theme of this research; most of which goes to explain and justify the *raison d’etre* of the subsequent conclusions and recommendations that follow in the last chapter of this thesis. In a nutshell the data generated in the field is presented and analysed succinctly. A pair of questionnaires, twenty (20) questionnaires, was designed tailored to specifics for two countries in West Africa (Cameroon and Ghana). The questionnaires followed the same pattern but had a few differences. They were dispatched to the respondents (participants – research students, environmental experts, and conservationists) electronically via email specifically to Cameroon and Ghana.

3.1 RESEARCH FINDINGS

Of the 100 questionnaires distributed in South Africa, 80 were filled and returned. For Cameroon, the rate of participation stood at 95% and for Ghana – 75%. This means of the 20 questionnaires distributed in Cameroon only one person failed to fill and submit the forms. For those sent to Ghana, only 15 of the 20 sent were completed, filled and returned to this writer.

3.1.1 FINDINGS FROM POSTAL QUESTIONNAIRES DISTRIBUTED IN SOUTH AFRICA, CAMEROON AND GHANA.

The research findings are discussed in three phases under this chapter and a perfect picture is given on what the situation on the terrain is like. See appendix for full questionnaires including their cover notes.

QUESTIONNAIRE ON BIODIVERSITY – SOUTH AFRICA

Topic: The impact of alien plant invasions on biodiversity in South Africa. The case of alien Acacia species in the Gauteng and Chromolaena odorata in the KwaZulu Natal provinces.

TABLE 3: ANALYSIS OF RESPONSES EXPRESSED IN PERCENTAGES (A)

QUESTIONS	ANALYSIS OF RESPONSE IN PERCENTAGES (%)			
	SA	A	D	SD
1. Biodiversity is important for South Africa.	95	5		
2. The loss of biodiversity is important for the growth of the South African touristic industry.			35	65
3. There are good reasons for the protection of the earth's biodiversity.	72	28		
4. The biodiversity of:	70	14	16	
- Gauteng province is seriously under threat by alien Acacia species.				
- KwaZulu Natal province is not hampered by Chromolaena Odorata.		13	10	77
5. Chromolaena Odorata is a major invasive specie in the KwaZulu Natal province.		8	52	40
6. Sensitization about the need to conserve South Africa's biodiversity has not been sufficient.	21	60	17	2
7. There are more invasive species (problem plants) in South Africa than native species.	45	38	17	
8. Chemical methods of controlling invasive species are not adequately used.	27	21	52	
9. Successful bio – control is not favored in the fight against exotics in South Africa.	2	20	66	12
10. The use of a combination of control methods to fighting invasive species is ideal in the Gauteng and KwaZulu Natal provinces of South Africa.	79	11	10	
11. The spread of Chromolaena Odorata is fast gaining grounds across the Southern African region.	55	10	35	
16. A lot of sensitization has been carried out to educate the public on the risks of the spread of alien plants?		26	04	70
17. Is biodiversity conservation a “successful story” in the Gauteng and KwaZulu Natal provinces?		2	90	8

18. In the fight against alien infestations (invasive species) the following is the best approach:				
In the case of Chromolaena Odorata				
- Mechanical control methods			40	60
- Chemical control methods		25	75	
- Biological control methods	38		62	
- Cultural control methods		5	15	80
- Integrated control methods	95		5	
In the case of Acacia mearnsii				
- Mechanical control methods			70	30
- Chemical control methods			60	40
- Biological control methods		25	75	
- Cultural control methods			10	90
- Integrated control methods	80	10	10	
In the case of other Australian acacia species				
- Mechanical control methods			100	
- Chemical control methods	5	70		25
- Biological control methods		75	25	
- Cultural control methods	100			
- Integrated control methods	60	35	5	
20. Could bio – control be successful in the fight against:				
(i) Chromolaena Odorata?	70	25	5	
(ii) Acacia mearnsii?		20	80	
(iii) Other Australian acacia species?		5	40	55

(Source: Author's own)

Expalantion: This table highlights ratings in percentages of scores obtained by the questionnaire distributed in South Africa.

Results drawn from the analysis of the responses to the close - ended questions found in the postal questionnaires distributed in South Africa:

- Biodiversity is very important for South Africa and so must be saved.
- Biodiversity loss does not favour the touristic industry.
- Protecting the earth's biodiversity is essential and makes sense to most people.
- Biodiversity of the Gauteng province is greatly at stake.
- Some parts of the KZN province is hard hit by Chromolaena odorata.
- Chromolaena odorata is spreading in the KZN province.

- *Chromolaena odorata* if not checked (controlled) could become a major invasive specie in KZN.
- Sensitization on the need to conserve S. Africa's biodiversity is in a good footing but much is yet to be done.
- Sensitization on the needs and importance of biodiversity conservation is not enough.
- Invasive plant species in South Africa is vastly outnumbering native plant species.
- S. Africa is flooded with exotic plant species (trees).
- Chemical methods of controlling invasive species are adequately used.
- It is evident that a chemical approach to clearing out invasive plant species in South Africa is not effective.
- Bio – control is increasingly being selected as an ideal option to the fight against invasive species.
- Combination of various control methods aimed to curb the spread of invasive species are ideal.
- *Chromolaena odorata* is fast spreading across Southern Africa.
- The relevant departments of government and private sector have done much in educating the public on the risks of the spread of alien species.
- Biodiversity conservation in Gauteng and KZN provinces has not been successful so far.
- Integrated control methods are thought to be the best approach in fighting against *Chromolaena odorata*.
- Most experts deem cultural, mechanical & chemical control methods inappropriate to fighting *Chromolaena odorata*.
- Integrated and chemical control methods are said to be ideal in eradicating *Acacia mearnsii* and other Australian acacia species.
- A bio-control approach may seem to work well against the spread of *chromolaena odorata* than for other invasive species.

The questionnaires distributed in Cameroon and Ghana were more or less similar but varied in certain aspects. It however focused mainly on *Chromolaena odorata* as it is one of the species this writer winds down upon in this study due to the concern of its spread in the continent, in addition its presumed impact on biodiversity. The study sought to scheme the views on

impacts of alien plant invasions in Cameroon and Ghana and the continent as a whole. Not only that, but the perceptions of field officers, land resource managers and other concerns

were sampled to better assess the spread of invasive species (particularly – *Chromolaena odorata*) in Cameroon, Ghana and the rest of the African continent. In all the questionnaires, meanings of the following SA, A, D, SD remained the same, (SA; strongly agree, A; agree, D; disagree, and SD; strongly disagree).

QUESTIONNAIRE ON BIODIVERSITY - CAMEROON

Topic: The impact of alien plant invasions on biodiversity in Cameroon. The case of Chromolaena odorata.

TABLE 4: ANALYSIS OF RESPONSES EXPRESSED IN PERCENTAGES (B)

QUESTIONS	ANALYSIS OF RESPONSE IN PERCENTAGES (%)			
	SA	A	D	SD
1. Biodiversity is important for Cameroon.	80	20		
2. The loss of biodiversity is important for the growth of the Cameroon's touristic industry.			5	95
3. There are good reasons for the protection of the earth's biodiversity.	100			
4. The biodiversity of:				
- Cameroon's coastal areas are seriously under threat by alien <i>Chromolaena odorata</i> .	5	40	50	5
- The grassland areas of Cameroon are not hampered by <i>Chromolaena Odorata</i> .		55	45	
5. <i>Chromolaena Odorata</i> is a major invasive specie in the North West and Western Provinces of Cameroon.		10	90	
6. Sensitization about the need to conserve Cameroon's biodiversity has not been sufficient.	70	30		
7. There are more invasive species (problem plants) in Cameroon than native species.			75	25
8. Chemical methods of controlling invasive species are not adequately used in Cameroon	15	50	35	
9. Successful bio – control is not favored in the fight against exotics in Cameroon.		35	65	
10. The use of a combination of control methods to fight invasive species is ideal in Cameroon.	10	30	60	
11. The spread of <i>Chromolaena Odorata</i> is fast gaining grounds across the West African region.	10	85	5	

16. A lot of sensitization has been carried out in Cameroon to educate the public on the risks of the spread of alien plants?			20	80
17. Is biodiversity conservation a “successful story” in Cameroon?			5	95
18. In the fight against alien infestations (invasive species) the following is the best approach:				
In the case of <i>Chromolaena odorata</i>				
- Mechanical control methods		65	35	
- Chemical control methods		40	55	5
- Biological control methods	10	45	45	
- Cultural control methods		1	99	
- Integrated control methods	10	55	35	
In the case of other alien invasive species				
- Mechanical control methods		80	20	
- Chemical control methods		25	75	
- Biological control methods	15	55	30	
- Cultural control methods		5	95	
- Integrated control methods	8	50	42	
20. Could bio – control be successful in the fight against:				
(i) <i>Chromolaena Odorata</i> ?		40	60	
(ii) Other species?		10	70	20

(Source: Author's own)

Expalantion: This table highlights ratings in percentages of scores obtained by the questionnaire distributed in Cameroon.

Summary of results drawn from the analysis of the responses to the closed- ended questions found in the postal questionnaires distributed in Cameroon are as follows:

- Biodiversity is vital.
- Loss of biodiversity is counter productive to the prosperity of the tourism sector.
- The earth's biodiversity must be protected at all cost.
- Coastal areas are not necessarily threatened by *Chromolaena odorata*.
- *Chromolaena odorata* in the grasslands poses some problems.
- *Chromolaena odorata* is not a widely spread alien specie in the NW & SW provinces.
- Sensitization on the need to conserve biodiversity is grossly insufficient.

- Government has made little or no effort in sensitising the public on biodiversity concerns.
- The number of problem plants are on the rise.
- Control of invasive species through chemical approaches are not adequately explored.
- Bio – control is favoured in the fight against invasive plant species.
- The combination of several control methods in fighting invasive species is slightly used.
- *Chromolaena odorata* is rapidly spreading across West Africa.
- Sensitization of the public on issues of invasive specie spread is at a lower peak.
- Biodiversity conservation is not on the right path.
- Integrated and mechanical control methods are tipped best in fighting *Chromolaena odorata*.
- Biological approaches to eradicating *Chromolaena* are being considered by experts.
- Mechanical, biological and integrated control methods are most favoured in fighting the spread of other alien invasive species.

Mechanical approaches are found to be ideal in controlling some species, for example - *Eucalyptus* trees in Cameroon. It is effective as most people in the rural areas use it as a source of firewood to cook in their kitchens. This way of using alien species is more or less traditional in terms of energy provision at households. But then, there lies other impacts, pollution, though far less than that produced by cars in the developed countries.

QUESTIONNAIRE ON BIODIVERSITY - GHANA

Topic: The impact of alien plant invasions on biodiversity in Ghana. The case of Chromolaena odorata.

TABLE 5: ANALYSIS OF RESPONSES EXPRESSED IN PERCENTAGES (C)

QUESTIONS	ANALYSIS OF RESPONSE IN PERCENTAGES (%)			
	SA	A	D	SD
1. Biodiversity is important for Ghana.	76	24		
2. The loss of biodiversity is important for the growth of the Ghana's touristic industry.			10	90
3. There are good reasons for the protection of the earth's biodiversity.	99	1		
4. The biodiversity of:				
- Ghana's coastal areas are seriously under threat by alien Chromolaena odorata.	25	45	30	
- The grassland areas of Ghana are not hampered by Chromolaena Odorata.		30	70	
5. Chromolaena Odorata is a major invasive specie in the North West and Western parts of Ghana.		35	65	
6. Sensitization about the need to conserve Ghana's biodiversity has not been sufficient.		60	40	
7. There are more invasive species (problem plants) in Ghana than native species.			80	20
8. Chemical methods of controlling invasive species are not adequately used in Ghana.	5	45	50	
9. Successful bio – control is not favored in the fight against exotics in Ghana.		25	5	70
10. The use of a combination of control methods to fight invasive species is ideal in Ghana.	25	40	35	
11. The spread of Chromolaena Odorata is fast gaining grounds across the West African region.	5	90	5	
16. A lot of sensitization has been carried out in Ghana to educate the public on the risks of the spread of alien plants?			70	30

17. Is biodiversity conservation a “successful story” in Ghana?		30	70	
18. In the fight against alien infestations (invasive species) the following is the best approach:				
In the case of Chromolaena Odorata				
- Mechanical control methods			80	20
- Chemical control methods		10	90	
- Biological control methods		30	65	5
- Cultural control methods				100
- Integrated control methods	15	70	10	5
In the case of other alien invasive species				
- Mechanical control methods		40	60	
- Chemical control methods		65	35	
- Biological control methods		25	70	15
- Cultural control methods		20	80	
- Integrated control methods		70	30	
20. Could bio – control be successful in the fight against:				
(i) Chromolaena Odorata?		45	50	5
(ii) Other species?		35	65	

(Source: Author’s own)

Expalantion: This table highlights ratings in percentages of scores obtained by the questionnaire distributed in Ghana.

Results drawn from the analysis of the responses to the close- ended questions found in the postal questionnaires distributed in Ghana:

- Experts do agree that biodiversity is important for the country.
- Loss of biodiversity is not in favour of the tourism industry.
- Reasons for the protection of the earth’s biodiversity strongly outweigh those against.
- Chromolaena odorata is found to be threatening the biodiversity of Ghana’s coastal areas.
- Chromolaena odorata has not yet greatly affected the grassland area.
- Chromolaena odorata is spreading in the North West and South Western parts of the country.
- Sensitization on biodiversity conservation issues is on a good footing.
- Control of the spread of invasive species is yielding interesting results.
- Chemical control methods are being properly employed.

- Bio-control is favoured in curbing the spread of exotics.
- Combination of control methods is preferred most in the combat of the spread of invasive species.
- *Chromolaena odorata* is spreading so fast across W. Africa.
- Sensitization on biodiversity conservation is low.
- Biodiversity conservation is not that successful.
- The spread of *Chromolaena odorata* could be best controlled by an integrated approach.
- Cultural and biological approaches used in fighting the spread of alien invasive species are least successful.

COMMON POINTS FROM AFRICA IDENTIFIED IN THE INTERPRETED RESULTS OF THE CLOSED-ENDED QUESTIONS OF THE QUESTIONNAIRES CIRCULATED IN THE 3 COUNTRIES ARE AS FOLLOWS:

- Respondents across the continent agree that biodiversity is important to be protected.
- Biodiversity must be sustainably used in order to protect the touristic industry.
- Biodiversity loss is unacceptable by experts.
- It makes sense to protect the earth's biological diversity.
- *Chromolaena odorata* and other alien species may rapidly spread across the continent if not checked.
- Overall sensitisation of masses on biodiversity issues across Africa is still inadequate.
- Bio-control and integrative control methods are the most preferred ways to eradicating alien invasive species.

A range of ideas could be drawn from the answers provided in the questionnaires, (*open ended questionnaires for South Africa*) and from it, strong arguments were being presented for the curtailing of invasive alien species, rapidly and through a much more effective approach. This in a way was acknowledgement made by some of the respondents and that meant all other control methods have not delivered the 'fruits' and hence was the time to consider the integrative options as opposed to the favoured bio-control methods of the past. The growing concern over the loss of biodiversity was also expressed by a good number of respondents to be as a result of the rapid expansion of human populations and economies in recent decades. This according to them has placed enormous stress on natural ecosystems and

the species within them. It is also evident today that one-third to one-half of the world's terrestrial surface has now been substantially altered by human activity. The vast majority of species must persist on a greatly reduced and increasingly fragmented natural landscape.

The most direct and tangible measure of the loss of biodiversity is said to be the extinction of species as pointed out by most of the respondents. The causes of species endangerment and extinction include destruction of habitat, over harvesting (hunting and fishing), and the introduction of non-native species into new areas. The respondents in their bit argue that this is where the failure of policy implementation could be seen. In the concerned provinces, (Gauteng and KZN), the respondents admitted that biodiversity conservation to a very limited extent has been successful, but overall and from a national perspective, it has been a failure.

For the respondents (mainly research students at University) who later had a one to one chat with this author (personal communication) claimed estimates of the rates of global extinction more or less are made difficult by their limited understanding of the total diversity and distribution of species on the planet. This author could infer from the answers provided and the discussions held with several experts that legislation for environmental management as well are constantly being modified based on new scientific information gathered in the field.

3.1.2 FINDINGS FROM INTERVIEWS

The results of the interview gave this author a perfect picture of the state of affairs viz a viz the infestations of *Acacia* species and *Chromolaena odorata* in the Gauteng and KZN Provinces. The up coming paragraphs is a summary of the opinions, (answers) respondents shared with this writer, but before then this writer will have to make it clear that the reasons for using simpler questions at the beginning was to draw each participant into the picture stage by stage. Also it was aimed at getting the respondents relaxed but more involved in the discussion (interview session).

On the question - what biodiversity was all about? - all the respondents trusted on the fact that biodiversity was a shorthand term for biological diversity, or the rich variety of life on earth. A few made mentioned of the fact that it encompasses the diversity of genes within species, of species within ecosystems, and of ecosystems -- coral reefs, prairies, forests, wetlands and so on -- within the biosphere.

Reasons advanced as to why biodiversity was important for South Africa incorporated the fact that species and ecosystems provide a wealth of essential goods and services upon which

human well-being fundamentally depends. Also, aspects of many insects, birds, and bats, for example, pollinating flowering plants, including agricultural crops were drawn into the responds given by others. Essential goods as one other respondent mentioned come in the form of foods, fuels, fibres, and medicines. This is true, and as a matter of fact, for example the top 150 prescription drugs in the United States, 118 were originally derived from plants, fungi, and other species. Cyclosporin, an important suppressor of immune responses, was also derived from a relatively obscure fungus found in Norway. However, the vast majority of plants, fungi, and micro organisms have yet to be tested for potential medicinal properties, and the opportunities for doing so are being irreversibly diminished. Similarly, the wild relatives of major agricultural crop plants provide important sources of genes for increasing the resilience of agricultural systems to effectively cope with changing climates and outbreaks of pests and diseases.

As concerns the points advanced for the growing concern over the loss of biodiversity in the Gauteng and KZN provinces, South Africa and the continent at large; a handful of respondents made this writer to understand that the rapid expansion of human populations and economies in recent decades has placed enormous stress on natural ecosystems and the species within them. It is true that the terrestrial surface has now been substantially altered by human activity. The vast majority of species must therefore now persist on a greatly reduced and increasingly fragmented natural landscape. Some ecosystems, such as tall-grass prairies and tropical dry forests, have almost entirely disappeared; others, such as wetlands, have been greatly diminished. The most direct and tangible measure of the loss of biodiversity is the extinction of species. In the United States, an above the norm percent of the well-studied plants and animal species that were present in 1900 are now extinct, and the remainder are threatened or rare. Causes of species endangerment and extinction include destruction of habitat, over-harvesting (hunting and fishing), and the introduction of non-native species into new areas.

This writer gathered from the responses that biodiversity protection in South Africa for species that are threatened with extinction can be protected under the relevant legislative acts which call for the development of a plan for the recovery of the species' population, and allows for designating and protecting habitat critical to the species' survival. It was established in the interviews that there are other laws to protect biodiversity in South Africa and the SADC (Southern African Development Community).

Inquiring on the meaning of 'endangered' species and other related terms, this author obtained a wide range of answers. The most striking one was that obtained from a seasoned conservationist in Pretoria, he said: "endangered" refers to species in danger of extinction throughout all or a significant portion of their range, while "threatened" ties to species that are likely to become endangered within the foreseeable future. Other supportive statements followed and to the best of this writers knowledge, the answer was a brilliant one.

Furthermore this writer gathered from the respondents that the most endangered species were the key stone species, native species and thus the biodiversity of the country was at stake. The species are said to be located in the various biomes with the Gauteng and KZN provinces altogether carrying a bulk of them. A few of the respondents could give precise figures of the distribution of endangered species, atleast on a national scale. However, one researcher this writer spoke with, had this to say concerning the location of species: 'they are in our own backyards, wetlands, estuaries, ocean bottoms, mountain tops, forests - even city parks, school yards and that all backyards - are all homes to diverse communities of plants and animals.'

Scientists in South Africa are continually researching and trying to stop the many threats facing biodiversity. Many of these threats stem from a growing human population. We have to also realise that humans are using more energy, land, water and natural resources (like trees, fossil fuels, minerals, plants and animals) than ever before.

As to the answers concerning the threats of biodiversity in South Africa from the perspectives of those interviewed, the following threats featured;

- Habitat Fragmentation and Degradation
- Climate Change
- Pollution
- Over-fishing, Hunting and Poaching
- Introduction of Species

Posing the question on the *raison d'être* for conserving biodiversity, this writer was simply reminded by one of the respondents that life on earth would not have been the same if its rich biodiversity were severely altered. Species, the respondent went ahead, (including humans) and the ecosystems in which they live are linked together through the flows of energy and materials (e.g. molecules, chemicals, etc.) and that any change in the life of one species -

especially extinction - could ripple throughout an ecosystem, changing the life of many other species, including humans. This was one of the best answers received during this writer's endeavour to collect as much information and facts as he could. These are some of the what biodiversity provides:

- Foods like fruits, vegetables, and other plants and animals,
- Shelter, including homes for many species of plants and animals,
- Timber, fuel, resins, gums and other useful products,
- Medicines,
- Natural beauty and inspiration.

Biodiversity also provides other ecological services, such as keeping our air and water clean, regulating our climate, pollinating our crops, and keeping our soils healthy and productive. Harming our biodiversity could have serious repercussions. For instance, over-logging forests fragments and destroys habitat for the animals that live in the forests. This could threaten some plant species with extinction, and can take away the trees we need to clean our air and water and to keep our soils, rivers, lakes, streams and oceans healthy. Or looking at this from another perspective, what if the world had no more pollinators - animals like bees, flies, butterflies, moths, birds, bats and others - that help pollinate flowers so that fruits like apples or strawberries can grow? Thus, reducing or harming the habitats in which pollinators live or the pollinators themselves, then the amount of fruits and vegetables that we and many animal species eat every day will be automatically reduced.

This writer gathered from the respondents' clues on how best ordinary South Africans could help in conserving the biological resources of the country. Many expressed that, South Africans could learn more, donate time and money to environmental organizations doing biodiversity conservation work, buy eco-friendly products, drive less, be energy efficient, using less pesticides, fertilizers and other chemicals on lawns. The one catching phrase this writer got from a respondent in the light of conservation efforts was – spread the word! – meaning citizens should feel free to talk about it in every day discussions. This was impressive, but how many could do such a thing in a country riddled with poverty and AIDS where most of the people are seeking for ways to survive.

It was evident from the discussions that more information on biodiversity could be obtained from ecological societies, parks (zoological) and botanical gardens, government related departments (Nature Conservation, DEAT, Agriculture), and Universities.

Other responses to the questions (11 – 27) gathered from the interviews included the following:

- Invasive exotic plants disrupt South Africa's natural environment by forming novel habitats and by altering ecological processes that permit native plant and animals to survive. Endangered plants, animals, and native ecosystems are being pushed closer to extinction by invasive exotic plants.
- Not all terrestrial plants in South Africa are weeds.
- Native plants are not targeted for control unless they have become noxious. Spray crews are directed to minimize, as much as possible, exposure of herbicides to native plants. The herbicide formulations that are often recommended for use kill the exotics, but will only temporarily "brown" the natives.
- They have the potential to hinder the growth of other beneficial plants and thus devastating to the environment. They adversely affect the public welfare or the natural resources of the provinces.
- Maintenance control is a systematic planned approach for controlling noxious weeds.
- A lot is said to be done about exotic species in South Africa. This is seen in Government Initiative Programmes, support for research on this branch of environmental management, and funding of control projects across the country.
- Get rid of invasive species on their own land, learn more about exotic species
- Herbicides are not all that safe for use. The aspect of pollution of water bodies was raised...
- No, only the amount of herbicide needed to adequately control exotics is allowed for use. Lots of money has in the past been spent on chemical control methods but of late being sized down. Currently money is diverted to alternative approaches for control of weeds such as bio-control and integrative options (still researched upon).
- Was found to be ineffective. Also not all invasive alien species could be got rid of using the mechanical approach only.

- Partially the extensive spread of *Chromolaena odorata* and *Acacia* species in most grassland and savannah areas of South Africa is said to being blamed on poor management programs.
- The spread of *Chromolaena odorata* across Africa has already been taking place due to changes in climate, movements of people in the continent and many other reasons advanced.
- For *Chromolaena odorata* and *Acacia* species bio-control methods (one of the most favored methods in Southern Africa) have not lead to successful recovery and for this reason other methods are being sought which entail a combination of methods.
- Government institutions and also NGO's are increasingly playing vital roles in conserving the biodiversity of the two provinces and the nation as a whole.
- There are specific obstacles – mainly economic and cultural that hinders sustainable biodiversity use in South Africa. Sensitisation and the search of funds abroad, expert advice aimed at counteracting all the obstacles is intensifying for some time now.

3.2 RESULTS OF DOCUMENTARY ANALYSIS

It will be true that much of these aspects have been dealt with under chapter two – Literature review. However, it was deemed imperative by this writer to further chip in more data gathered from documents he came across. Scientific studies strongly indicate that invasive exotic plants harm the natural environment and lead to a loss of biodiversity. It is widely accepted that invasive alien plants disrupt South Africa's natural environment by forming novel habitats and by altering ecological processes that permit native plant and animals to survive. This was justified by one of the participants of this study in an interview. Nonetheless, endangered plants, animals, and native ecosystems are being pushed closer to extinction by invasive exotic plants.

On the other hand, according to data compiled by the World Resources Institute, the percentage of animal species known to be under threat of extinction is about the same (2-10 percent) in temperate and tropical countries, while the percentage of plant species known to be threatened is actually higher in temperate countries. This is probably due to the much greater research and conservation efforts expanded in temperate countries; the percentage and

total number of threatened animal and plant species in the tropics will probably greatly increase as tropical biodiversity is completely studied. So one could be certain of the fact that there is light at the end of the tunnel.

Conversely, current control methods employed in South Africa range from hand pulling of undesirable species to applying herbicides selectively to avoid harming native plant and animal communities.

This study reveals that there are several reasons, but most important is that aliens find themselves in an environment different from that in which they evolved. Usually such a drastic change in environment is fatal to an alien. Occasionally, however, conditions are superior to those in the native land. In particular the alien specie is normally free of the diseases, parasites and predators, which keep its numbers in check in its natural environment. Under these conditions populations can explode with the invaders overwhelming the indigenous fauna and flora, usually by crowding it out.

Plant invaders are plentiful, especially in the South Western Cape, KwaZulu/Natal, and the Eastern Transvaal. The cape fynbos, a unique floral kingdom, is severely threatened by Australian acacias, which were originally introduced for timber, bark products, or to stabilise sand dunes. In the eastern Cape, KwaZulu/Natal, and the Transvaal lowveld the worst invaders are lantana, chromolaena (triffid weed), seringa, and black wattle. Other local South African (unpublished) studies also reveal that many alien plants have been declared undesirable and may not be grown on any public or private property. These alien plants as it is often acknowledged were originally introduced as commercial plants or as ornamental garden plants. For sure, few or none of these invasive species do cause problems in their native lands. Their invasive qualities of alien plants are however often unsuspected, which goes to show that no alien species should ever be released into the *veld* without screening for its invasive potential. Unfortunately this can be expensive as well, but we all have to remember that almost any alien species could become an invader.

So far South African authorities now advise concerned parties to do the following:

- List and map all the invaders in your area and find out how to control each invader.
- Draw up a report outlining an overall control plan and submit it to your local authorities.

- Check all gardens and nurseries to ensure that none are cultivating invaders - bring offenders to the attention of your local conservation authority.
- Do not move any aquatic plant or animal (including fish) from one water body to another.
- Never release unwanted pets into the wild - rather give them to a pet shop.
- Abide by the regulations regarding the importation of plant and animal material when returning from abroad, and encourage friends to do so.

TABLE 6: SOME CHARACTERISTICS OF THE VARIOUS CONTROL METHODS

Mechanical approach	Chemical approach	Biological approach	Cultural approach
- Causes extensive Soil disturbance	Undesirable in most situations – esp. along water courses as it may pollute the water, hence poisonous to certain living organisms	- Efficiency depends on skills of professionals	- Relatively ineffective overall
- Allows more sunlight to reach the soil	- Kills surrounding vegetation (natural)	- Works relatively slowly	- Lacks an internationally accepted pattern
- Enhances germination of accumulated seeds	- Expensive	Generally unrealistic e.g. could insect species increase in numbers within 1-2 years to a level significant to reduce the invasive plants.	
Costly as it requires constant follow up			

(Source: Author's own)

Explanation: The above table highlights properties of mechanical, chemical, biological and cultural ways of curbing the spread of alien invasive species.

Already recent research studies call for a combination of methods to combating invasive alien species, *Chromolaena odorata* and *Acacia* species included. According to the recommendations of the PPRI (Plant Protection Research Institute) Biennial Report 1996/1997 cited by (Florentin, 2001), infested land should always be graded into high, medium and low priority areas regarding control. The reason behind this is that high priority

areas are those where control costs are low compared to the expected benefits (e.g. increased biodiversity, water yield grazing capacity). Thus, by implication, this approach tends to optimize the use of available resources by concentrating them in high priority areas. The co-factor here is cost – analyses, but the question that quickly comes to mind is; how probable is it for large-scale farmers to apply such a concept?

3.2.1 FURTHER BACKGROUND INFORMATION ON SOUTH AFRICA VIZ A VIZ THE ENVIRONMENT

WATER MANAGEMENT

Water management has taken priority over the recent years. With the WfW programme put in place to counter the effects of alien invasive – river side plants that dry up South Africa's rivers. The government has invested millions of dollars into research and management schemes to deal with this problem.

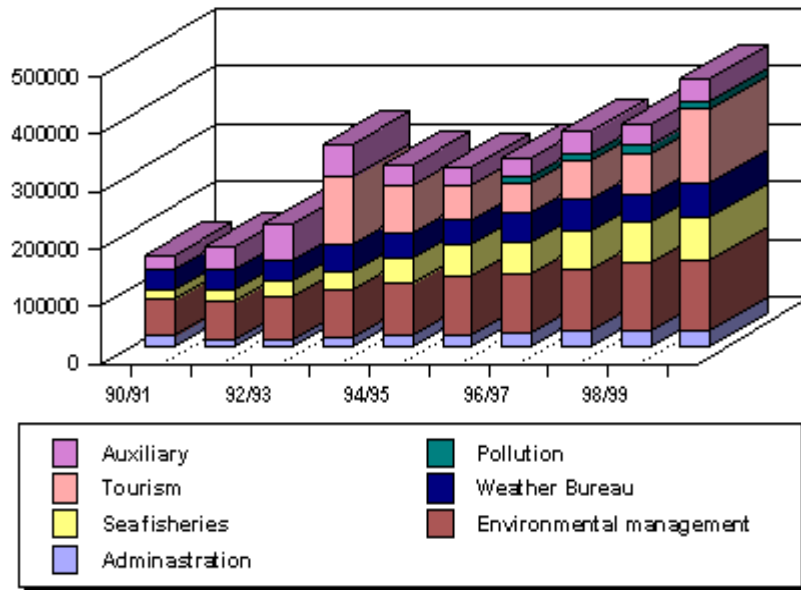
The Vaal (Grey) river for example which brings water *to and fro* the Gauteng Province was monitored and assessed in terms of the spread of Acacia species along its sides. It is no doubt a source for seeds of alien invasive species. It also transports eroded top soil and floods as wells.

Much about South Africa's commitment and government expenditure to dealing with alien infestations, hence securing a safe and healthy environment is dealt with in the following paragraphs.

CURRENT ENVIRONMENTAL POLICIES

The current environmental policies are widely believed to be taking into cognissance the data in the previous graphs and tables seriously. Estimates and projections on the environmental situation in the foreseeable future have also led to a review of the state of current environmental policy in South Africa, national and international expenditure on environmental issues, and an assessment of the capacity in South Africa to effectively promote sustainable development.

FIGURE 4: BUDGET ALLOCATION - DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM



(Source: DEAT, 1999)

Explanation: The chart shows a progressive increase in South Africa's budget allocation to the DEAT from 1990 – 1999.

The South African government's expenditure on environmental issues has increased steadily over the last decade. The budget allocation for the Department of Environmental Affairs and Tourism is reflected in the chart above. The chart indicates that there has been a progressive increase in the overall budget of the DEA&T (in actual Rands, not adjusted for inflation). During 1993 / 1994 a tourism component was established in the Department and a significant proportion of the total budget was allocated to this new function. During 1996 / 1997 the Chief Directorate Pollution Control was established and some new funding was provided for this function. Compared to other government programs, the environmental budget is still low at about 1-2% of total government expenditure, (DEAT, 1999). Also at different sectoral Departments at the national level, environmental budgets are also put in place. However, it is not always possible to separate what has been allocated for environmental purposes from the rest of the departmental budget.

It is reported in the DEAT (1999) that foreign donor presence in South Africa increased significantly after 1994. Also the Official Development Assistance (ODA) has assisted South Africa in meeting the incremental costs associated with the implementation of Agenda 21 and re-ordering priorities among the social, economic and environmental components of sustainable development. Many of the new policy developments and implementation

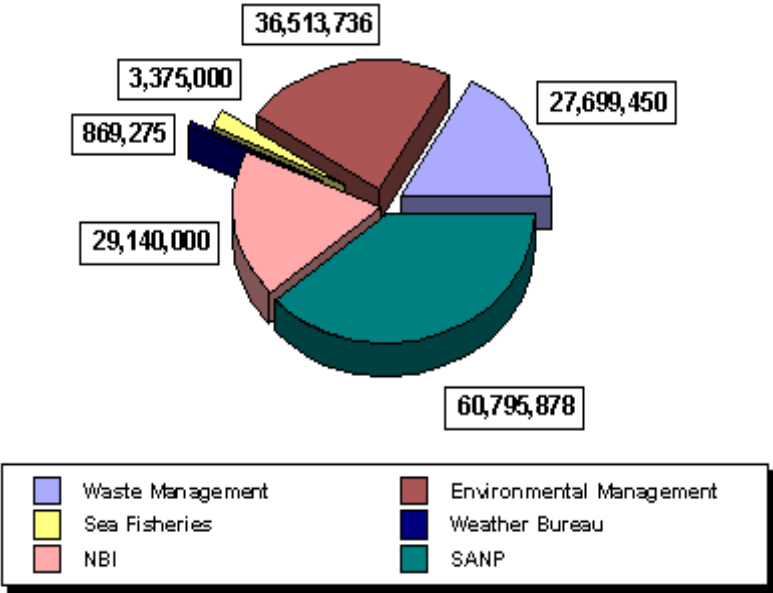
programs would not have been possible without foreign donor funding. Examples include the Coastal Management Policy Programme, Phases I-IV of the Sea Fisheries Policy and the development of the White paper on Biological Diversity.

It has been established that ODA normally comprises grants or loans of a financial nature. In addition to funds, technical cooperation is often included – this is similar to the GTZ of Germany that offers assistance in several respects to many of developing countries.

As part of the National **Local Agenda 21** campaign of the DEA&T, funding has been granted by USAID to develop and implement training programmes for senior and middle management in local and provincial government with regards to sustainable development. The aim is to make provision for training according to the needs of the target group in terms of implementing the principles and processes of local sustainable development. Training started in April 1999 and is coordinated by the Environmental Evaluation Unit of the University of Cape Town, (DEAT, 1999).

FIGURE 5: PROGRAMMES FUNDED BY DONOR AGENCIES (DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM, NATIONAL BOTANICAL INSTITUTE & SOUTH AFRICAN NATIONAL PARKS). THE CURRENCY IS IN RAND. (Source: DEAT, 1999)

Most of ODA funding for the Department is channelled to the South African National Parks and the National Botanical Institute (56%), and for projects related to pollution, waste management and environmental management (EM) 40%. The Weather Bureau and Sea Fisheries receive only a small proportion of donor funding made available to the DEA&T.



Explanation: Chart shows the distribution funds in the DEAT. Parks as of 1999 received most funds followed by EM.

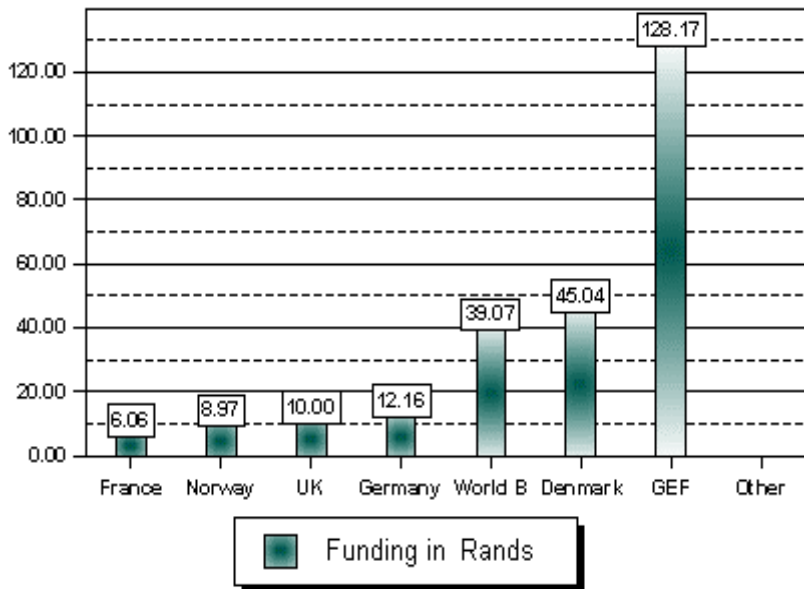
ODA assistance of some R286 629 201 has been made available to the Department of Environmental Affairs and Tourism since 1994. It must be stressed that ODA assistance is also provided to other departments for environmental projects such as the Working for Water

project, funded in part from Norway. The following figure (figure 6) does not represent all ODA assistance received for environmentally related projects, (DEAT, 1999).

Donor funding however, while being important is not the solution for the long-term as much of the funding was provided to support South Africa's transition to democracy.

FIGURE 6: PROGRAMMES FUNDED BY DONOR AGENCIES (ONLY AMOUNTS > R5 000 000 SHOWN). (Source: DEAT, 1999)

With South Africa becoming more stable politically, and not really being seen as a developing country, it is anticipated that foreign assistance will be reduced. The DEA&T is generally believed to have evolved mainly organically over the years as specialist fields of interest came to the fore or external demands such as international involvement became more prominent, (DEAT, 1999). However as the changes in policy and the environment in South Africa occurred just of recent, and as a result of this short time gap the impacts are largely unknown at this stage. Thus, there can be no further responses to them. In the meantime a shift to a more transparent process and greater participation by organisations, communities, and business and industry, will facilitate on-going demand for policy reform and improvement.

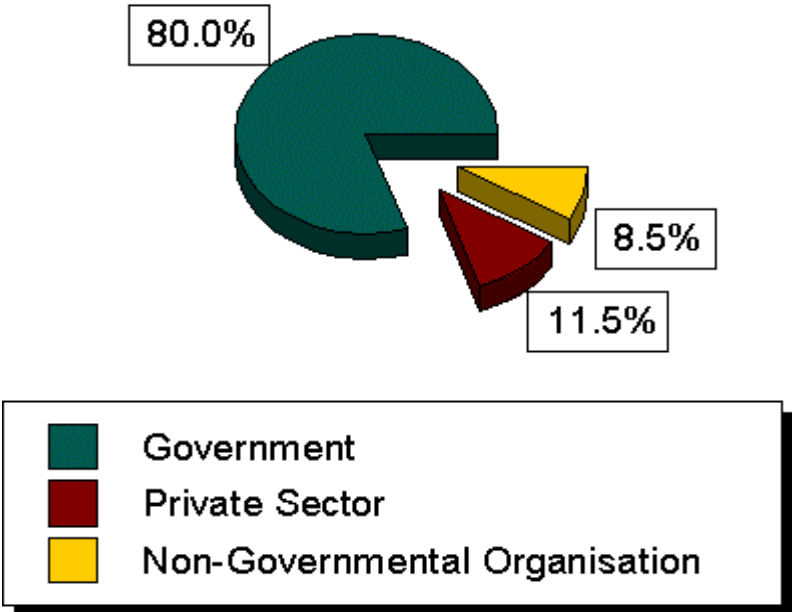


Explanation: Distribution of funds in rands from countries and other donor groups in 1999.

As stated in the DEAT report – 1999, the success of policy implementation is largely a function of political will, funding, good integration and co-ordination between the lead agency and other agencies where functions and responsibilities have been delegated, and a well-trained group of staff to manage programs and projects. An additional factor that will contribute to success in South Africa is partnership with institutions in civil society where environmental problems are solved jointly. This is simply because government does not have the resources necessary to deal with all the environmental problems we face. The National

Environmental Management Act makes it possible for the Minister of the DEAT to enter into agreements with communities in order to solve particular environmental problems like waste or to protect certain indigenous plant or animal species. This both empowers the community and promotes a culture of ownership, and relieves the pressure on the resources of the DEA&T. The National Environmental Management Act took three years to develop, and needs strong capacity building programmes at all levels of government to be implemented effectively. Due to the lack of funds and other issues most recently, the World Wide Fund for Nature (WWF)-South Africa assisted government in raising substantial funds for the Table Mountain Fund from the private sector and the Global Environmental Facility. To address this problem and other pertinent ones the Department of Environmental Affairs and Tourism established an Environmental Capacity Building Unit in 1999. Changes in policy have also given direction to the kinds of research and technology that need to be developed. While South African research institutions, which are numerous as compared to other African states, have a strong research tradition in the field of environment and extensive infrastructure and capacity, more work has to be done in addressing the challenges put forward by the new policy agenda. During 1991/92 between R550 million and R770 million was spent on environmental research.

FIGURE 7: FUNDS PROVIDED BY GOVERNMENT, PRIVATE SECTOR AND NON-GOVERNMENTAL ORGANISATIONS FOR ENVIRONMENTAL RESEARCH



(Source: DEAT, 1999)

Explanation: Chart shows that a greater amount of funds for environmental research comes from the Government followed by the private sector.

About 80% of funds for environmental research were provided by government, 11.5% by the private sector, and 8.5% by NGOs (National Research and Technology Foresight Project, NRTFP DACST), DEAT (1999). It is a pity that this writer could not assess figures regarding the change in funding since 1994 due to the simple reason that they were not available at the time this writer was compiling the report of this study. However, there have been extensive reviews of the 11 government science councils, with the aim of establishing how these institutions, either individually or as components of the National System of Innovation could be restructured and resourced to meet broad national needs. Many of these 11 institutions are actively involved in environmental research in one way or the other.

The NRTF Project as reported in the (DEAT, 1999) is meant to identify technologies and technological trends that will contribute to economic growth and social upliftment of all South Africans over the next 10 - 20 years. Of the 12 sectors that have been chosen, two are related directly to environmental research, namely the environmental and biodiversity sectors. This will guide future research and investments within the public and private sectors.

The establishment of the Innovation Fund Scheme by the Department of Arts, Culture, Science and Technology (DACST) is designed to encourage new innovations in the field of environment that are related to national priorities. The fund was established in 1998.

Given declines in net contributions by the government to science councils and tertiary institutions, funding for environmental research has largely remained the same in Rand terms, but decreased in real terms. (Source: National Research Foundation). See the following table, (Table 11) for the funding of the Environmental Sustainable Scheme by the NRF.

TABLE 7: NRF FUNDING FOR ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT PROJECTS				
	1996	1997	1998	1999
Funding awards	10 960 000	11 287 000	12 382 000	12 382 000
<i>(Source: NRF, 1999)</i>				
<i>Explanation: Table proves that there has been a steady increase in NRF funding for environmentally sustainable development projects from 1996 to 1999.</i>				

3.3 RESULTS OF FIELD SURVEY

GUATENG PROVINCE

Number of Sites surveyed:

9

TABLE 8: SURVEY RESULTS OF SITE 1

Code:	EL 1
Sampling date:	June 2001
River	Elands
Quaternary catchment:	
Locality:	
* Latitude (°S):	25.57537
* Longitude (°E):	28.57685
* Altitude (m.a.m.s.l):	1300
Vegetation:	Riparian
* Width of riparian zone:	30 m
* Dominant vegetation:	Trees and Grasses
* Substrate:	Sand, soil, cobbles and bedrock

(Source: Authors' own)

Explanation: The table above shows the latitude and longitude at which site 1 is located along the mid Elands river. It also highlights aspects of its vegetation and bits of information on the substrate.

Access to this site was not easy as such, thus the number of visits were limited to two. The ecoregion - a Bushveld basin with its streams classified as being mountainous. Also this author noticed the single channel type in which the site remains embedded. About the surrounding land use, this author will liken it to be generally recreational and having a medium level in terms of ecological importance. Here, the four dominant species are as follows; *Acacia mearnsii*, *Combretum erythrophyllum*, *Phragmites* sp, *Euclea crispa*.

TABLE 9: SURVEY RESULTS OF SITE 2

Code:	EL 2
Sampling date:	June 2001
River:	Elands
Quaternary catchment:	
Locality:	
* Latitude (°S):	25.55149
* Longitude (°E):	28.56792
* Altitude (m.a.m.s.l):	1220
Vegetation:	Riparian
* Width of riparian zone:	50 m
* Dominant vegetation:	Mainly trees
* Substrate:	Sand, soil, cobbles and bedrock

(Source: Authors' own)

Explanation: The table above shows the altitude, latitude and longitude at which site 2 is located along the mid Elands river. It also highlights aspects of its vegetation and bits of information on the substrate.

Access to this site was problematic and the number of visits scaled to two. The channel type at site two could be categorised as single / anabranching, the surrounding land used for recreation, agriculture and irrigation. Medium is the appropriate term to characterise the

ecological importance of the site. The dominant species numbered four and they include; *Melia azedarach*, *Acacia mearnsii*, *Combretum erythrophylum*, and *Phragmites* sp. The ecoregion is typical of a bushveld basin. It is needless to emphasise the obvious aspects of the hydrological type of the sites. The stream in this site classification wise is foothill cobble bed.

TABLE 10: SURVEY RESULTS OF SITE 3

Code:	EL 3
Sampling date:	June 2001
River	Elands
Quaternary catchment:	
Locality:	
* Latitude (°S):	25.43328
* Longitude (°E):	28.57778
* Altitude (m.a.m. s.l):	1200
Vegetation:	Riparian
* Width of riparian zone:	50m
* Dominant vegetation:	Grasses
* Substrate:	Cobble / sand / bedrock

(Source: Authors' own)

Explanation: The table above shows the altitude, latitude and longitude at which site 3 is located along the mid Elands river. It also highlights aspects of its vegetation and bits of information on the substrate.

Despite the relatively easy access to this site, the number of visits was kept at two. The channel type – anabranching, the surrounding land use was and remains predominantly Livestock and game farming. However, the ecological importance of the site was observed by the author and ranked high. Being a bushveld basin and the stream typically foothill gravel bed much could be told about the site. The main dominant species included - *Acacia karoo*, *Sesbania punica*, *Combretum erythrophylum*, and *Melia azedarach*.

TABLE 11: SURVEY RESULTS OF SITE 4

Code:	EL 4
Sampling date:	June 2001
River	Elands
Quaternary catchment:	
Locality:	
* Latitude (°S):	25.408
* Longitude (°E):	28.56900
* Altitude (m.a.m.s.l):	1180
Vegetation:	Riparian
* Width of riparian zone:	50.75m
* Dominant vegetation:	Grasses
* Substrate:	Sand / soil / cobbles

(Source: Authors' own)

Explanation: The table above shows the latitude and longitude at which site 4 is located along the mid Elands river. It also highlights aspects of its vegetation and bits of information on the substrate.

With the vegetation portraying a single channel type and with evidence of game farming / livestock farming as the main activities in the surrounding areas of the site, still the ecological importance of the site was found to be high indeed. The dominant species that measured included; *Rhus lanceae*, *Acacia karoo*, *Combretum erythrophyllum*, and *Melia azedarach*. This was a major contrast to the other sites within the bushveld basin having a Foothill gravel bed stream. Access here was easy and two visits were carried out.

TABLE 12: SURVEY RESULTS OF SITE 5

Code:	EL 5
Sampling date:	June 2001
River	Elands
Quaternary catchment:	
Locality:	
* Latitude (°S):	25.30307
* Longitude (°E):	28.46375
* Altitude (m.a.m.s.l):	1052
Vegetation:	Riparian
* Width of riparian zone:	35m
* Dominant vegetation:	Trees / forbs / grasses
* Substrate:	Sand / soil / cobbles

(Source: Authors' own)

Explanation: The table above shows the latitude and longitude at which site 5 is located along the mid Elands river. It also highlights aspects of its vegetation and bits of information on the substrate.

This site held similar characteristics as that of site 4 in respect to the surrounding land use, its ecoregion, access to the site and number of visits made. On the other hand though the channel type was single, this was unique in several respects. Also the stream could undoubtedly be classified as foothill cobble bed. *Acacia dealbata*, *Melia azedarach*, *Combretum erythrophyllum*, and *Sesbania punicea* are some of the dominant species in the area. In terms of ecological importance the site is ranked medium.

TABLE 13: SURVEY RESULTS OF SITE 6

Code:	EL 6
Sampling date:	June 2001
River	Elands (Mid - Elands)
Quaternary catchment:	
Locality: * Latitude (°S): * Longitude (°E): * Altitude (m.a.m.s.l): * Bearing:	Start: 25.3250 / End: 25.3251 Start: 28.3358 / End: 28.3401 >1000 m 123°
Vegetation: * Width of riparian zone: * Dominant vegetation: * Substrate:	Riparian > 50m Trees / grasses Sand / cobbles

(Source: Authors' own)

Explanation: The table above shows the latitude and longitude at which site 6 is located along the mid Elands river. It also highlights aspects of its vegetation and bits of information on the substrate.

Site number 6 was relatively easy to access and as such the number of visits rose to 4. Here the channel type was clearly single with the surrounding land use being livestock farming only. Medium is the appropriate term to characterise the degree of ecological importance of the site. The dominant 6 species ranked in ascending order were found to be; Combretum erythrophyllum, Blue gum, Un identified sp., Sesbania punicea, Melia azedarach, and Acacia dealbata. Tables 19 & 20, alongside Table 21 sheds more light to how the results displayed for site 6 are achieved using the PCQ approach.

TABLE 14: A POINT-CENTERED QUARTER ANALYSIS USING VALUES OBTAINED FROM SITE SIX ALONG ELANDS RIVER. (ALONG THIS TRANSECT, FIVE SAMPLING POINTS, ONE AT EVERY 5M ALONG ABOUT 25 - 30°).

Sampling point	Quarter Number	Distance (m)	Species	Diameter at base (cm)
1	1	1.05	Acacia dealbata	0.8
	2	3.3	Un identified	1.1
	3	1.9	Melia a	2.9
	4	1.78	Un identified	1.4
2	1	1.37	Combretum e	13
	2		No woody plant	
	3	No woody plant		
	4	1.37	Blue Gum	4.2
3	1	1.4	Un identified	1.1
	2	1.2	Un identified	0.5
	3	0.8	Un identified	1.4
	4	0.24	Un identified	0.4
4	1	1.8	Sesbania p	0.6
	2	1.2	Sesbania p	0.4
	3	1.7	Blue gum	17.8
	4		No woody plants	
5	1	0.4	Un identified	2.0
	2	0.6	Sebania p	3.4
	3	0.4	Sesbania p	3.7
	4	0.56	Un identified	0.9
		21.07 (Total)		

(Source: Author's own)

Explanation: Values in the table above is illustrative of how measurements in the field were recorded. Analysis of these values follows the PCQ method. The values seen in this case were obtained from site six.

Results:

Mean distance (D) = $21.07 / 20 = 1.0535$

Absolute density = Area / D^2 Where D = mean distance

Number of trees per $100 \text{ m}^2 = 100 / (1.0535)^2 = 100 / 1.10986 = 90.1$

Absolute dominance = mean *ba* per tree X number of trees in species. Where *ba* = basal area

Number of trees in species, $\Pi = 22 / 7 = 3.14$

NB: $\text{Area} = \Pi r^2$

TABLE 15: INVASIVE SPECIE NUMBER PER QUARTER

Species	Number in Quarters	Number of trees in 100 m ²
Acacia dealbata	1 / 20 = 0.05	0.05 X 90.1 = 4.505
Un identified tree specie (small leave privittes)	8 / 20 = 0.4	0.4 X 90.1 = 36.04
Melia azedarach	1 / 20 = 0.05	0.05 X 90.1= 4.505
Combretum erythrophyllum	1 / 20 = 0.05	0.05 X 90.1= 4.505
Blue Gum (Eucalyptus sp)	2 / 20 = 0.1	0.1 X 90.1= 9.01
Sesbania punicea	4 / 20 = 0.2	0.1 X 90.1= 9.01
		Total = 67.575

(Source: Author's own)

Explanation: This shows us how the number of each invasive species per quarter and number of trees in 100 m² were obtained.

1. Relative density = $\frac{\text{number of individuals of species}}{\text{total number of individuals}} \times 100$

$$\text{Un identified} = 36.04 / 90.1 \times 100 = 40\%$$

$$\text{Blue gum} = 9.01 / 90.1 \times 100 = 10\%$$

$$\text{Sesbania punicea} = 9.01 / 90.1 \times 100 = 10\%$$

$$\text{Acacia dealbata} = 4.505 / 90.1 \times 100 = 5\%$$

$$\text{Melia azedarach} = 4.505 / 90.1 \times 100 = 5\%$$

$$\text{Combretum e.} = 4.505 / 90.1 = 5\%$$

2. Relative dominance = $\frac{\text{dominance of a specie}}{\text{dominance of all species}} \times 100$

$$\text{Un identified} = 7.8906 / 389.65965 \times 100 = 2.025\%$$

$$\text{Blue gum} = 262.5668 / 389.65965 \times 100 = 67.38\%$$

$$\text{Sesbania punicea} = 95.613 / 389.65965 \times 100 = 24.54\%$$

$$\text{Acacia dealbata} = .5024 / 389.65965 \times 100 = 0.129\%$$

$$\text{Melia azedarach} = 6.60185 / 389.65965 \times 100 = 1.69\%$$

$$\text{Combretum e.} = 597.656 / 389.65965 \times 100 = 153.38 \%$$

3. Relative frequency = $\frac{\text{frequency of a specie}}{\text{sum frequency of all species}} \times 100$

$$\text{Un identified} = 3 / 11 \times 100 = 27.27 \%$$

$$\text{Blue gum} = 2 / 11 \times 100 = 18.18 \%$$

$Sesbania\ punicea = 2 / 11 \times 100 = 18.18\ \%$

$Acacia\ dealbata = 1 / 11 \times 100 = 9.09\ \%$

$Melia\ azedarach = 1 / 11 \times 100 = 9.09\ \%$

$Combretum = 1 / 11 \times 100 = 9.09\ \%$

Importance value (I.V.) = Relative density + relative dominance + relative frequency

TABLE 16: DETERMINING DENSITY, DOMINANCE AND FREQUENCY OF SPECIES.

	Relative Density	Relative Dominance	Relative Frequency	I.V.	I.V. Rank
Un identified sp	40	2.025	27.27	69.295	3
Blue gum	10	67.38	18.18	95.56	2
Sesbania punicea	10	24.54	18.18	52.72	4
Acacia dealbata	5	0.129	9.09	14.219	6
Melia azedarach	5	1.69	9.09	15.78	5
Combretum e.	5	153.38	9.09	167.89	1

(Source: Author's own)

Explanation: Results showing the relative densities, dominance, frequencies and importance values of each invasive alien specie. Their ranks are based on their importance values.

The PCQ method has become well accepted as shown by many vegetation studies (Caplenor (1968); Habek (1968); Risser and Zedler (1968), among others as cited by Dombois & Ellenberg (1974). Overall, even though it is less complicated in field applications it yields greater information value per sampling point and more reliable than others, but has its own weaknesses that need to be overcome. Literature suggests several modifications to overcome the pattern problems in the PCQ methods (distance method) when extending their use to single species population studies. These modifications are numerous, one of which is to employ combinations of point-to-point and plant-to-plant distant measures. The author did much in this regard to overcome the problems and complications that arose in this specific study.

TABLE 17: SURVEY RESULTS OF SITE 7

Code:	EL 7
Sampling date:	June 2001
River	Elands (Mid - Elands)

Quaternary catchment: Locality: * Latitude (°S): * Longitude (°E): * Altitude (m.a.m.s.l): * Bearing:	Start: 25.3249 / End: 35.3252 Start:28.3434 / End: 28.3434 >1000 m 208°
Vegetation: * Width of riparian zone: * Dominant vegetation: * Substrate:	Riparian 50 – 100m Grasses Sand / soil / cobbles

(Source: Author's own)

Explanation: Table indicates that site 7 had a predominantly grass dominated vegetation. It also gives the altitude and bearing of site 7.

The stream at this site classified as foothill gravel bed was relatively easy to access and so four (4) visits could be made by the author. Astonishingly the main land use activity in the vicinity of the site was grazing. The site still falls within the bushveld basin (ecoregion), has a single channel type but holds a high degree of importance ecology wise. Here the dominant tree specie is Acacia karoo.

TABLE 18: SURVEY RESULTS OF SITE 8

Code:	EL 8
Sampling date:	June 2001
River	Elands (Mid - Elands)
Quaternary catchment:	
Locality: * Latitude (°S): * Longitude (°E): * Altitude (m.a.m.s.l): * Bearing:	25.3341 28.34.12 >1000 m 150°
Vegetation: * Width of riparian zone: * Dominant vegetation: * Substrate:	Riparian 50 m Trees & Grasses Sand / cobbles / bedrock

(Source: Author's own)

Explanation: Table indicates that site 8 had a mixed dominant vegetation consisting of grass and trees. It also gives the altitude and bearing of the site. The substrate is made of sand, cobbles and bedrock.

At this site, the only visible ongoing activity was livestock farming. With a medium level of importance ecologically the following species could be identified as dominant; Acacia dealbata, Acacia species, Combretum erythrophyllum, and Blue gum (Sesbania Punicea).

This site (in the bushveld basin) was assessible. Based on observation, the stream running at this site could be classified as foothill cobble bed.

TABLE 19: SURVEY RESULTS OF SITE 9

Code:	EL 9
Sampling date:	June 2001
River	Elands (Mid - Elands)
Quaternary catchment:	
Locality:	
* Latitude (°S):	25.3341
* Longitude (°E):	28.34.11
* Altitude (m.a.m.s.l):	>1000 m
* Bearing:	330°
Vegetation:	Riparian
* Width of riparian zone:	40 m
* Dominant vegetation:	Grass / Trees
* Substrate:	Sand / cobbles / soil / bedrock

(Source: Author's own)

Explanation: Table indicates that site 9 had a mixed dominant vegetation consisting of grass and trees. It also gives the altitude and bearing of the site. The substrate is made of sand, cobbles, soil and bedrock.

Access, number of visits, channel type and aspects of the ecoregion are the same as those in Site number 8. However the surrounding land use in contrast to site number 8 involves not only livestock farming but game farming as well. The visible mountainous stream and high ecological importance attributed to this site may account for the presence or absence of some species. The dominant species here are; *Acacia dealbata*, *Burkea a.*, *Combretum m.*, *Acacia c.*, and *Combretum z.*

KWAZULU NATAL PROVINCE

Number of Sites surveyed:

4

TABLE 20: SURVEY RESULTS OF SITE 1

Code:	KZN – CG 1
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Sampling date:	October 2001
Nearby River:	Mtwalume
Locality:	
* Latitude (°S):	30° - 32°
* Longitude (°E):	30° - 32°
* Altitude:	35 m
Vegetation:	Grassland
* Dominant vegetation:	Grasses
* Substrate:	Regic sands, clay, and sandy loam

(Source: Author's own)

Explanation: River Mtwalume is the main river in this table. The vegetation on the site 1 along this river is mainly grassland, substrate regic sands, clays, and sandy loam.

Grazing is common here and the ecological importance of the site is medium. Most commonly seen species are; *Bracharia serrata*, *Digitaria eriantha*, *Ditheropogon amplexans*, and *Themeda triandra*. The site is embedded in a lowland hillock (ecoregion) and this may as well partly explain the degree of relative easy access this author made into it. Nonetheless the number of visits was tied at 2 only.

Other characteristics of the site are that: Indigenous woody species have been found burnt by fire due to high fuel load and wildfires in the area. About some 500 m from the West Sand dunes are located in this site, and of size greater than 2 hectares.

TABLE 21: SURVEY RESULTS OF SITE 2

Code:	KZN – CG 2
Sampling date:	October 2001
Nearby River:	None
Locality:	
* Latitude (°S):	30°14'27"
* Longitude (°E):	30°47'26"
* Altitude:	50 m
Vegetation:	Grassland
* Dominant vegetation:	Grasses / Trees
* Substrate:	Regic sands, clay, and sandy loam soils
* Surrounding land use:	Agriculture (Mainly farming)
* Ecological importance:	High

(Source: Author's own)

Explanation: Site 2 is located at an altitude of 50 m. Table 26 indicates that it is an agricultural site as observed in the field. The ecological importance of this site is high, and vegetation grassland.

Chromolaena odorata is the most dominant woody species in this coastal forest region and site 2 specifically. For this reason and more access was not easily gained at this site. Despite that, this author could still make 2 visits.

It is worth mentioning that Site 2 is partly undulating grassland, closed to 2 hectares in size. Its position lies 1000 m from the littoral dunes. Much of the area has been chopped down by the expansion of the sugar cane plantations over six decades ago. Farming activity was predominant between the years 1960 to 1990. *Chromolaena odorata* species grow to heights above 1.5 m. Occasionally *Albiza adianthifolia*, and *Brahylaena discolor* occur within this site as dwarf shrubs.

TABLE 22: SURVEY RESULTS OF SITE 3

Code:	KZN – CG 3
Sampling date:	October 2001
Nearby River:	Mahlongwana
Locality:	
* Latitude (°S):	30°15'45"
* Longitude (°E):	30°46'05"
* Altitude:	90 m
Vegetation:	Grassland
* Dominant vegetation:	Trees
* Substrate / Soil form and texture:	Glenrosa (Mac et al., 1991), sandy clay loam soil.

(Source: Author's own)

Explanation: Site 3 is nearby the Mahlongwana river. The soil form and texture as recorded at the time of observation was sandy, clay, loam soil.

Farming activities (land cultivation) accounts for most of the activities here. Ecologically the level of importance for this site attains the medium range only. *Chromolaena odorata*, *Combretum molle*, *Dichrostachys cinerea*, and *Heteropyxis natalensis* are the dominant woody species within and around the vicinity of the site. Being a coastal forest, access to the site was not easy at all. For this reason the number of visits was kept at two only.

This site is found near Clansthal, located North of the slope dropping down the Mahlongwana River – about 3 km inland from the sea. Historians of the area have revealed to this writer that as far back as 1939 the grasslands in this locality were very extensive. Today trees of heights ranging from 2 – 5 m dominate the area thus reducing the grass cover.

TABLE 23: SURVEY RESULTS OF SITE 4

Code:	KZN – CG 4
Sampling date:	October 2001
Nearby River:	None
Locality:	
* Latitude (°S):	30°15'46"

* Longitude (°E):	30°44'07"
* Altitude:	100 m
Vegetation:	Grassland
* Dominant vegetation:	Trees
* Substrate / Soil form and texture:	Glenrosa (Mac et al., 1991), sandy clay loam soil.

(Source: Author's own)

Explanation: The dominant vegetation in site 4 are trees. The soil form and texture are typical of KZN and very similar to those at site 3

In this site, farming activities (land cultivation) is dominant. The degree of ecological importance is medium. The most dominant woody specie(s) are; *Chromolaena odorata*, *Combretum molle*, *Dichrostachys cinerea*, and *Protorhus longifolia*.

The ecoregion being a scrub forest clearly explains the problematic nature of access to this site and nearby ones. Here, the number of visits was kept at 2 only. Trees dominate site 4, *Chromolaena odorata* of heights 2 – 5 m is an ideal example. *Protorhus longifolia* of height close to 8 metres interspersed among the *Chromolaena*.

MANAGEMENT OF ALIEN INVASIVE PLANTS

So far this author could ideally ascertain the fact that management of alien invasive plants – specifically *Acacia* species and *Chromolaena odorata* definitely involves prioritizing areas marked for control.

3.3.1 APPROACH TOWARD INTERPRETATION AND ANALYSIS OF FIELD FINDINGS

It is worth to note that the interpretation of the findings followed the proper analytical patterns. That of field surveys along the Mid Elands River, for example, followed a replicative procedure in certain areas (near and at established but permanent transects with continuous quadrats) of the riparian zones. Slight shifts, but the results remained significant and instrumental. Along other riversides, such as the Mtwalume and Mahlongwana rivers of the grassland regions in the KZN this was not the case as such. Overall, analysis of variance with post comparison means – ANOVA based was used to detect significant differences in species richness between surveys in relation to *Chromolaena odorata*, selected *Acacia* specie densities and propagative tendencies. Fire was also considered as well. The significance of all differences in richness between sites was ascertained and this guided the conclusions of the research study to a greater extent. Species composition of the sites and succession were

examined using several multi – variable approaches. This was helpful in interpreting much of the findings.

Based upon a congruent analysis of the climatic data, this writer came to realise that the trend in climatic change slightly varies in Southern Africa and across West Africa, for countries like South Africa, Cameroon and Ghana. In short, they seem to be converging to almost near similar figures on average. Pollution, and global warming is to be blamed for this changes in climate across the African continent, thereby influencing the spread of invasive alien species.

3.4 COMPARISON OF RESULTS

The results obtained from interviews, questionnaires and documentary analysis served as a springboard for this writer to carefully tackle the core of the problems from the perspective of other experts. In the field, across the nine sites in the Riparian vegetation, and four sites mostly in the coastal areas of the KZN, evidence was carefully assembled. The impact of *Chromolaena odorata* and *Acacia* species on biodiversity became stronger than what this writer simply read from publications, filled questionnaires and government documents, or what he simply recorded during the interview sessions. The evidence of the impact of alien infestations on biodiversity and hydrology of the country picked up from the field was strongest and conformed with what was being gathered from the participants. However each method of arriving at the results now being released in this report was a complement of the other. This approach served as a means to achieve proper but higher validation and hence reliability rate.

CHAPTER FOUR

DISCUSSION

4.1 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Biodiversity here will imply a contraction of biological diversity. One may infer from literature written by Heywood & Baste (1995) that biodiversity implies being equal to biological evolution, cultural diversity, plus cultural and historical development of mankind (cultural evolution). This term ‘biodiversity’ is indeed best suited in describing the number, variety and variability of living organisms. This very broad usage, embracing many different parameters, is essentially a synonym of ‘Life on Earth’. In the context of this work biodiversity entails aspects of *genetic diversity, species diversity, ecosystem diversity and its measurement*. For this study the author has based the focus on species diversity. But then it will be wise to take a look at a few other definitions of what biodiversity is all about. The following is a run down of two definitions that stroke the mind of this author while reviewing literature for this study:

- Kato (2000) is of the opinion that biodiversity refers to the universal attribute of all living organisms that each individual being is unique – that is, no two organisms are identical.
- The notion of biodiversity became popular only recently. The CBD defines it as follows:
“Biological diversity means the variability among living organisms from all sources, including, inter alia, terrestrial marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity between species and of ecosystems”.

Although the word biodiversity has already gained wide currency in the absence of a clear and unique meaning, greater precision will be required of its users in order that policy and programmes (particularly research programmes) can be more efficiently defined in the future.

Courtesy of the following website; <http://www.wcmc.org.uk/infoserv/biogen/biogen.html>

It is widely believed in the scientific community that the cost of biodiversity conservation are often borne locally whereas its benefits may accrue to regional, national, and global levels of society. Decentralisation is by no means simple in dealing with issues raised in this study. It

may make conservation more difficult in cases where local people bear the cost of conservation but experience few benefits. The main challenge for each region, country, and province is to find the appropriate degree of decentralisation of various government functions that will best promote rural development and alleviate poverty while enhancing the creativity and enterprise of its citizens and the protection and wise use of its living resources. The World Bank today, more than ever is committed to helping countries, especially developing countries (mega diversity nations) meet this challenge and to assist them to reconcile the divergent interests of local communities, national governments and global society so that more sustainable development may be attained. This takes us to problems such as the impact of human activities on ecosystem function.

On this issue, Kato (2000, 111) argues that not everyone agrees that transformations are serious or that they can have dire consequences for the survival of the human species. Global warming is denied by some, Kato (2000) persists, and further claims that its consequences are represented as benign, loss of biodiversity is considered inconsequential to human welfare and that those of us who worry about it are called alarmists; and chemical contamination is not taken seriously. As long as there is doubt regarding the impact of human activities there will be differences of opinion, and people who, always are reluctant to change their behaviour will use these varying opinions to rationalise their actions; reiterates Kato (2000). A rigorous, unbiased, and mechanistic science of biodiversity can help resolve their differences.

The report of a panel on the board on science and technology for international development, cited by Nelissen et al (1998, 16 – 17) clearly points to the fact that the proximate causes of biodiversity loss are biological, but the root causes of the problem include sociological and economic processes that operate on a global scale. A thorough understanding of the phenomenon will require the investigation and elucidation of both biological and social components, will be necessary to develop both this scientific knowledge and successful mitigation and management strategies. Unless the international community can, indeed, reverse the trend over the next few decades, the erosion of the earth's biological legacy will continue to accelerate.

Gaston (1996, 5) on the other hand stresses one point which this writer equally agrees with, and that is: “There is a general acceptance in many communities that biodiversity is per se a good thing, that its loss is bad, and hence, that something should be done to maintain it”.

South Africa along side other countries of the world are signatories of the CBD (Convention on Biological Diversity).

TABLE 24: SIGNATORIES TO THE CBD

Parties Information	
Convention on Biological Diversity:	182 Parties (168 Signatures)
Cartagena Protocol on Biosafety:	9 Parties (103 Signatures)
Cameroon	
CBD Party:	Yes
Signature Date:	14/06/1992
Ratification Date:	19/10/1994
Ghana	
CBD Party:	Yes
Signature Date:	12/06/1992
Ratification Date:	29/08/1994
South Africa	
CBD Party:	Yes
Signature Date:	04/06/1993
Ratification Date:	02/11/1995

(Source: Undetermined - (Modified by Author)

Explanation: The table shows the dates South Africa, Cameroon and Ghana signed the CBD.

The Contracting Parties (South Africa included), amongst other agreements are determined to conserve and sustainably use biological diversity for the benefit of present and future generations, agreed on all the 42 articles. The alien vegetation has adapted so well to the South African environment that it threatens to disrupt the country's delicate ecosystem. Invader species are crowding out native varieties, contributing to floods, fires and soil erosion, and steadily slurping up the country's precious water supply.

Environmentalists have been concerned about South Africa's aggressive alien plants for some time, especially with the awareness that invader plants and trees have an insatiable appetite for water. Those thirsty botanical squatters steal nearly 7% of South Africa's total run off. In response, the South African government has declared these botanical invaders public enemy

number one. Species falling into *Category One* are so dangerous to the South African ecosystem that they may not be planted, maintained, multiplied, imported or sold within the country without expressing permission from the Department of Water Affairs and Forestry, (see list at appendix). *Category Two* species are threatening but also quite useful. The South African countryside is quite expansive and the government has recognized that returning to a pure South African ecosystem is not only impossible, but also potentially harmful. The *Category Three* classification allows South Africa to focus on her true biological hot spots. To win this botanical war, the South African government has created the Working for Water Programme (WfW). So far, it appears that South Africa's WfW Programme might finally be gaining an upper hand on the country's botanical invaders. The real victors, though, may be the local South African people themselves.

4.1.1 THE SITUATION OF INVASIVE SPECIES IN SOUTH AFRICA'S BIOMES

Invasive species can have adverse ecological and economic impacts by causing declines in native species and permanently reducing biological diversity all together. The easiest way to describe the country's natural heritage is on the basis of a systematic classification of regions, or biomes. South Africa has six biomes, namely the Savannah, Nama-Karoo, Grassland, Succulent Karoo, Fynbos and Forest biomes.

Some of the **acacia species** reported to be invasive in South Africa include: *Acacia baileyana* F. Muell (Bailey's wattle), *A. cyclops* A. Cunn. ex G. Don (red eye); *A. dealbata* Link (silver wattle), *A. decurrens* (J.C. Wendl.) Willd. (green wattle), All are of Australian origin (Henderson, 1995). Acacias are abundant in the Gauteng Province (Savannah biomes) whilst the *Chromolaena odorata* has invaded the entire coastal grassland areas of the KwaZulu Natal Province.

4.1.2 USES AND IMPORTANCE OF BIODIVERSITY

Biodiversity is important and has several uses. The thrust of the argument on the vital uses of biodiversity centres on:

- The distribution between morality and prudence, and
- The intrinsic values of nature.

The basic concept surrounding the intrinsic values of nature includes: Diversity, rarity, complementarity, endangerment, representativeness, area, naturalness, replaceability and health, (Wiegand, 2000).

In Sagoff's explanations, prudential reasons for preserving biodiversity are illuminated. On the importance of biodiversity, Becher (1998, 15) states that; valuing biodiversity for its own sake is a natural approach for biologists and conservationists. Most other people, however, still consider biodiversity in terms of what it offers humanity, Becher (1998) adds.

Becher (1998, 18) stresses that biodiversity is important because there are many different ethical and philosophical positions on nature and our relationship with it. Some positions, for example, would argue that nature has value beyond any that humans hold for it. Others would argue that nature is only important for human activity. Categorisation of biodiversity values to humans simply implies a break down of biodiversity into ecosystem services, biological resources, and social benefits.

Kratochwil (1999, 7) is of the view that, 'when investigating biodiversity man has to be considered as biological and an ecological factor, too. A study of biodiversity thus allows not only a more detailed understanding of life processes in general, but also of human life; moreover it is, a component of the survival programme "sustainable development", important for the future of man. Possible benefits of outcomes for policy and for practice are obvious. It is a glorious moment when a researcher contributes to resolving of a problem in the scientific community.

South Africa alone is known to have 12 climatic regions due to the varying topography and rainfall, Wodrich (1997, p1). This country is the only one to completely contain one of the world's six floral kingdoms, Rebello and Barie (1996).

Centuries ago, colonisers, and later settlers brought with them a vast array of agricultural and horticultural plants from areas such as Europe, Indian continent and Indonesia to South African biomes. About 65% of the approximately 150 invasive alien species of South African savannas arrived between 1800 and 1900 (Henderson and Wells, 1986) quoted by Mistry (2000, 181 – 182). These plant invasions posed several threats to savannas, including native plant extinction and fire regimes (Cronk and Fuller, 1995).

Savannas are the most common vegetation type in the tropics and subtropics, (Solbrig 1991) quoted by Mistry (2000, 1). They can be loosely defined as ecosystems with a continuous and important grass / herbaceous stratum, a discontinuous layer of trees and shrubs of variable height and density, and where growth patterns are closely associated with alternating wet and dry seasons (Bourliere and Hadley, 1993) cited by Mistry (2000). Rainfall in savannas is highly seasonal, and the dry season can last from 2 to 9 months.

In the savanna zone of Gauteng; the availability of moisture and nutrients for plants make it resemble a typical dynamic ecosystem and peculiar in these and other characteristics to other savannas around the world. Overall, the savanna in South Africa hold a distinct topography: Landscape – characterised by gently sloping hills – which play an important role in the spread of fire spread common in the region.

The **grassland** and **savanna** interject in the Gauteng province. More than 500 different alien species are numbered in this province. How these plants invade is not more a mystery, but a sound knowledge of this paves the way for us all to ascertain and why not postulate findings to their precise impact on biodiversity. Also to top - up with that, one will be able to *analyse the rate of recovery of biodiversity in some areas of the provinces where successful biological control projects have been effected, and above all predict with certainty the future spread of Chromolaena Odorata to other areas of Africa.*

Biodiversity needs to be upheld and protected and constantly surveyed and scrutinized to get rid of all hazardous plants (alien plants which are invasive and destructive to the ecosystem to which they belong). Rosenzweig (1995) and Higgins (1995) have sparingly addressed these concerns as well. Higgin (1995) has pointed out the need for control of alien plant infestations and their consequent negative impacts on biodiversity and the environment as a whole. In the Gauteng province where the abundance of alien plants is clearly visible, one may question the role played by the drainage pattern of the area. This also accounts for the prevailing climatic conditions a view shared by several schools of thoughts within the Great Lakes Basin / South African development community – SADC. Located on the high veld (most elevated range) this province of South Africa (known for its clay and sandy soil) holds a geologic status which has a bearing on the patterns of drainage and climatic factors on the ground. Plenty of

this province's water supply is brought about by the Vaal (Grey) River. The geology and geographic balances of the area partly accounts for the spread of the exotics that invaded it.

Furthermore, one will not have to lament on the fact that management regimes, climate and other factors contribute to the alien plants outcompeting the indigenous once and thus negatively affecting the biodiversity of the said zone. This writer presumes this reader knows this and subsequent issues as to why the alien plants can grow faster and produce seeds at a younger age than indigenous plants – A hint: Lack of its natural enemies is just one of those factors. In other related studies predicting invasions has been inherent. Nevertheless this forms a basis – a fundamental one for that matter for any research of its kind.

An internationally satisfactory and accepted explanation of biodiversity must be rooted in:

- the rates both at which alien invasive plants operate now and in the past,
- their extent of impact on the biodiversity, and
- the rate of recovery of biodiversity after successful biocontrol projects help to determine lots of unknown phenomena such as the diversity of species and their corresponding impact on biodiversity.

Human actions have been identified to queue amongst the many reasons for most alien plant invasions. These could be deliberate or accidental. However, one must note that there are invasions into natural habitats having an upper hand in terms of their impacts on biodiversity, Williamson (1996). The fun about alien plants is that they come from elsewhere. They have become numerous in the Gauteng Province. They include approximately 40 floral species. A few include the *Opuntia*, *Acacia dealbata*, *Acacia mearnsii* (silver and black wattle respectively), and firethorns just to name a few, Musil and Henderson (1987, 3).

This writer notes that the term invader is used to supplement the second part of the research topic and lies strictly more in terms of utility to the geographical sense. Climatic matching is a point not neglected in this research work. It is now clear to the reader that this writer in his preliminary readings has noticed that alien plants have both economic and ecological effects. The ramifications bore damages indirectly and directly by way of interfering within the context of the province's biodiversity. The genetic nature and extent of the impact of alien

plants on biodiversity needs to be unraveled. For this, the writer has endeavoured taking a bold step forward. Mayda et al (1987) states that, integrated control may involve the use of a combination of several types of methods and approaches to the problem.

In a nutshell, Wiegleb (2000) states that no general rule can be established to assess invasion and introduction categorically as good or bad. It depends on the respective vision of nature. From this we could decipher a great deal of philosophical touch to this problem of alien plants and their influence on biodiversity. The single approach of using mainly the biological means and methodology, does not necessarily imply that it yields the much needed changes and results.

Another question will be if these can be unique amongst the others. However there are often drawbacks, which need to be taken care of. This writer will seek to unravel the research questions. In this light, assessing the impact of acacia species and chromolaena odorata on biodiversity and the water systems of South Africa is essential. The the following table gives an overview of the situation.

TABLE 25: THE SPECIES RICHNESS OF SOUTH AFRICA'S TERRESTRIAL AREAS

Province	Biomes	Number of species				
		Plant	Mammal	Bird	Amphibian	Reptile
Eastern Cape	7	6,164	156	384	51	57
Free State	3	2,984	93	334	29	47
Gauteng	2	3,303	125	326	25	53
KwaZulu-Natal	4	6,141	177	462	68	86
Mpumalanga	3	4,782	160	464	48	82
North-West	2	3,025	138	384	27	59
Northern Cape	6	5,067	139	302	29	53
Northern Province	3	4,236	239	479	44	89
Western Cape	6	8,925	153	305	39	52

(Source: Data from DEAT, Pretoria, as illustrated in Vegetation of South Africa, Lesotho and Swaziland, edited by A.B. Low and A.G. Rebelo. Published by the Department of Environmental Affairs and Tourism, January 1996)

Explanation: The above table shows the species richness of South Africa's in numbers. it gives a broad view of the whole country.

TABLE 26: THE IMPACTS OF INVADING ALIEN PLANTS ON THE AMOUNT OF WATER IN RIVER SYSTEMS (SURFACE RUNOFF) IN EACH PROVINCE OF SOUTH AFRICA, AND LESOTHO.

Province	Mean annual runoff (millions of m ³)	Reduction in mean annual runoff (millions of m ³)	Percentage reduction	Condensed invaded area (ha)	Reduction rainfall equivalents (mm)
Eastern Cape	10 428.26	599.73	5.75	151 258	396.49
Free State	3 546.08	93.42	2.63	24 346	383.72
Gauteng	551.97	53.34	9.66	12 875	414.29
KwaZulu-Natal	12 087.65	676.93	5.60	250 920	269.78
Lesotho	4 646.82	2.01	0.04	502	400.40
Mpumalanga	6 303.01	487.17	7.73	185 066	263.24
Northern Cape	910.94	468.37	51.42	166 097	281.99
Northern Province	3383.61	729.52	21.56	263 017	277.37
North West	1 081.64	166.63	15.41	56 232	296.33
Western Cape	6 555.18	1 168.11	17.82	626 100	186.57
South Africa	49 495.16	4 445.23	8.98	1 736 413	256.00

(Source: Modified from <http://aliens.csir.co.za/plants/global/continen/africa/safrica/bigpic/howmuchw/>)

Explanation: The table above gives a picture of how invading alien plants greatly affect the amount of water in river systems across South Africa and neighboring Lesotho. A comparison of these results over the years gives a unique insight on the detriment alien invasive species have on both biodiversity and water systems.

TABLE 27: ESTIMATED MEAN ANNUAL VOLUMES OF WATER USED BY THE TOP 25 INVADER SPECIES FOR THE WHOLE OF SOUTH AFRICA, RANKED ACCORDING TO THE VOLUME OF WATER USED

Species	Water-use (millions of m ³)	Cumulative percentage of the total reduction
Acacia cyclops	635.440	19.01
Prosopis spp	480.719	33.40
Acacia mearnsii	299.911	42.37
Eucalyptus spp	214.674	48.79
Melia azedarach	204.173	54.90
Pinus spp	195.969	60.76
Acacia saligna	175.213	66.01
Acacia dealbata	163.142	70.89
Acacia spp	153.716	75.49
Solanum mauritianum	134.601	79.51
Lantana camara	107.564	82.73
Chromolaena odorata	68.268	84.78
Jacaranda mimosifolia	66.942	86.78
Hakea spp	64.029	88.69
Sesbania punicea	63.628	90.60
Populus spp	56.667	92.29
Opuntia spp	43.528	93.60
Rubus spp	41.698	94.84
Caesalpinia decapetala	37.796	95.97
Psidium guajava	37.084	97.08

Salix spp	33.637	98.09
Acacia longifolia	25.298	98.85
Acacia melanoxylon	21.770	99.50
Acacia decurrens	8.482	99.75
Nerium oleander	8.281	100.00

(Source: Department of Environmental Affairs and Tourism, January 1996)

Explanation: Table 32 shows the amounts of water used in millions of m³ by invasive species and their Cumulative percentage of the total reduction for the whole of South Africa. The data generated is based on estimates only.

A review on the most recent study carried out by Calder and Dye (ND) on the *”hydrological impacts of invasive alien plants”* throws more light on the harm invasive species cause on hydrological cycles. From the study it is now well recognized that invasive alien species, particularly tree species, often have much increased water usage compared with native vegetation. If well understood, are the reasons for this increased water use and whether such increases should be expected from all species of invading alien trees under all environmental conditions. The paper written by Calder and Dye (ND) examines the reasons for increased water use from trees as compared with short crops. From a knowledge of these reasons and a knowledge of the limiting processes (the Limits Concept) governing alien tree and native tree and short crop water use, (derived from case studies in India and South Africa), they suggested that, it is now possible to assess under what conditions high water use by aliens may occur. Inverse solutions based on knowledge of growth rates are also suggested as another approach for assessing alien and native tree water used under water limited conditions. They concluded that in dry climates the greatest increases in water use from aliens, in both absolute and percentage terms, may occur in water limited rather than riparian (water unlimited) conditions. Hydrological models, which can predict the spatiality, distributed increase in water use by aliens within catchments, coupled with ecological models which can predict controlled and uncontrolled invasion, can assist the evaluation and design of improved cost effective eradication programmes. Such coupled models, linked with an economic evaluation component, should indicate in what circumstances the value of the extra streamflow may alone be sufficient to cover costs of the eradication programme and under what circumstances the ecological (protection of indigenous communities) and other socio – economic benefits also need to be taken into account to justify costs of the programme.

The study on *“the impact of alien flora species on soil and water systems in the Gauteng Province, South Africa ...”*, carried out by (Florentin, 2000) constituted a basis for carrying out the present research study. The study was aimed at determining the different types of invasive alien species in the Gauteng province of South Africa. Furthermore, it stretched out in no small way the extent to which these plants influence and affect the soil and water systems in this province and its general situation in the country. The cardinal objectives set aside for the study was to analyze the role of government, industries and other stakeholders in their bid to search for solutions to the prevailing problems of the impact of these species. The study, also sought to succinctly uproot the ecological implications of these alien flora species in the concerned province. The dissertation deals with key environmental concepts and issues, so a comprehensive literature was included. In carrying out the research study, this author at the time relied on structured questionnaires and utilized these by way of interviews and also did effective fieldwork along the Mid Elands River. This was the sample site for vegetation analysis. The data generated there was useful for the scientific judgments made about the magnitude of the conservation status within the riparian vegetation of the province. Evident from the analysis of the data uplifted from the field and interviews, it was crystal clear that the vivid spread of invasive flora species has got an adverse effect both on the ecology of the country and the people’s life.

Finally, the most recent study carried out by Godall (2000) who looked at *the “monitoring of serial changes in coastal grasslands invaded by Chromolaena odorata (L.) R.M. King & Robinson”* was also closely reviewed. The objective of his study was to describe the impacts of the density of *Chromolaena odorata* (*chromolaena*) on species composition in coastal grasslands and to investigate serial changes in the vegetation following the implementation of a burning programme. The upcoming paragraphs will expantiate on the research findings of Godall’s study.

Chromolaena according to Godall (2000) invades coastal grasslands that are not burnt regularly (i.e. biennially). Grasslands that were not burnt for 30 years were seral to secondary forest. The successional pathway from open grassland to closed canopy forest varied according to soil type, as revealed by Godall’s study. Coastal grasslands on Glenrosa soils were characterised by savanna at an intermediate stage between the grassland and forest

states. Shading ended the persistence of savanna species (e.g. *Combretum molle*, *Dichrostachys cinerea* and *Heteropyxis natalensis*) in forest, whereas forest precursors (e.g. *Canthium inerme*, *Maytenus undata* and *Protorhus longifolia*) only established where fire was absent. *Chromolaena* infestations were characterised by multi – stemmed adult plants and variable height (i.e. 1 – 3 m), depending on soil types. Regic sands did not support stratified woody vegetation and *Chromolaena* infestations were self – supporting, reaching a maximum height of 1.5 m. Glenrosa soils supported tree communities and *chromolaena* reached more than 3m in places. The density of *chromolaena* affected species composition in grasslands with moderate to dense stands (>5 adult plants m^{-2} or 50 000 shrubs ha^{-1}). *Chromolaena* stands became monospecific when the number of adult plants exceeded $7m^{-2}$. Succession to forest also increased once *chromolaena* became thicket – forming.

Fire induced mortality of the *chromolaena* depended on grass fuel loads. Grass cover of 30% (c. 1 000kg ha^{-1}) was required to achieve 80 % mortality of the parent infestation after the initial burn. Dense infestations could only be killed by running head – fires from adjacent grasslands into thickets. Under conditions where head – fires could not be used, infestations were slashed and burnt at the height of the dry season (July to August) to achieve an 80% kill rate. Seedlings were killed (99%) by annual burning in sparse ($\leq 50\ 000$ shrubs ha^{-1}) infestations. The suppression of *chromolaena* and other alien species, establishing on bare ground after clearing dense infestations, required chemical control until grass cover was sufficient (i.e. 1 000 kg ha^{-1}) to effect uniform burning. Certain secondary alien invaders (e.g. *Lantana camara*, *Psidium guajava* and *Solanum mauritianum*) persisted by coppicing profusely after fire and herbicides need to be integrated into burning programme when these species occur. Grasslands on regic sands (e.g. *Ischaemum fasciculatum*, *Panicum dregeabum* and *Themeda triandra*) were more resilient to the modifying effects of woody vegetation, than grasslands on Glenrosa soils. Grasslands on Glenrosa soils did not revert to an open state but persisted as ruderal savanna grassland (e.g. *Eragrostis curvula*, *Hyparrhenia tamba* and *Cymbopogon validus*) once fire – resistant tree species (e.g. *Combretum molle* and *Heteropyxis natalensis*) had established.

Depending on the objectives of land management and the vegetation's condition, coastal grasslands can be rehabilitated and managed in multiple states, i.e. grassland, savanna or

forest communities. A state – and – transition model based on the empirical data recorded in Godall's study was presented and shows chromolaena altering vegetation states from open grassland to chromolaena dominated thicket. The model illustrates chromolaena thickets as the dominant phase of a moist coastal forest / savanna succession, irrespective of soil type, in absence of appropriate land management practices (e.g. control burning and integrated control of alien vegetation). Godall (2000) is of the opinion that this model should aid in planning strategies for the control of chromolaena in subtropical grasslands in South Africa.

Acacia species, Chromolaena odorata and other alien invasive species are a serious threat to biodiversity not only at a local scale, but at a regional, continental and global scale. As a matter of fact these invasive species do well in their host countries due to the lack of natural enemies, and the fact that they are pre-adapted to the conditions in the host country. Apart from that, there is also the problem of genetically manipulated species (hybridized seeds), which has now called the attention of environmentalists and nature conservationists worldwide. Some of these 'man made' – hybridized seeds or species render bio-control efforts virtually impossible, not only that but pose a threat to indigenous species. Biodiversity is now a tool useful in understanding ecosystem integrity over the mechanics determining diversity, (Walker, 1992). This enables the proper management of habitats in a functional manner. However, by all means ecosystem degradation must be averted by managers.

The biological weed control fraternity in South Africa reached a milestone in July 1999 when a volume of reviews of all current projects appeared in July 1999. It was published as *African Entomology* Memoir No. 1, with the subtitle *Biological control of weeds in South Africa (1990-1999)*. Terry Olckers and Martin Hill, both from ARC-PPRI, edited the papers. Despite such similar remarkable efforts across the region, much is still left undone. The aspect this thesis leans on is highly contributive since it inco-operates aspects not yet researched upon in the region.

Combating the invasion and degradation of grazing land by invasive alien plants, as well as livestock injury, in the case of acacia species (as an example) in South Africa, has resulted in great employment of time and resources, and has cost millions of Rands. This is essential a

measure, since it is aimed at eroding the impact of these species onto the biodiversity of the land. There are reasons for putting on such a fight, part of which constitutes the necessity for carrying out this piece of research.

It is worth mentioning that biodiversity in all its aspects represents the very foundation of human existence. Recognition and knowledge of the importance of biodiversity and the accompanying genetic wealth has become part of the public awareness of the dual role of biodiversity as an economic resource, but as well as an essential condition for the survival of individuals and biotic communities, (Barthloth & Winiger, 1998). The loss of biodiversity risks having serious ecological consequences and considerable economic costs. It is no joke, and for the mentioned reasons that biodiversity has fast become a critical component of global environmental change.

The most diverse ecosystems are not found in industrialised countries. The greatest variety of genetic diversity is located predominantly in tropical rainforests and in certain subtropical areas. This enormous contrast between megadeveloped countries and megadiversity countries reinforces the need for us to devote greater attention and priority to: biodiversity – a challenge for development research and policy. In this clash of contrasting views in environmental debates today, biodiversity has fast taken a moral stance. From the economic stand point the argument between the less developed nations (rich in biodiversity) and the industrialised nations (which rely on the biodiversity of poorer nations for chemical and pharmaceutical uses) has turned into a political instrument for protecting the earth's biodiversity, rainforests and thus the climate.

The release of the Brundtland report in the late 1980s and the preparations leading up to the earth's summit in Rio in 1992 gave prominence to the words "sustainable development". That phrase is now used to describe everything from corporate environmental performance, to the policies of the World Bank, to the priorities of South African government departments.

Most policies with the label "sustainable development" are in reality environmental – protection or environmental management policies. Although environmental protection is a necessary condition, it is not sufficient. The Brundtland report's definition of sustainable

development – “the ability to make development sustainable without compromising the ability of future generations to meet their own needs” (WCED 1988) – implies a strong social and ethical dimension. It implies the need to integrate environmental and social concerns into all major economic decisions, (Schnurr and Holtz, 1998).

One may ask, what is development? What is rural development? What is local development? And of course what is sustainable development? ...

The world commission on environment and development (1987) defined sustainable development as meeting the needs of the present generation without compromising the needs of future generations, (Furze, Lacy & Birckhead 1996, 13). Perhaps not precise a definition, but it goes in the lines of asking oneself – how do we grow and use acacia species and *chromolaena odorata* and other invasive alien species without negatively imparting the earth’s biodiversity, and its environment at large. In short how do we implement sustainable development in South Africa without destroying the biodiversity in the region? Pondering over these questions reminds us all of one thing – Biodiversity represents the very foundation of human existence.

Yet by our heedless actions we are eroding this biological capital at an alarming rate, (Heywood & Watson, ND).

Biodiversity is and will remain an issue of pressing global concern. The more we know about how changes in biodiversity might affect ecosystem processes, community structure, and population dynamics, the more clearly we understand why and what kind of biodiversity we should conserve. Reciprocally, the more we know about how ecological processes and mechanisms affect the creation and maintenance of biodiversity, the more clearly we understand how we can conserve and even recover biodiversity. Thus, basic understanding of the ecological causes and consequences of changes in biodiversity provides a critical perspective on applied challenges, (Abe et al., 1997).

Also the OECD ‘handbook of incentive measures of biodiversity’ - pages 25 - 26 asserts that, the causes affecting biodiversity and even more so their impacts, are more complex and are rarely known with any precision. The term “biodiversity” refers to the intrinsic indivisibility of ecological phenomena. This leads to difficulties in information and the measurement of

preferences in the formulation of economic incentive measures. The challenges of biodiversity policy: heterogeneity, irreversibility, accumulation of impacts, information gap, mixture of values and Trans - national aspects. The CBD is widely believed to be only the latest expression of the law's concern with the planet's biological capital.

This study goes a long way in coming up with succinct answers relating to the impact of the specified invasive species on the biodiversity of the Gauteng and KwaZulu Natal provinces of South Africa. It leads us into some major contributions of how fast these species could spread across the continent, what could be done in terms of policy, and practically in terms of the control approaches best suited in dealing with the invasive species in the region.

The collapse of ecosystems worldwide is being attributed to alien invasive plants. Most especially the woody species. They have major negative effects on their surrounding environments as studies have shown.

In South Africa alien plants have been growing so well over the years more or less due to the absence of their natural enemies. These enemies could be, insects; animals; and diseases that could have been useful to curb down their spread. Thus if alien plants are not controlled, they will impact non – selectively on the environment, as Cronk and Fuller (1995) put it, this will replace species (rich in plant communities) with monospecific vegetation.

Answers to the question why alien plants are dangerous do not only encompass factors such as their use of plenty of water; their contribution to devastating fires; soil erosion; and the fact that they take the place of local plants and trees.

The last point leads us to the context specifics of this study. And as Goodall (2000, 1) pointed out in his recent study; *“as weed density increases, internal resilience decreases, resulting in a breakdown in community structure, function and diversity. The breakdown of the vegetation component affects ecosystem dynamics and food webs. Resultant habitat loss is a direct threat to displaced fauna and rare plants”*.

Acacia species (in the Gauteng Province) left alone are eliminating on constant basis year in year out vast amounts of plant species, as well as the animals associated with them. This loss

in one way or the other assumes a loss of global significance. *Chromolaena odorata* (in KwaZulu Natal Province) is today a serious threat to other living species in these parts of South Africa. The chromolaena are found to pose problems to Rhino and Nile crocodile habitats in Zulu areas of South Africa.

This invasion and occupation of the thicket vegetation by chromolaena and other alien species constitute a reason for the eminent displacement of the endangered rhinos. The Nile crocodiles as they tend to depend on the river banks where light and other favorable conditions that facilitate multiplication of their numbers are left astray as most of such areas today have been invaded by alien species that shades out nesting sites. Chromolaena is no exception to this category of weed. With these conditions, the mortality of eggs rises tremendously, Godall (2000).

Derived statistics in South African records have prompted the government and other concerns to tackle the problems brought about by alien invasive species. No doubt, a National Water Act (Act 36 of 1988) was put in place to set out the framework for the management of water resources in South Africa. The main purpose of the Act is underpinned by the principles of equity, efficiency, sustainability and representativity, Department of Water Affairs and Forestry - South Africa, National Water Act News, (November 1999, 1).

Nutrient cycling in most alien plant species enrich soils, thus enabling other species of their kind get established. In the life cycles of these alien plants, some do accumulate salts in large amounts which are released into the system time in, time out. This tends to amplify saline conditions and hinders natural plant succession from taking place. On the other hand, fires in alien vegetation are much more intense, and they are found to damage the soil. When alien trees burn, flames can be up to 14 meters and above, often destroying houses and damage the soil. Because alien vegetation is much denser than natural shrubs, containing these fires can be so difficult and costly. These fires, owing to their intense nature have a tremendous impact on biodiversity as a whole. The first rains often wash all the top soil into the rivers and these cause the rivers and dams to be filled with sand. This leaves the dams with less space to store water.

What is being done about this problem is a tricky question, which though still deserves full attention to. All across South Africa, previously unemployed people are cutting down invading alien plants as though this was enough a thing to do in order to solve the huge problems being faced with alien species. Definitely by clearing invasive species we improve water supplies. Money is also saved in this way, because many dams will not have to be built. Also, this goes a long way to protect local plants (trees) and animals, which are also important for tourism.

4.2 CURRENT DISTRIBUTION OF ALIEN INVASIVE SPECIES IN SOUTH AFRICA

Alien invasive species are highly distributed in South Africa. In Table 33, this writer lays out the distribution of Acacia species and Chromolaena odorata provincially.

TABLE 28: DISTRIBUTION OF ACACIA SPECIES AND CHROMOLAENA ODORATA IN SOUTH AFRICA

Scientific name of species	GP	KZN	NP	MPUM	NW	FREE S	N CAPE	W CAPE	E CAPE
Acacia cyclops							III	V	V
Acacia dealbata	IV	V	III	V	I	IV		III	IV
Acacia decurrens	III	III	I	IV	I	I			IV
Acacia elata	I	I		I				III	I
Acacia longifolia	I	III	I	I			I	V	IV
Acacia mearnsii	IV	V	III	V	III	III		V	V
Acacia melanoxylon	I	III	III	III				V	III
Acacia podalyriifolia	II	III	I	I	I	I			I
Acacia pycnantha								III	II
Acacia saligna		I					I	V	IV
Chromolaena Odorata		V	IV		III				III

(Source: Author's own)

KEY

GP	=	Gauteng Province
KZN	=	KwaZulu Natal Province
NP	=	North Province
MPUM	=	Mpumaōanga Province
NW	=	North West Province
Free S	=	Free State Province

N Cape	= North Cape Province
W Cape	= West Cape Province
E Cape	= East Cape Province
Note: In terms of abundance of species provincial wise –	
	I. Means Occasional,
	II. Widely spread,
	III. Abundant,
	IV. Very Abundant,
	V. Extensively abundant

Explanation: Table 33 indicates the degree of spread of *Acacia* species and *Chromolaena odorata* across South Africa.

4.2.1 EXOTICS AND THEIR RATES OF SPREAD

Chromolaena Odorata like other alien invasive species came about in the grassland regions of South Africa both accidentally and as a result of man's desire, for vast reasons not clearly established in the minds of many. The case of Chromolaena odorata (a shrub of South American origin), King and Robinson (1970), found its way through the coastal areas of South Africa, especially Durban in the KwaZulu land sometimes close to a century ago. The weed till date holds several local names amongst the locals in conjunction with the cultural diversity of the region. The spread of Chromolaena odorata is fast becoming alarming and of course a

crisis. A major weed in most parts of Sub Saharan Africa, South Africa hard hit most by its spread.

In so short a time, this specie has extensively invaded parts of KwaZulu Natal where this study has as its point of focus, Eastern Cape, North and North West provinces. Typical a problem weed in the Northern Province due to the low altitude of the area. Such humid and desert like a condition all together is one of the many reasons for Chromolaena's most extensive spread in those areas.

The *Acacia* species are also markedly spread. Reasons for this are numerous. The seeds of wattle are long – lived, and may remain dormant in soil for perhaps a century. This dormancy may be broken when the veld is burned, a phenomenon held by many conservationists in

South Africa. The seed coat cracks, and the seed germinates during the following rains. Perhaps the seed numbers in the soil under different densities given below serves as a clue to the rates of spread of the acacias’:

TABLE 29: SEED NUMBERS OF ACACIA SPECIES IN THE SOIL UNDER DIFFERENT DENSITIES

Number of stems / ha	Mean stem diametre	Range seed numbers in 1m x 1m x 6cm	Maximum seed numbers (1ha x 6cm)
5 000	5cm	2 000 – 63 000	600 million
13 000	5cm	1 000 – 150 000	1 500 million
2 300	9cm	7 000 – 540 000	5 000 million

(Source: Author’s own)

Explanation: This table indicates the seed and stem numbers of Acacia species in soil. The maximum range of seeds is calculated per hectares.

Approximately 70 % of wattle seeds are found in the top 6 cm layer of the soil. This is the zone where fire is most effective either to kill the seeds or to stimulate germination, courtesy of the plant protection research institute handbook No. 3.

4.2.2 VEGETATIONS INVADED BY ACACIA SPECIES AND CHROMOLAENA IN SOUTH AFRICA

Drawing from Acocks (1953), Low and Rebelo (1996) veld types were classified according to structures and floristics and / or based on agricultural potentials – Acocks. In this study our focus sets unto the impacts the alien flora has on these vegetations owing to their severe distribution. Chromolaena is well known to have infested coastal forests, afro-montane forests, sour bushveld, coastal bushveld – grasslands, Natal lowveld bushveld, mixed lowveld bushveld, sweet lowveld bushveld, and sub humid lowveld areas. The severity of the spread varies from area to area. In some places even the water courses are affected. With this and more Chromolaena tends to be a threat in that; it increases the risk of fire damage, in some areas a problem to nature conservation, and setback to eco tourism.

This study will seek to further analyze the potentials chromolaena has for unlimited spread. This is important as many researchers are now coming to realize that even though the plant is sensitive to frost and aridity, it is now fast being established that its modifying adaptability

makes it possible for it to equally spread in savanna biomes of Southern Africa and rapidly with time. Thus, eventually *Chromolaena odorata* could in a short time span cover much of Africa if nothing serious is done to curb its expansion in the South.

Acacia species on the contrary do well in riparian zones where *Chromolaena* so far has not been a threat, neither has it been established that it holds any significant presence. This writer in his recent research worked in a riparian area. This study since will equally cause this writer to do a kind of follow up, re - survey of the riparian zone (a swath of land adjacent to a river or stream) in the Gauteng province where some measurements will be carried out once more, it is then important that this writer recaps issues (characteristics) that are pertaining to this vegetation. This zone provide critical habitat for lots of species, serves as a buffer, and encourages natural flows.

The condition of a riparian ecosystem reflects the cumulative effects of all the activities in its watershed. Despite other reasons for the problems faced by riparian zones such as the problems brought about by man (extractive industries and the span of urban development), non-native species (aliens) that have been introduced into the riparian zone, either accidentally or deliberately, pose a threat as they can wipe out native species. These alien invasive plants spread rapidly but do not provide food or useful shelter for native birds and wildlife in the areas where they occupy.

4.3 CONSERVATION AND MANAGEMENT OF ECOSYSTEMS AND BIODIVERSITY

The Gauteng, KZN provinces and South Africa as a whole no doubt has a unique natural environment and biological diversity, for which there is no blueprint for conservation and sustainable use. But there is need to protect this natural heritage. Similarly, good management of these renewable natural resources is essential, at local, provincial, national and regional levels – progress has to be achieved and in a co-ordinated manner. But all these do depend on research issues; within various natural systems (namely atmospheric, terrestrial, marine, estuarine and freshwater). In this regard, the following aspects are thought by most experts to form the focus of attention, as applicable:

- Management of species, populations and ecosystems and decision support
- Society, the natural environment and ecosystem services
- Long-term monitoring and research

The transformation of ecosystems is considered to be the most important human impact in the southern African subcontinent (Macdonald 1989). The conversion of natural ecosystems for intensive agricultural or forestry production, or for grazing purposes, has been identified as major pressures on plant diversity (Cowling & Hilton-Taylor 1994). Land pressures arise from forestry because of the large tracts of land required (about 7-10 000 hectares for a large modern sawmill, and 50-100 000 for a pulp mill of the necessary scale). On the other hand, pressures on water arise because plantation forests and many crops require large amounts of water as compared to natural vegetation, and are therefore located in the areas with higher rainfall in South Africa. Pressures on habitats and biological diversity arise because cultivation and afforestation often involve replacement of natural or near-natural habitats rather than of already transformed habitats. Populations of plants and animals need large areas of land in order to find sufficient food and mates, during changes in seasonal and annual climate.

Nonetheless, invasion of exotic trees and shrubs, especially in the wetter regions of South Africa such as the Fynbos Biome and in riparian habitats specifically, pose a severe threat to plant and animal diversity (Macdonald 1989). The invasion process has many ecological impacts which include alteration of soil nutrient cycling, reduction of runoff and subsequent stream flow, increased river bank erosion, altered fire intensity (Macdonald & Richardson 1986) and reduction of light to the forest floor or near to the ground (Midgley *et al.*, 1992). Invasive species pose a threat to ecosystem functioning, because they use greater amounts of water than the natural vegetation, and therefore reduce the amount of runoff that reaches the streams and rivers. These impacts reduce the diversity and cover of indigenous plant species, but may be reversible even after up to 20 years of dense infestation (Macdonald & Richardson 1986) cited in the DEAT (1999) report. On the contrary, invasions by alien birds and mammals seem to be of less importance (Macdonald *et al.*, 1986).

Naem et al (ND) indicate in their article that there is available evidence which identify the following certainties concerning biodiversity and ecosystem functioning:

- Human impacts on global biodiversity have been dramatic, resulting in unprecedented losses in global biodiversity at all levels, from genes and species to entire ecosystems;
- Local declines in biodiversity are even more dramatic than global declines, and the beneficial effects of many organisms on local processes are lost long before the species become globally extinct;
- Many ecosystem processes are sensitive to declines in biodiversity;
- Changes in the identity and abundance of species in an ecosystem can be as important as changes in biodiversity in influencing ecosystem processes.

From current research, Naem et al (ND) have identified the following impacts on ecosystem functioning that often result from loss of biodiversity:

- Plant production may decline as regional and local diversity declines;
- Ecosystem resistance to environmental perturbations, such as drought, may be lessened as biodiversity is reduced;
- Ecosystem processes such as soil nitrogen levels, water use, plant productivity, and pest and disease cycles may become more variable as diversity declines.

There is no doubt that research in biodiversity places much emphasis on the uniqueness of individual species and their singular contributions to ecosystem services. Yet most ecosystem processes are driven by the combined biological activities of many species, and it is often not possible to determine the relative contributions of individual species to ecosystem processes, (Naem et al, ND). Groups of species that perform similar roles in an ecosystem process are known as functional types or functional groups. Within trophic groups, species may be further divided according to life history, climatic or nutrient needs, physiology or other biological traits. Researchers may place a species into several different functional categories depending on the ecosystem process they are studying.

Also it is because species can vary dramatically in their contributions to ecosystem functioning, the specific composition or identity of species in a community is important. The

fact that some species matter more than others becomes especially clear in the case of “keystone species” or “ecosystem engineers” or organisms with high “community importance values.” The nitrogen-fixing lupine *Lupinus arboreus* also enriches soils and, as a consequence, encourages invasions of weedy grasses. Among animals, moose (*Alces alces*) through their dietary preferences greatly reduce soil nitrogen levels and also influence the succession of trees in the forest. Resource managers in South Africa are thought to be aware of this concerns without which complete control can be sometimes complicated in the naked eyes of most parties concerned.

No reader’s understanding of ecosystem responses would not be clearer without an insight of the principles of ecosystem functions, and sustainability. Much of this is available on the following website: <http://bioag.byu.edu/zoology/b150/Chapter11.htm>

4.3.1 THE IMPORTANCE OF BIODIVERSITY IN ECOSYSTEM FUNCTION

It is worth noting that there are two opposing points of view, viz, the rivet hypothesis (all species are important) and the redundant species hypothesis (species are not all equals). What exactly do these terms mean?

Rivet suggests that all species are interdependent “rivets” in ecosystem structures and each contributes to function (Ehlich and Ehlich, 1981). To add, greater diversity equates to increased linkage and stability.

The redundancy model suggests that biodiversity *per se* is unimportant: given sufficient biomass, ecosystem function requires just one representative species from each functional group (Lawton and Brown, 1994). Functional redundancy has been concluded from observation that functional diversity, is greatly exceeded by species diversity (di Castri and Younes, 1990). Thus, rate changes of biotic processes are inferred not to reflect biodiversity loss (Franklin, 1993).

There are some implications as well for conserving biodiversity with respect to ecosystem functioning. Interesting as it is, biodiversity is not just a property of assemblages, but as well a repository of genetic resources, (Ricklefs and Schutler 1993). By implication, conservation policy needs to be strongly considered and over wide areas. Locally, diverse sites need to be as well dealt with adequately in this regard. But then, why conserve biodiversity? This could

be posed from a good number of varying perspectives, all conditioned by a variety of factors, (cultural and economic). Response to this query, arguing for the maintenance of biological diversity has for over the years still been found confusing and lacking in scope. As goals vary, (some of which are; the present and potential use of elements of biodiversity as biological resources, the maintenance of the biosphere in a state supportive of human life and the maintenance of biological diversity per se, in particular of all presently living species) so to does their implications for the elements and extent of biological diversity that must be maintained.

It has been established by researchers that plant productivity and other environmental conditions that affect human well being (at the ecosystem level) is profoundly influenced by certain critical processes. These ecosystem processes are controlled by both the diversity and identity of the plant, animal, and microbial species living within a community. Human modifications to the living community in an ecosystem – as well as to the collective biodiversity of the earth – can therefore alter ecological functions and life support services that are so vital to the well-being of human societies. Substantial changes have already occurred, especially local and global losses of biodiversity. The primary cause has been widespread human transformation of once highly diverse natural ecosystems into relatively species-poor managed ecosystems. Recent studies suggest that such reductions in biodiversity can alter both the magnitude and the stability of ecosystem processes, especially when biodiversity is reduced to the low levels typical of many managed systems. Naeem et al (ND) cited in the website; <http://esa.sdsc.edu/issues4.htm>

4.3.2 THE CAUSES AND CONSEQUENCES OF THE DISAPPEARANCE OF SPECIES

According to Paul & Anne Ehrlich (1995) extinction seems to be one of the best answers to the causes and consequences of the disappearance of species. Man is also responsible for endangering species (directly: overexploitation, both now and in our prehistoric past, for food, the wildlife trade, fur, other products, and via predator control; indirectly: paving and urbanization, agriculture, habitat degradation and fragmentation, flooding, draining, spraying

pesticides, polluting, logging, mining, transplanting species, and recreation). Some other schools of thought hold that other reasons for decline in species and / or biodiversity are as follows; alteration and loss of habitat, pollution, introduction of exotic (alien invasive) species, over use, and human population growth. Quantifying rates of species extinction, both at present and historically is difficult and predicting future rates with precision is quite impossible.

Nonetheless, changes in the natural environment is predicted by experts to occur within the next century not only as a result of vegetation, ecosystem and meteorological changes in South Africa, but due to large-scale changes in the global climate and weather patterns. There is a high probability that these will cause greater elevated extinction rates, although their exact effects are at present unknown. The spread of *Chromolaena odorata*, *Acacia* spp and others across the African continent has had a terrible toll on biodiversity as a whole.

4.3.3 ECOLOGICAL EFFECTS OF INVASIVE SPECIES

Accacia species (mainly in Gauteng), *Chromolaena odorata* (mainly in the KwaZulu Natal) province and other alien invasive species in South Africa were imported into these regions far earlier before the expansion of sugarcane cultivation in KwaZulu Natal (coastal grassland) region. This was as far back as the 20th century. Apart from the industrial needs, uses and reasons for their growing of these species, they as well served other purposes – such as decoration and so on at the time, (Florentin 2001). But with the passing of time, things took a different toll. *Chromolaena* for example is now being seen as a weed from its devastation on indigenous forest, grassland and the savannas. It is a highly flammable plant as analysis of its leaves has come to prove. Biller et al (1994) states that, *chromolaena* is allelopathic. Definitely by implication, the leaves of these famous plant would contain some kinds of oils. It is known for reducing species richness, as they grow tall to about two metres and well spread even beneath other trees in the forest, savanna and grassland areas. Furthermore, *Chromolaena odorata* is widely believed to destroy resilience in grasslands much more faster

than in other vegetations. In the KwaZulu Natal province, this has become one of the major reasons accounting for the overgrazing of old pastures year in year out. The degree of invasion has had ramifying effects even on the landscape as it is inevitably unable to support life for other species, and populations. This means food webs being unscrupulously broken and this results in the run down of specie numbers in the region. Not only that but the natural renewable resources that the local people depend upon also become terribly treathened, with all these the ecosystem is left fragile and accessible to all sorts of troubles. The distribution of *Chromolaena* is directly related to the areas receiving rainfall of 150 cm and above in parts of the world where they occur, Muniappan et al. (1989) cited by (King and Robinson, 1970). This weed is known to occupy pastures, marginal lands and open areas. It has finally become a menace in recent times in plantation industries, orchards and forests, of the coastal grasslands of South Africa. In forest ecosystems, it is well known for decreasing the value of timber, forest seeds, orchards, hence increasing the cost of seedling production in nurseries. Not only that, it hampers the harvesting operations in the forest and affects the overall productivity of the forest ecosystem. During the dry periods of the year, it has been established that this specie can be a serious fire risk in the forests.

In the Gauteng, this writer having observed acacia species for almost over a year and noticing their behaviour in the field, could immediately agree with 'literature' that; acacia species kills the grass and indigenous vegetation, it also tends to increase erosion on slopes (especially in riparian areas), and the worst of this scenario is that it decreases water supply. Control is long-term because of the vigorous regrowth potential these plants have. The fact that their seeds are long-lived, and knowing that they have few natural enemies to curb their growth makes the situation more frightening in regards to the ecological effects born. The cost of clearing such dense, extensive land infestations has not been proven cost effective, especially when one is looking at thousands of hectares of land. In the latter part of this write up, this writer will dwell further on issues pertaining to control more succinctly, hence succinctly conforming to the aims of the research study.

Weeds do cause enormous direct and indirect losses to biodiversity and ecosystems at large. They interfere with cultivation of crops and cattle grazing. In South Africa these noxious

plant species are of alien origin. Literature and evidence on the terrain reveals to us these species were either introduced negligently or accidentally into our country, and in the absence of host-specific natural enemies they have become a serious threat in their new environment. Most of these weeds have occupied such niches where chemical or mechanical control measures are neither feasible nor economical. Such situations include forest areas, sugarcane farms, and other plantations.

4.3.4 IMPACTS OF ALIEN INVASIVE PLANT SPECIES ON BIODIVERSITY

Biodiversity loss due to the introduction of alien invasive species is one of the most detrimental results and could lead to marginalization or even elimination of native species. Invasive species grow fast as they do not have any natural predators and as such, draw more nutrients and moisture from the ground more than the native species. Due to the frequent presence of toxic metabolites they also keep away the native species through allelopathy. As a consequence, they occupy more space and form purer populations. Whenever alien plant species (like wise acacia species and chromoleana odorata) invade a habitat, they also eliminate the natural fauna, since fauna always depend upon natural flora. The invasives can pave the way for further invasions by other alien species of plants, animals or micro-organisms, which may include agricultural pests or human pathogens, courtesy of the website <http://www.edu.sdnpk.org/impacts1.htm>.

Invasive species change the soil composition by releasing allelopathic substances from their roots or leaf litter thus, changing the structure and function of an ecosystem completely. This results in large-scale changes in the environmental conditions of a given area. The chemical nature and decomposition rate of their leaf litter and other dead parts may also alter the nutrient cycle in the ecosystem, as evident in research literature. When fast growing species invade a certain catchment area, they may drastically reduce the flow of streams and rivers due to high rates of evapotranspiration. The invasive species in aquatic habitats accumulate greater amounts of sediment. This, coupled with high loss of water through increased transpiration ultimately converts the wetland into dry land, etc. Due to these features, Clout & Lowe (1996) in this website, <http://www.edu.sdnpk.org/impacts1.htm> is cited as having defined invasive species as “an invasive species is an alien species, which colonizes natural or

semi-natural ecosystems, is an agent of change, and threatens native biodiversity". Alien invasive plants (usually large in size), such as *Acacia* species in the Gauteng province, tend to cause the extinction of other indigenous plants, (Florentin 2001, 86). In the KwaZulu Natal province *Chromolaena odorata*, uncontrolled as it is, impacts non – selectively on the surrounding areas, replacing species – rich in plant communities with monospecific vegetation, (Cronk & Fuller, 1995). This has a tremendous bearing on the ecosystem dynamics and food webs especially when the density of such weeds is terribly increased over time. Furthermore it promotes the decrease in internal resilience leading to a fall apart of community structure, function and diversity of all kinds. Loss in biodiversity may lead to economic setbacks. Invasive species may cause major financial losses to every national economy, South Africa being no exception. Invasive plant species in South Africa (especially in the Gauteng and KwaZulu Natal Provinces) have had a tremendous impact on biodiversity, and worse of all on water and soil systems, not leaving out tourism as this writer found in his recent study. Such losses translated in monetary value looks horrendous and disturbing to all conservationists and environmentalists alike.

This losses could be the result of the direct problems caused by invasive species, loss of land's living resources, and losses due to any pest brought with the invasive species. Occasionally, invasive species also bring financial benefits. Generally, the damage caused to biodiversity through them is far more than any benefits that might be associated with them. Thus, when indigenous biodiversity is at stake, it should always be given preference over alien species (Clout & Lowe 1996) quoted in this website; <http://www.edu.sdnpk.org/impacts1.htm>

It is therefore necessary that ecologists, conservationists, resource managers, and economists work together to quantify the costs and benefits involved in dealing with invasive species. Economic analysis can no doubt provide a useful and rigorous structure to guide the policy makers (McNeely 1996) in the website: <http://www.edu.sdnpk.org/impacts1.htm>

4.4 CONTROL MEASURES FOR INVASIVE PLANT SPECIES

There are several ways of controlling different alien invasive species. This may involve a single approach, a combination of one or two, or even more others (integrated) depending on several factors.

4.4.1 THE CASE OF ACACIA SPECIES IN THE GAUTENG PROVINCE

Biological control

Not much has been done in this arena of invasive control. However, research within the ‘plant protection research institute (PPRI) of South Africa,’ (a major and leading research organization in weed control) of recent released some seed attacking weevils in the South of the country. The effect of this weevil (*Melanterius maculatus*) is still being monitored. Other variants of this weevil are planned to be released soon in other parts of the country, and it is anticipated that this will limit seed production of certain strains of Acacia species. The only set back is that, these insects will not affect plant growth nor reduce the soil seed bank which has at moment surpassed alarming proportions. This approach however confines infestations by reducing viable seed numbers on the plants. The overall effect is that it curbs further spread of these invasive species. In a nutshell, current research is still on the way to finding more aggressive strains of fungus, insects and other organisms that could be capable of destroying the stumps of targeted species that have become invasive in the region.

Chemical control

Presently in South Africa, the ‘PPRI’ and several other parties concerned with the control of Acacia species in conjunction with relevant Government departments have identified certain herbicides deemed useful in the fight against invasive species. These chemicals are persistent and are advised to be used in the correct way, so does the PPRI stress in their handbooks distributed to the communities. This strategy as the PPRI researchers have agreed requires intensive management and close supervision. The one thing with the chemical control method is that, some of the herbicides attack specific types (variants) of certain weeds.

Mechanical control

This is often the initial form of control especially among the rural communities. In most cases, it requires no skilled labour. Cutting down and burning of the alien trees or shrubs is common, and has been the main approach over the years. The working for water programme used this method immensely, though the aim above all was to create jobs for the people.

Integrated control

This method incorporates a combination of all the methods available for particular species at certain periods. The sequencing or timing of the application of these various methods lies solely on the hands of usually a well seasoned expert who monitors the process, decides for whatever has to be done and at what time and as such manages the control scheme accordingly. With this method, several options are prone to be picked depending on lots of factors. One with the combination of several others and so on. In the case of Acacia species, fire apart from chemicals used, biological agents, and mechanical methods usually have often been recommended with care. This is so because the burning must be done in a controlled safe manner, and according to local burning regulations. The fires kill top growth and the advantages of it as a control option within the integrated framework as the 'PPRI' reports are as follows;

- Using a combination of chemical control and fire for example reduces cost immensely, and
- Livestock have been used successfully to graze dense small seedlings, and in addition,
- Runaway fires will not cause dense regeneration in the future, as the soil seed bank gradually becomes depleted after a number of burns.

4.4.2 CHROMOLAENA ODORATA IN THE KWAZULU NATAL PROVINCE

Biological control

Chromolaena odorata, is actually a native of the West Indies and continental Americas. It is a serious weed of pastures, forests, orchards and commercial plantations. It is a notorious weed mainly in the KwaZulu Natal province of South Africa. It is worth to note that the number of Indians (3rd generation South Africans one may put it this way) in this province far exceeds that elsewhere in the country. This to an extent explains the 'raison d'etre' for the massive abundance of *Chromolaena odorata* in this area. In the past years numerous and extensive surveys conducted for indigenous natural enemies revealed that none has biocontrol potential. Three exotic weed insects which have been introduced in various parts of the world are; *Apion brunneonigrum* Beguin-Billecocq (Coleoptera: Curculionidae), *Mescinia parvula* (Zeller) (Lepidoptera: Noctuidae), and *Pareuchaetes pseudoinsulata* Rego Barros

(Lepidoptera: Arctiidae). *P. pseudoinsulata* was declared safe after extensive host-specificity tests, (King and Robinson 1970). The insect has several constraints in breeding and field effectiveness, which include infection by a nuclear polyhedrosis virus and predation by ants, (King and Robinson 1970).

Several control options are being tested in the field these days. The physical approach of removal of the weed (exotic or invasive species) in a vast area of its current distribution has been found to be difficult, if not impossible. Herbicides could be effective but their large-scale application has been deemed neither economical nor environmentally sound. By implication, the alternative strategy, i.e. the classical biological control method seems to be feasible. The work on survey and identification of indigenous biotic agents and biological suppression of the *Chromolaena odorata* by introducing host - specific insects from their native home have been carried out in some parts of South Africa. On the other hand, establishment has not been succinctly reported on the performance of introduced natural enemies but perhaps their re - evaluation is necessary to further substantiate current claims of progress. We all have to bear in mind that bio – control started in South Africa not long ago, about 1988. It is very clear that it takes quite a number of years for it to have any impact whatsoever on the ‘population’ of the weed.

It is widely speculated that suppression of *Chromolaena* has not been that successful to an extent. With such revelations, some school of thoughts have suggested that for future introductions of natural enemies, the primary emphasis should be on those insects that affect the stem and the roots, the flower and the fruits and the foliage in that order. A perfect excuse could be that we need more time, and that biological weed (invasive specie) control is a long-term research approach. It requires appreciation and support from funding agencies, which for now is not forth coming as expected in this part of the world. Thus, to give it a hand, comes the need to strengthen the international co-operative research initiatives in order to succinctly resolve the many questions that have not been answered yet.

Chemical control

Herbicides have been so far successful than the current use of bio- agents. This as well has been fully adopted and implemented as a way out in dealing with the infestations of *chromolaena* by forest companies and other industries, though not suitable for local

subsistence farmers who lack the know how in using this chemicals across the country. Though sensitization has been going on within this low level groups, the impending risks of poor applications and improper usage overall still hang in the air. From the late 80's to the mid 90's several herbicides were developed, screened, and now being produced and marketed as patented products accepted for the control of Chromolaena, Erasmus (1985); Erasmus (1988) cited by Godall (1997). These active ingredients include gycophosate 359 g/l, triclopyr 480 g/l, metsulfuron methyl 600 g/kg, imazapyr 100 g/l, and tebuthiuron 752 g/kg just to name a few.

Mechanical control

Mechanical approaches employed in ecosystems bring about an increase in magnitudes of disturbance. This promotes a proper state for weeds to oncemore spring up. What this writer has observed in some areas (rural) in KwaZulu Natal is that, much of the mechanical approaches used often come with the tilling of the soil. This goes on over and over during the farming seasons. The approach is not well coordinated and indicates a lack of resources that does not match the available manpower present. In some situations, as Godall (2000, 31) is found to have quoted (Erasmus 1988); “mechanical control is usually practiced with the

application of herbicides. Examples include slashing tall growth (a) to promote coppice that can be sprayed later, or (b) applying herbicide to the stumps.”

Integrated control

In this domain, within the South African context it is widely believed that much could still be done to clearly identify the best strategies that work in particular habitats and the capabilities of the approach in varying densities. Here lies the real problem with integrated control. However, achievement rates have been on the rise and getting nearer to 95% in cases where it was well co-ordinated. Combination of all methods including cultural, seems ideal and a way out of the problems brought about by alien infestations, but then this demands both skilled and unskilled labour, not forgetting capital. Without government support and international co-operation, this method could still become a remarkable failure.

4.4.3 QUANTIFICATION OF THE IMPACT OF CHROMOLAENA ODORATA (IN KWAZULU NATAL) AND ACACIA SPECIES (IN GAUTENG) ON PLANT DIVIERSITY IN THE RESPECTIVE PROVINCES

This is not that easy a thing to do. There could be quantification of impact before control measures are effected or quantification during an on – going control session. As a matter of fact a close calculation on such an assessment can be achieved if based on control costs analysis as believed amongst several researchers. Though any given cost of control is likely to be inaccurate, it is based on a whole range of factors. From this dimension, resource requirements for different methods can be given in terms of time (man days per 1 000 stems) and volume of the products used – for example ‘X’ herbicides mix per 1 000 stems). For a mechanical approach, the man days will imply labour days or shifts. Differences in herbicides, labour, terrain, density and extent of infestations are vital. This gives an idea of the impact of such invasive species.

Quantification of impacts on biodiversity prior control could be based on several aspects, a view shared by a good number of scientists. It can be based for example on the degree of infestations, the location of the infested site, should it be in a particular vegetation, fragile ecosystem, by a fast flowing river, a valley, a hill side and so on counts much in assessing its impact on plant diversity.

4.5 ECOLOGY OF THE GRASSLANDS AND SAVANNAH AREAS

The grassland biome is a summer-rainfall area with heavy thunderstorms and hail, and frost in the winter. A number of perennial rivers such as the Orange, Vaal, Pongola, Kei and Umzimvubu originate in and flow through the area. Trees are scarce and are mainly found on hills and along river beds. Karee (*Rhus lancea*), wild currant (*Rhus pyroides*), white stinkwood (*Celtis africana*) and several acacia species are the most common, as cited by the website: <http://www.gov.za/yearbook/environ.htm>.

The Grassland is known to have a high percentage of plants indigenous to the country. Eight mammal species endemic to South Africa occur in a wild state in this biome. Three of these, namely the black wildebeest, blesbok and eland, do not occur outside the Grassland biome.

The area is internationally recognized as an area of high species endemism in so far as birds are concerned. Birds commonly found in the area include the black korhaan, blue crane, guinea-fowl and other grassland birds.

Only 1,1% of the Grassland biome is officially protected. The wilderness areas of the KwaZulu-Natal Drakensberg are the most significant.

The savannah is an area of mixed grassland and trees, and is generally known as Bushveld.

In the Northern Cape and Kalahari sections of this biome, the most distinctive trees are the camel thorn (*Acacia erioloba*) and the camphor bush (*Tarchonanthus camphoratus*). In the Northern Province of South Africa, the portly baobab (*Adansonia digitata*) and the candelabra tree (*Euphorbia ingens*) dominate. The central Bushveld is a home to species such as the knob thorn (*Acacia nigrescens*), bushwillow (*Combretum* spp.), monkey thorn (*Acacia galpinii*), mopani (*Colophospermum mopane*), and wild fig (*Ficus* spp.). In the Valley Bushveld of the south, the trees euphorbias and spekboom (*Portulacaria afra*) are predominant, as cited by the website: <http://www.gov.za/yearbook/environ.htm>.

An abundance of wild fruit-trees provide food for many birds and animals in the Savannah biome.

Grey louries, hornbills, shrikes, flycatchers and rollers are birds typical of the northern regions. The subtropical and coastal areas are home to Knysna and purple-crested louries and green pigeons. Raptors occur throughout the biome.

The larger mammals include lion, leopard, cheetah, elephant, buffalo, zebra, rhinoceros, giraffe, kudu, oryx, waterbuck, hippopotamus and many others.

Approximately 8,5% of the biome is protected. This is evident in the website that follows; <http://www.gov.za/yearbook/environ.htm> The Kruger National Park, Kgalagadi Transfrontier Park, Hluhluwe-Umfolozi Park, Greater St Lucia Wetlands Park and other reserves are located in the Savannah biome.

4.6 GEOGRAPHY OF THE GAUTENG AND KWAZULU NATAL PROVINCES

The Gauteng province has one of the largest meteorite impacts on earth some two billion years ago. The Vredefort Dome is on the border of the Free State province and Gauteng. A more recent crater, the Tswaing, 200 000 years old is perfectly preserved and is located in the

Pretoria region. Gauteng's Museums and research establishments have unique collections of fossils, rocks and San and Khoi paintings.

Soil samples (types) of the two provinces

The soil types in South Africa range from lateric (reddish, formed by rock decay w/high iron oxide, aluminum hydroxide) to clay, sandy, clay loam, and in some areas regic in nature.

Topographic data (mean annual rainfall, altitude, slope, aspect, soil types)

The Gauteng province is situated high on the central highveld plateau of South Africa at an average altitude of 1 500 metres above sea level. It has an average annual rainfall of 850 millimetres, and a mean daily sunshine factor of 8, 7 hours per day, one of the highest in the world. Daily temperatures range between an average midsummer (January) maximum of 26°C and an average winter (June) maximum of 16°C. Gauteng lies in the summer rainfall area of South Africa, often resulting in spectacular afternoon thunderstorms sweeping across the highveld.

The province is characterized by rolling hills, Fold Mountains and flat, savannahs with sporadic scrub brush. Acacia trees are the original flora, but foreign species of trees include Jacaranda trees with their purple flowers in October and Eucalyptus trees in woody clusters. There are a few streams (named “rivers”), but the Vaal River to the south and the impressive Magaliesberg mountains to the north form natural boundaries.

Vegetation type

The vegetation in the Gauteng province is mainly grassland, although it is interspersed by savannah vegetations in the northern side. The KwaZulu Natal is entirely grassland, (Coastal grassland areas towards the Indian Ocean).

Land use type

South Africa as a whole according to the CIA world fact record as cited in their internet site (see reference list) has for land use: 10% *arable land*; 1% *permanent crops*; 67% *permanent pastures*; 7% *forests and woodland*; and for others 15% (1993 est.). The Gauteng which lies at the heart of this Rainbow nation being mainly grassland has as land use, grazing and farming activities. Like wise in KwaZulu Natal, the predominant use of land is for farming,

this as Zimmermann (2001) puts it – ‘this explains why there are lots of plantation industries in KZN, the sugar industry being one’, (personal communication with author).

Ecological conditions

The ecology of the two provinces being studied vary, as such, are the conditions that constitutes them. In the Gauteng province, the riparian vegetation, and typical grassland conditions set the scene. Whilst in the KwaZulu Natal provinces, the coastal grassland areas become the centre of in this study. More on the ecology of the region and related aspects tied to the theme of this inquiry will be dwelled with as we go along.

Disturbance gradient

Levin and Paine (1974) cited by (Ricklefs and Schluter 1993, 24) showed that habitats characterised by a colonization – competition trade-off should have maximal diversity at intermediate rates of disturbance, given that there is a fixed pool of potential species. In these models, intermediate disturbance rates generate the greatest effective spatial heterogeneity because they create the full range of successional habitats, with some habitats being newly disturbed, some being of intermediate time since disturbance, and others being late successional. For the Gauteng and KwaZulu Natal provinces, the disturbance has reached alarming proportions, worst with the recent spade of fires in the past years, wide spread of alien species, and the so called development which has lead to enormous habitat fragmentation. In contrast at high disturbance, almost all areas are newly disturbed, and at low disturbance rates almost all are late successional. Indeed, this prediction is qualitatively quite similar to that of peak diversity at intermediate productivity. In both cases, the extremes (very unproductive habitats or highly disturbed habitats) are predicted to be dominated by a single species. The greatest effective heterogeneity occurs in intermediate habitats. This heterogeneity allows numerous species to co-exist. Cornell 1978; Lubcheno 1978; Petraitis, Latham, and Niesenbaum 1989) as in (Ricklefs & Schluter, 1993).

Disturbance obviously plays a significant role in the organization of all ecosystems. Whatever turn it takes, it may be operative, or may resort to gross interference with the exclusion of species by competition, (Mooney and Godron 1983). This is similar to the situation in South

Africa where the alien species are clearly seen to have out competed the indigenous species. In this country the impact on ecosystems has been accelerating rapidly through; extensive clearing of natural vegetation for agricultural purposes, selective harvest of desirable species and the wanton introduction of alien ones, abandonment of unproductive agricultural land, mining and reclamation of mined lands, drainage of wetlands for agricultural or fuel usage, introduction of chemicals (willfully and sometimes) with no knowledge of what harm it will lead to and so on. Be it a man made or natural disturbance, fire is one of the agents whose consequences will remain same for years to come.

Fire incidence

Fires interfere with nutrient cycling, if their effects are limited in intensity and frequency, the ecosystem tends to restore to the initial nutrient cycling condition. These fires in South Africa equally have effects on nutrient cycling yearly, most especially in the dry periods of the year when it is frequent. This is predominant in the grassland areas of South Africa (the Gauteng and KwaZulu Natal provinces inclusive) where "locals" attempt to maintain the best structure of the vegetation for pasture, farming and so on. Such fires in every case bring about the loss of certain vital elements from the ecosystem, by run-off and especially wind erosion, meaning the available pool of nutrients (N, P and K) steadily decrease sharply every year as a result to these malicious practices. These human influences on the ecosystems provoke major disturbances some of which are still being investigated by scientists in the region.

On the other hand, we must bear in mind that, fires will only occur if some source of ignition is present. Lightning is the chief cause of fires in natural vegetation. This as well has been documented as a major cause of fires in South Africa, mainly in the mountains of the Cape, Kruger and Bigalke, (1984) in Bond and Wilgen 1994, 19.

Fire is well known to be capable of destroying the vegetation and initiate the development of a new set of plant formations, (Wright and Bailey 1982); (Mooney and Godron 1983). This holds true for most forests. In the savanna, when fire occurs several times on a stand of savanna which had been previously protected, often leads to a decrease in the tree stratum. Thus, the rate of incidents of fire could be a major cause of concern in South Africa, as we know it could bring about untold damage to an entire system. On other living organisms such

as birds and mammals, fire has got lots of impacts upon them, (Kozlowski and Ahlgre 1974). If at all, a form of a control measure, if not well done could always be a major setback. The frequency with which these fires occur in South Africa is of growing concern as till this time, there are few accurate quantitative data on its ecological effects in the region.

4.7 THRUST OF THE RESEARCH STUDY

This study nonetheless takes into account the issue of changes in time and space viz `a viz changes over time (increases in latitudes and altitudes), changes over space, loss of biodiversity and the causes of this loss. Species richness and species diversity are some of the most important structural features of most communities – for example, a forest. They are influenced by a range of factors such as the degree of largeness in geographic scale and habitat. This gradually links us to the issue of how integrated the concept of spatial differentiation will be handled. Other important factors are the history of vegetation development in the provinces of Gauteng and KwaZulu Natal that will count very much in this research work.

Thus, the thrust of the study will lead to sorting out the trends in this field of research. It will lead to succinctly predicting the spread of these notorious invasive species across the African continent, should more efforts not be done to curb the spread.

4.7.1 THE RESEARCH PROBLEMS

The problems this current research study aimed at investigating falls within the aims of the research which are:

Measuring the impact of Acacia species on biodiversity in the Gauteng province of South Africa; Research indicates that Acacia species could be having a negative impacts on the biodiversity of the province. In this study, this writer was interested in finding out the proportions to which these problems exist, hence, outlining recommendations that could best solve the problems.

Assessing the impact of Chromolaena odorata on the biodiversity of the KwaZulu Natal province; Research results are alarming concerning the threat Chromolaena has on the

biodiversity of the provinces in South Africa. Thus, a need for this writer to succinctly quantify its spread.

Looking at links between the root structures of these alien invasive species, their effects on soil and water systems, and abilities to spread widely, this writer was faced with enormous problems as it demanded in-depth analysis of the roots of the specific species under study.

Predicting the spread of *Acacia* species and *Chromolaena odorata* across Africa (South Africa, Cameroon and Ghana) to be precise based on geological and climatological data. The whole exercise into other countries was fruitful but was not all that easy as this involved costs not initially envisaged for the research.

Looking at the control methods aimed at curbing the spread of alien invasive species (particularly *Acacia* sp and *Chromolaena odorata*); trials needed to have been done but the problem of lack of time was the issue. Hence, this writer had to depend on available literature and use of computer aided softwares to draw conclusions based on data available.

Checking out the ramifications of chemical control methods on the environment at large, was not that easy due to the fact that current experiments could have been so costly and time consuming. However, this writer had to make use of documented evidence in South Africa on these control approaches. Suggesting different ways of controlling the spread of *Chromolaena* and *Acacia* species across South Africa and beyond needed careful thinking and thorough literature review in function to the requirements of the level of this study.

Biodiversity related problems brought about by *Chromolaena* and *Acacia* species in South Africa as a whole is critical. These species have and are found to still spread rapidly within the region. In most areas of the concerned provinces, infestations of these alien species have attained epidemic dimensions one may conclude. Researchers in this field of research are making effort to alleviate the burden these species bear on the plant and animal community. This with little success. The methods used in this study is aimed at getting a clearer, closer, and independent picture of the situation in the velds. The extent of the problem is so vast that other life forms in the region and the continent at large need to be assessed – hence, predicting the spread of the species and coming up with succinct measures to control them. The whole phenomena boils down to experts including this researcher asking a common question - What should one do and how?

Finding out more about the impact of the *Chromolaena odorata* and *Acacia* species will foster the scientific community once more on how best to resolve the issues arising viz a viz biodiversity threats. The impact as established in the literature survey has a tremendous bearing on the ecology and economy of the provinces.

4.7.2 KEY QUESTIONS ADDRESSED IN THE STUDY

Some of the key questions being addressed in this study are as follows:

- What exactly is the impact of acacia species on biodiversity in the grassland and savannah areas of Gauteng?
- What is the total impact of *chromolaena odorata* on the biodiversity of the coastal grasslands of KwaZulu Natal?
- Has education on the need to conserve South Africa's biodiversity been sufficient to deal with the present dilemmas?
- What methods of controlling invasive species are deemed best to curtail the spread of acacia species and *chromolaena* in South Africa?
- Is the spread of *Chromolaena Odorata* fast gaining grounds across South Africa and beyond its borders? Why and what are the contributing factors?
- What could be the extent of the impact of alien plants on species diversity in the Gauteng and KwaZulu Natal provinces of South Africa?
- Can bio - control as a single method be ideal for recovery of biodiversity in South Africa?
- What is the government and non – governmental institutions doing in conserving the biodiversity of the Gauteng and KwaZulu Natal provinces?

4.8 ALIEN INVASIVE SPECIES, BIODIVERSITY MANAGEMENT AND THE ECOLOGICAL THEORY

Ecological theory and research delivers the necessary tools to evaluate effects / impacts (environmental) of alien invasive species thereby improving efficacy and safety of biological control. The key component of crop protection worldwide includes integrated pest management (IPM) developed as a result of concern about reliance on chemical pesticides.

IPM depends on both the conservation of local natural enemies and their mass release as alternatives to chemicals. Some schools of thought strongly believe that there are still some needs to be met..., for example - further development and harmonization of international protocol, with greater attention to non target, ecological effects.

Classical biological control on the one hand, and the introduction of exotic biological control agents to permanently suppress exotic pests, is practised even more widely as successes accumulate, and as new exotic pest problems follow trade liberalizations.

It is well established that natural enemies – persist in the environment – reproduce – spread – hence making biological control a unique pest control method. The present day shift(s) in paradigm, for example: from the use of chemical pesticides to the New paradigm of IPM implies safety to humans is being put at the forefront, thus emphasizing the notion of [environmentally friendly / self-sustaining] approaches in combating the spread of invasive alien plant species. The question that quickly comes to mind is that, would this be the best of solutions to South Africa's biodiversity problems? No doubt this approach has for many years been a success story in other countries. Chemical pesticides in the past had a competitive edge over biological control costs.

Today, pest control likewise dependence on chemicals is a major issue debated in environmental circles, but preferably today the IPM approach (based on biological control) has taken fore front. Such a method has been found to be important because of its potential to be safe to humans, environmentally friendly and self sustaining and this explains why farmers are moving away from pesticide use.

There are however problems with bio – control methods. Risks for non target species; meaning – indigenous specie could be extinct and the fact that it could be both ineffective and unsafe at times is one of the issues being looked at.

In South Africa, bio - control is practiced by government and NGO's with little experience in this technology. Generally speaking, application of ecology in biocontrol efforts depends on a whole range of things:

- Accumulated experience from previous bio – control programmes.
- Retrospective hypothesis creation and testing using specific, completed programmes.

- The retrospective application of broad principles arising from theory in the selection of agents (e.g. for specificity, density dependence, impact on vulnerable life stages of the pest).

Nonetheless, in the minds of some ecologists and other experts it is widely believed that the knowledge in ecology – assists in our understanding and predicting indirect ecological effects of biological control.

Risks of biological control to native species, both direct and indirect, constitutes a basis to foster sensible means of dealing with alien plant infestations. Biological control remains a valuable tool for conservation as well as for agriculture. Balancing the benefits against the risks is the task at hand in the research community today. Reform is thus necessary for sustaining the public's trust in this powerful technique.

The conservation status of animal and plant species over the past thirty years in South Africa has been the subject of in-depth discussions amongst experts. A report on South Africa's status is soon going to be produced by the World Wide Fund for Nature (WWF).

4.8.1 STATE OF TERRESTRIAL ECOSYSTEMS AND THE PURSUING CHANGES IN SOUTH AFRICA'S BIODIVERSITY

This writer has in earlier sections of this thesis discussed aspects of the state of South Africa's terrestrial ecosystems, but despite that a revisit to some of the key issues oncemore is vital to cementing the argument for a sound and practical policy and strategy for South Africa's biodiversity management programs. This segment of the chapter will cut across current land use issues (quantity), and current land conditions (quality) of natural and man-made terrestrial systems. The current biodiversity levels (changes) are also discussed amongst other things.

CURRENT LAND USE

The map above shows the land cover of South Africa. About 25% of its land surface area has been transformed by various intensive uses since the colonization of the country, Macdonald (1989). Land use is normally divided into cultivated areas, grazing areas, forests,

conservation, settlements and “other”. Changes in each of these categories have been noticed over the years and are discussed further in the subsequent paragraphs.

Close to the late 1980’s, it was estimated that roughly 12-13% of South Africa’s land cover was transformed by *cultivation*, Macdonald (1989). With these vast cultivated areas, implicitly one may have to note as well that intensive agriculture is unequally distributed among biomes and vegetation types. However, some vegetation types have been almost completely transformed. As an example, almost 96% of southwest - and west - coast Renosterveld in the western Cape have been transformed, mainly by agriculture, says Hoffman (1997).

Intensive cultivation on the other hand has transformed large areas of coastal lowland vegetation in Kwa-Zulu Natal. Here, sugar cane plantings increased ten-fold, from 2 to 10 million hectares in the last eighty years, Hoffman (1997). Cultivated areas are generally perceived as having declined over the last ten years, however (Hoffman *et al*, 1999), for reasons including increases in settlements, grass conversion schemes, and higher input costs to agriculture. The highest percentage of cultivated areas is in the Western Cape, Free State, Mpumalanga and the North West Province (30-36%).

Grazing areas occupy between 19% and 96% of the provinces, with the lowest in Gauteng and the highest in the Northern Cape. It appears that there has been a decline in grazing lands over the past ten years in all provinces except the Free State. Rapid urbanisation and the spread of invasive species are some of the main reasons for this loss in Gauteng, Western Cape, KwaZulu-Natal, and the Northern Province.

Forests are estimated to comprise 4% of the Eastern Cape, 5% of the Western Cape and 8% each of KwaZulu-Natal and Mpumalanga. Forest cover (natural and plantation) was perceived to be increasing, Hoffman *et al*. (1999), probably due to increases in commercial forest plantations. Commercial forests presently cover over 1.5 million hectares (mainly *Eucalyptus* spp., *Pinus* spp., and *Acacia* spp.).

It is also highly perceived amongst researchers that *formal conservation areas* were also on the increase, Hoffman *et al*. (1999), through the acquisition of new areas or the expansion of

existing conservation areas by the South African National Parks. At present the most conservation activity is in Mpumalanga (7% of the Province), KwaZulu-Natal and the Western Cape have 3% of their respective areas conserved, the Northern Province has 2%, and the other provinces have only 1% conserved each. The target set at the UN Conference for Environment and Development in Rio in 1992 is 10% of each vegetation type conserved for pristine or near pristine use. It is crystal clear today that South Africa lags significantly behind this, as only 6% of the whole country is formally conserved, and several vegetation types are under-represented or not represented at all. Private reserves, of which there are approximately 160 nationwide, add to this in total, but figures per vegetation type were not available. Courtesy of the National State of environment report (1999).

To wrap up things, *settlements* in the form of urbanisation is by far the greatest in Gauteng (50% of the total area). The Eastern Cape, North West Province, KwaZulu-Natal, Western Cape and Northern Province have between 10% and 14% covered by settlements, and other provinces have less. Urbanization was estimated to have transformed roughly 2.5% of South Africa's land cover in the early 1990's, but the ecological impacts of urbanisation are out of proportion to its low spatial extent, so does Macdonald's (1989) postulates. The reasons for increasing urbanization include:

- General rapid population increase;
- Movement of rural and immigrant families to towns, in search of employment opportunities;
- Scrapping of influx control laws making people more mobile.

Programmes such as the granting of housing subsidies for South African citizens, and electrification programmes have also encouraged the expansion of formal settlements in urban areas. This has a bearing on the ecosystem and biodiversity of the various regions of the country.

Discussing the impacts on terrestrial ecosystems at large without closing in and on the impacts that human activities that humans have on these systems would be a grievous

mistake. Some of these impacts include habitat loss and fragmentation, changes in biodiversity and so on.

Rosenzweig (1995) and Bond *et al.* (1988) have clearly demonstrated that the species richness of ecosystems is closely related to their unbroken (contiguous) surface area. As a matter of fact this important theory implies that continued land transformation will reduce species numbers, even without direct utilization pressure on species. Thus major transformation of land accompanying colonial expansion has resulted in the near-destruction of wild ungulate and predator communities, (Macdonald, 1989) and the replacement of natural grazing and browsing species by domestic stock. Also, changes in defoliation patterns in turn (forage selection and grazing intensity) have probably caused large-scale vegetation change, though this is poorly quantified, Macdonald (1989).

Nonetheless, conversion of natural habitats (that have a high agricultural production potential) to cultivated areas, has reduced the extent of several vegetation types. These are, most notably, communities of the Grassland biome (Macdonald, 1989) and renosterveld shrublands of the western Cape, which presently occupy a fraction of their original range. Interestingly forest plantations have been a further cause of transformation and fragmentation of natural habitats due to selection of certain sites for afforestation.

On the other hand, there have been both positive and negative impacts on biodiversity. Plantation forestry as it is widely believed, has contributed to the protection of natural habitats and species on about 300-400 000 hectares of land, as it is a legal requirement of afforestation permits that 25% of the land under plantation be conserved.

Unfortunately still, afforestation has led to local loss of biodiversity, and changes in species composition. In Mpumalanga Province, the species diversity of grassland birds in general, and of globally threatened grassland birds in particular, is significantly negatively impacted by afforestation, Allan *et al* (1997). See Table 35.

TABLE 30: NUMBER OF GRASSLAND BIRD SPECIES AFFECTED NEGATIVELY OR POSITIVELY BY AFFORESTATION

	Negatively affected	Positively affected
Number of Species	90	65

Southern African endemics	26 (29%)	9 (14%)
South African endemics	15 (17%)	2 (3%)
Globally threatened	10 (11%)	0
Threatened	25 (28%)	1 (2%)

(Source: Allan *et al.* (1997,182)

Explanation: Table 35 shows the percentages of grassland bird species affected by afforestation in South Africa and globally.

It is well established that alien invasive organisms also contribute to reductions in biodiversity. Hall *et al.* (1980) estimated that 33 of 70 threatened plant species of the southwestern Cape were the potential extinction victims of invasions of alien woody plants. Alien woody plants also alter animal diversity significantly, for example reducing the densities of insect-feeding birds but increasing seed-feeders. The mite *Varroa*, which attacks bee colonies for example, can cause such damage that it has raised concerns that there may be insufficient bee colonies available for pollination of deciduous fruits in a particular season (Allsopp, 1999).

Well over 18 000 species of vascular plants occur in South Africa, of which over 80% occur nowhere else. Estimates of total species numbers in the country vary from 250 000 to 1 000 000 and it is estimated that South Africa has 5.8% of the world's mammal species, 8% of the world's bird species, 4.6% of the world's reptile species, 16% of marine fish species and 5.5% of the world's recorded insect species (DEAT, 1997). Also, over 10 000 species of the coastal animals and plants (almost 15% of the world's total coastal species) are found along South Africa's coast, with about 12% of these occurring nowhere else. In terms of the number of endemic species of mammals, birds, reptiles and amphibians, South Africa ranks as the 5th richest country in Africa and the 24th richest in the world, courtesy of the (DEAT, 1997). This diversity is caused by variation in climate, geology, soils and landscape form.

Nonetheless, this country also has the highest concentration of threatened plant groups in the world (Cowling & Hilton-Taylor, 1994). Approximately 3 435 of South Africa's plant groups are considered to be globally threatened with extinction (Hilton-Taylor, 1996). A further 204 groups are estimated to be threatened at a local level.

South Africa's terrestrial systems are fragile, and must be managed carefully. Nearly 91% of the country falls within the United Nations definition of "affected drylands" (UNCCD, 1994). Extraordinarily dry are these areas where the rainfall is low, and potential evaporation is high. Dryland systems are often very sensitive to change, and therefore need to be managed carefully. Thus, removal of vegetation (ground cover) from dryland areas can increase the risk of soil erosion, making the soil less fertile, and less able to support vegetation (natural or cultivated crops) in future.

Maintenance of biodiversity is thus a prerequisite for ecosystem sustainability; once extinct, species cannot be brought back. The local extinction of species constitutes transformation of an ecosystem. The over spill effects of this contributes to further transformation of the ecosystem. A good case to illustrate this point further is that whereby large browsers like elephants select certain types of plants from the vegetation, and therefore control the structure of the vegetation, and the species which can survive there. Moreover, local extinction of elephants from, say, a savanna system, would lead to transformation of the vegetation composition and structure, by increasing the woody component in relation to the grass component. This has further consequences for animals that use both woody and grassy species for food and shelter. A proper environmental management therefore requires that researchers and all concerned should apply precaution and try to minimise the risk of extinctions, until we are sure that the impacts will not be detrimental to ecosystem functioning or to human quality of life. One way of making sure this happens is to manage populations of plants and animals within an area, and make sure they do not fall below a minimum viable size (Minimum Viable Population or MVP; Gilpin & Soulé (1986); Soulé (1987). This is the smallest number of individuals who can reproduce and function normally, even under stressful conditions such as drought, cited in South Africa's National State of environment report (1999).

The significant increase in demand on land, combined with a growing population, and hence growing demand for food, space and other resources, make it essential that land and its resources in South Africa are used wisely and sustainably. Plantation forests alone occur on about 1.5 million hectares of land in South Africa. These forests support industries important to the economy of South Africa. Although the area of these forests is relatively small (a little more than 1% of total land area), the forests place high demands on the environment, (e.g. in

terms of water use) compared to both the area occupied, and compared to the natural vegetation which they replace. There is therefore special concern about the role of forestry, hence, biodiversity management in national sustainable development.

To substantiate further, the need for sustainable development and natural resource management, many international conventions and commissions have been brought about by the global recognition of the need to manage terrestrial ecosystems and resources on a sustainable basis, and South Africa is party to many of them. The Intergovernmental Forum on Forests of the United Nations Commission for Sustainable Development (UNCSD), for example, recognises the economic benefits and the social and environmental costs of plantation forests as important policy issues. The Convention on Biological Diversity on the other hand aims to promote the sustainable use of living natural resources worldwide. It also seeks to bring about the sharing of the benefits arising from the utilisation of natural resources.

Still, special attention needs to be paid to effective land-use planning and minimizing the effects of loss of habitat and of prime agricultural land, as well as land degradation and other environmental problems in their broadest sense.

Experts worldwide agree that with increasing demand for land restitution, it is anticipated that there will be increased loss of natural habitats and, with it, potential loss of biodiversity. Land will certainly be more intensively utilized and hospitable environments outside formal conservation areas will come under increasing pressure for food production and plantation use. The question that comes forth is; can we successfully combine conservation and food production with community involvement? Some schools of thought believe that abandonment of biased assistance schemes will facilitate this process. Thus reassessment and redirection of research and technology objectives could ensure more equitable availability of the rangeland research expertise in South Africa, and result in credible, improved management practices to help ensure sustainable utilisation and management of natural resources. Is it not true that if a concerted effort is made at all levels nationwide to address the problems of land degradation, control of alien invasive species, and biodiversity management, it can be anticipated that there will be positive changes in the soil systems. Efforts such as those to also increase soil organic

matter, and many other aspects will contribute to effective land-use planning, with optimal resource allocation. This would minimize habitat loss and thus maintain biodiversity.

In South Africa the 'success' so far of programmes such as Working for Water and LandCare will also have an extremely positive impact. With balanced attention to the needs of both the commercial and communal sectors (courtesy of the National State of environment report, 1999), through research, extension and education, as well as a renewed focus on conservation in general, the sustainability of terrestrial ecosystems can be ensured. Continued efforts by nature conservation authorities to involve local communities in management and sharing of the benefits of conservation areas will reform the attitudes which resulted from the exclusionist policies of the past, and will contribute to greater understanding and ownership of natural resources in all spheres.

In a nutshell, significant loss of species with potentially important medicinal and cultural values, and rare species endemic to South Africa can also be prevented if the responses above are implemented.

We may not downplay the fact that plantation forest industry appears to have matured in South Africa, in several ways. Extensive expansion of plantation has slowed, and may not add more than 10% of the current area over the next decade or so. Adjustments are being made to its area, to meet environmental standards. It is presumed within the research community that more adjustments might have arose to meet the requirements of South Africa's National Water Act, especially since all forests are supposed to have been licensed by now, as anticipated in the National State of environment report (1999).

Continuous environmental improvement within transparent environmental management systems is thus called for in the case of South Africa.

Although there are a number of perceptions and ideas relating to the state of terrestrial ecosystems, they are mostly qualitatively and geographically limited.

Excellent databases exist containing plant and animal species inventories and their distributions, and on plant conservation status, states; Hilton-Taylor (1996). Also, good databases also exist concerning the most significant alien plant invasive problems in the

country. However, data on trends in plant and animal trade, statistical information on alien invasive species and harvesting rates in the world are lacking, and should be pursued. A reason out of many for which this study is being carried out.

Generally speaking, there are good statistics on plantation forestry in South Africa. However, the industry and its environmental impacts on biodiversity remain controversial and to a wide extent lacking. Public policy instruments, whether Environmental Impact Assessments, or work required to develop criteria and indicators of sustainable forest and biodiversity (specifically alien invasive species) management, all require that the good information they have should be effective. The principal requirement now and in the future is to improve information of this kind. This research work seeks to do just that.

The high demand for resources such as food and energy, has resulted in the transformation of large areas of land in South Africa to the cultivation and livestock production; and large quantities of urban and industrial emissions and wastes. Improper management of these processes is continuously resulting in the degradation of the land in some areas, and reduced capacity to continue to support life. It is clear as well that uneven settlement patterns intensify the demand for resources in some areas and the urban and international demand for certain biological resources, for medicinal and other purposes also place pressure on populations of these often rare or endangered species. Man's activities also result in the introduction of alien species and have had serious consequences for most natural habitats, in terms of changes in biodiversity, and altered functionality of ecosystem processes.

In terms of levels of degradation, the Northern Province, KwaZulu-Natal and the Eastern Cape are the provinces with the highest. It is scientifically argued that areas with steep slopes, low rainfall and high temperatures are significantly more degraded, especially in communal areas (which are associated with conditions of poverty). However, these trends may be slow.

As we all know, the plantation forestry has developed over the years in South Africa for more than a century ago in response to domestic and international demand for wood and wood products, and now occupies about 1.5 million hectares of land (1.2% of the country), evident in the National State of environment report (1999) . The trends in the development of the industry have placed significant pressures on land, water, natural habitats, and biological

diversity. Some experts still believe that forestry (with most of the tree species alien and invasive in nature) has also contributed to conservation of natural habitats and cultural heritage, as well as social upliftment, and economic growth. From the perspective of government, much is being done to ensure a more sustainable approach to plantation forestry and this includes provisions in the National Forestry Action Programme and the National Forests Act, the National Water Act, and the National Environmental Management Act. Community forestry projects though found to be contributing to social and environmental improvement, still needs the necessary impetus from research experts in the field of nature conservation.

Despite the exploitative use of natural resources, and conversion and fragmentation of natural habitats, it makes South Africa to have the highest concentration of threatened species, and high extinction rates. Poverty alleviation, population stabilisation, and formalisation of the production of plants and animals for medicinal and horticultural markets, is deemed will go a long way to reduce pressures on scarce biological resources, so is the thought in the research community.

It has been scientifically established by researchers that over 8% (10 million hectares) of South Africa has been invaded to some extent by alien plant species (Acacia species and *Chromolaena odorata* among). These alien species has an impact on water resources and threaten biodiversity. For example, aliens in the Northern and Western Cape use about 15% to 16% of mean annual rainfall, and almost half of the threatened plant species in the Western Cape are threatened with extinction from invading alien vegetation. The case of the KwaZulu Natal and Gauteng Province is in fact alarming. At a conservative expansion rate of 5% per annum, the impacts of aliens could double in 15 years. This is in fact a serious problem. Alien removal is therefore a priority, although it is estimated to cost about R5.4 billion per year. The Working for Water scheme cleared 107,565 hectares of alien infested areas, 128,648 hectares of follow-up clearing, and employed 23,662 people in 1998/1999. Statistics cited in the National State of environment report (1999). The subsequent paragraphs lay out the policy and strategies in approach of South Africa's sustainable management in a slightly summarative manner while retaining the main issues as stated in the government's policy.

4.8.2 IMPACTS OF CHANGES TO TERRESTRIAL ECOSYSTEMS

With transformation and fragmentation of natural habitats the number and type of species that occur may change and this could disable any vital ecosystem processes that support growth. Changes in temperature and water availability conditions are likely to induce stresses in vegetation and component plant species, and may encourage mobile organisms to alter their distributions in the medium to long term. These may also favor the success and spread of alien plant species (Richardson *et al.* 1999). Changes in animal species composition can change the composition of the vegetation, because different animals choose different plants to feed on. No doubt changes in vegetation can also lead to changes in animal species, because there may be more or less material available for food, nesting, and camouflage. Conservationists alike agree not to fully know how each species functions within its community or habitat, and therefore cannot predict what will happen when some species are lost and others are gained. However, most of the changes in the composition of species that have been studied in Southern Africa, show negative impacts of the system.

The introduction of alien plant species (either by accident or plan) has serious implications for water availability. In total, South Africa's forestry plantations use about 3% of the available surface water, and alien plants use 7% of the available surface water every year. Courtesy of South Africa's National State of Environment report – (1999). Biodiversity managers monitoring the spread of various alien invasive species, hence ensuring the management practices in place within South Africa do consider all these in varying degrees.

Nonetheless, changes in distribution of species and communities due to climate change, and other environmental pressures may increase or decrease agricultural production capacity, may contribute to species extinctions, and may encourage the spread of alien organisms as is the case seen in some provinces of South Africa. The extent of each of these has remained uncertain, and at this stage the study seeks to unravel the impacts of all these.

To these changes that affect growing parts of the world's terrestrial ecosystems, there exist responses from the scientific community. From the South African perspective, several international conventions have been ratified which aim at improving the sustainability of terrestrial ecosystems internationally. Some of them include the Convention on Biodiversity,

the Convention to Combat Desertification, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Apart from that, South Africa also has over the years developed policies and passed a number of laws which promote conservation and sustainable use of natural resources (further ahead more on the Conventions and Agreements signed by South Africa is discussed). Despite these initiatives other sorts have been introduced to promote sustainable management of plantation forests, and biodiversity at large. Some of these initiatives include restoring and maintaining healthy soils and water systems.

Nonetheless population is still growing, and hence the demand for resources continues to increase. Loss of habitats and resources (indigenous species) is fast becoming a major concern than ever, and so unless control measures are implemented and adhered to. To beef this up, it becomes absolutely necessary to cite South Africa's National State of Environment report (1999), which puts forth this: *“formalisation of the trade in medicinal plants, through development of nurseries and commercial farms to meet demand, will create economic and social upliftment, whilst halting biodiversity loss and habitat transformation. The cut flower industry and commercial game farming are successful examples of formal exploitation of natural resources”*.

Thus involvement of communities in decision making and sharing of benefits from conservation areas, together with education, extension and research, and a balance between addressing social and environmental issues, will enhance feelings of ownership, and contribute to the success of schemes to promote biodiversity management practises and above all sustainable development. Are the various conventions and agreements to which South Africa is a signatory to contribute to similar successes and how?

4.9 SOUTH AFRICA AND INTERNATIONAL ENGAGEMENTS ON ENVIRONMENT

South Africa has like many other nations contributed to the United Nations Environment Programme (UNEP). In this light a good number of national programs, policies and legislations have been initiated in order to further protect the environment.

Also, South Africa had in 1997 ratified the UN Convention to Combat Desertification (UNCCD) which has as its primary objective “to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, through the effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach which is consistent with Agenda 21, with a view to contribute to the achievement of sustainable development in affected areas”. This official stand of South Africa in effect legally binds that country to practical actions at the local level. At moment, South Africa is currently and further developing a National Action Programme whose aim is “to identify the factors contributing to desertification and practical measures necessary to combat desertification and mitigate the effects of drought”.

On the other hand, the *Convention on Biological Diversity (CBD)* aims to effect international cooperation in the conservation of biological diversity and to promote the sustainable use of living natural resources worldwide. Cooperation in ensuring the conservation and sustainable use of biodiversity is attended to in Southern Africa, with all relevant role-players. International and regional meetings are held to incorporate traditional knowledge into the implementation of the CBD and related aspects of biodiversity.

The CBD as a matter of fact also aims to bring about sharing of the benefits arising from the utilisation of natural resources. The paper (white paper) on the Conservation and Sustainable Use of South Africa’s Biodiversity (July 1997) implements this at a national level, through the use of applicable resources in the tourism industry; community participation (including industry and business) in biodiversity management; and integration of conservation and sustainable use of biodiversity into all sectors, including industry.

In 1975, South Africa ratified the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). So far, this country is deemed with justification to be a world leader in the field of international wildlife conservation, as demonstrated by its active participation in CITES. This is exemplified further by the fact that, the issuing of permits are strictly regulated at the provincial level, and measures to combat smuggling of species are enforced by Customs and Excise and the Directorates of Plant and Quality Control and of

Veterinary Services of the Department of Agriculture. This has in no small way aided the curbing of the spread of invasive species.

To sum up, South Africa in August 1997 ratified the United Nations Framework Convention on Climate Change (FCCC). This convention addresses the threat of global climate change by urging governments to reduce the sources of greenhouse gases. The ultimate objective of the convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climatic system of the world. The consequences of this for the distribution of biomes and species, and therefore the composition of biomes, will depend on its effectiveness, and on the time delay in regulating concentrations of greenhouse gases in the atmosphere.

4.9.1 NATIONAL POLICY AND LEGISLATION OF SOUTH AFRICA VIZ `a VIZ THE ENVIRONMENT

It is clear that environmental policy guidelines and statutes, motivated by the concept of sustainable utilization can be instrumental in assisting to ensure sound management of terrestrial ecosystems. Some of the recently promulgated acts are listed below. These list of acts however is not a comprehensive one which illicuditates on the implications for terrestrial ecosystems, as in the policy. They are:

- *Mountain Catchment Areas Act (Act No. 63 of 1976)*
- *Conservation of Agricultural Resources Act (Act No. 43 of 1983)*
- *Minerals Act (Act No. 50 of 1991)*
- *National Environmental Management Act (Act No. 107 of 1998)*
- *National Water Act (Act No. 36 of 1998)*
- *National Forests Act (Act 84 of 1998)*

The forest Act makes provisions for the development of criteria, indicators and standards for sustainable forest management.

In addition to these Acts, a few policies which are yet to be legislated are worthy of mention here. The Discussion Document on Agricultural Policy in South Africa (1998), for example, emphasises the importance of achieving sustainable, equitable and efficient agricultural

development. With respect to the conservation of plants and animal species and the protection of endangered ecosystems, the emphasis will be on meeting internationally agreed standards and commitments and translating these into national standards. Courtesy of South Africa's National State of the environment report (1999).

4.9.2 PROBLEMS FACING NATURE CONSERVATION LEGISLATION IN SOUTH AFRICA

The problems that hit hard on South Africa's biodiversity are numerous. The case of alien invasive species have not been dealt with as such. To worsen things, there are other related problems facing nature conservationists and policy makers that divert their attentions from the alien invasive plants (some of which have been illegally) imported into South Africa.

With particular reference to wild life trade, Bürgener, Snyman & Hauck (Date Unknown) state that: *“The sustainable legal wildlife trade is supported as a fundamental tenet of biodiversity conservation, which supports sustainable use as a movement away from the old paradigm of a solely hands-off (total prohibition) policy”*.

The illegal wildlife trade, on the other hand, should be minimised, as proposed by Bürgener, Snyman & Hauck (Date Unknown) in their published article.

Thus, effective regulation of the wildlife trade is largely dependent on sound legislation which facilitates the work of conservation authorities in promoting a sustainable legal trade and addressing the illegal trade. Wildlife trade in South Africa is currently regulated in terms of a highly fragmented potpourri of provincial Ordinances, Acts, Decrees and Proclamations which are, in numerous aspects, inconsistent, incomplete, outdated and overtly complex. There are, for example, a number of inconsistencies in permitting procedures, sanction provisions, legal definitions, and the conservation status of many indigenous species. This confusing legislative structure makes it extremely difficult for conservation authorities already facing budgetary and capacity constraints, to carry out their work effectively and efficiently. Provincial restructuring in 1994, combined with a failure to repeal nature

conservation legislation of the former Independent States and Self-governing Territories, has served to exacerbate an already fragmented legal environment.

Problems are not only created through inconsistencies between various Ordinances and Acts. The existing legislation is for the most part outdated and there are, for instance, no provisions dealing with the use of incentives to encourage persons involved in the trade to utilise natural resources sustainably. Finally, the existing system does not allow for national monitoring and oversight of the extent, and nature, of wildlife trade, Bürgener, Snyman & Hauck (Date Unknown). A similar problem of this nature is faced in the efforts aimed at controlling alien invasive species in the country. This is given a thorough analysis in the up coming chapters.

South Africa has one of the world's greatest diversity of plant and animal species contained within one country with 7.5% of the world's vascular plants, 5.8% of the world's mammal species, 8% of the world's bird species, 4.6% of the world's reptile species, 16% of marine fish species and 5.5% of the world's recorded insect species. It is a home to many species found nowhere else in the world. This high level of diversity is due to the broad range of climatic, geological, soil and landscape forms found in South Africa, (Florentin 2000). However, many species are threatened, and extinction rates in South Africa are high by global standards.

Most of the land area (86%) is used for crop cultivation or grazing of livestock. Less than 10% of the area is conserved. South Africa is a semi-arid country, and drought and desertification are real threats to food security.

Terrestrial ecosystems no doubt are very complex, and research has only been able to cover a few aspects. It is not fully known within the scientific community what the impacts of extinction are, or what might happen if certain ecosystem processes are interfered with: these impacts are of relatively recent origin, and the consequences are yet to play out. This goes further to justify the reason for carrying out this study.

Terrestrial resources in that country are rapidly disappearing however, due to conversion of natural habitat to farmland, forestry (by introduction of alien invasive trees), human

settlement, and industrial development. Some species are under threat because of rampant collection for medicinal, ornamental, and horticultural purposes.

As we must have noted by now, invasion by alien species of plants and animals is a major problem in South Africa. Alien organisms are capable of replacing large numbers (even whole populations) of native animals and plants, and **alien plants use greater quantities of scarce water resources**, (Bürgener, Snyman & Hauck, Date Unknown). For this reason and more degradation of vegetation and soils is also a widespread problem in South Africa. Rapid population growth and inappropriate government policies in the past encouraged cultivation in unsuitable areas, and use of poor agricultural methods to produce sufficient food. It is believed that the recent policies, international conventions, and community-based initiatives being carried out would improve conservation and more sustainable use of natural resources in future.

4.9.3 INDEGENOUS FOREST AND FOREST BIODIVERSITY

In 1995 the Forest Biodiversity Programme (FBP) was established to provide a framework for the coordinated study of indigenous forest and forest biodiversity. It used current research concepts in biogeography, community ecology and conservation to develop guidelines for the wise use, management and protection of the indigenous forest of South Africa.

As a matter of fact, the indigenous forest in South Africa covers only 0.56% of the total land area, yet it accounts for a disproportionately high share of the country's biodiversity. Programmes like this are well placed in KwaZulu-Natal (KZN) because this province contains a large portion of South Africa's indigenous forest and all the eight different forest types found in the southern African subregion. However, KZN also has the highest human population and agro-commercial impact on natural resources. It is also a place where the spread of invasive species such as *Chromolaena odorata* have reached alarming proportions.

Over recent decades the indigenous forests of South Africa has become much reduced in area and highly fragmented resulting in the gradual loss of biodiversity from the region. However the ecological effects of area loss, fragmentation and environmental disturbance on forest communities remain poorly understood. Since 1995, the Forest Biodiversity Programme has been doing much to fill this knowledge gap.

The FBP also provides focussed research on indigenous forests in South Africa, with four main thrusts:

- large-scale biogeography, emphasising the processes that maintain biodiversity
- habitat-scale community ecology
- sustainable use and management of forest resources
- Criteria and Indicators for sustainable plantation management.

The past 7 years have been a very busy one for the Forest Biodiversity Programme. Studies examining historical change in forest area and landscape pattern in the Karkloof-Balgowan region, and plant regeneration following subsistence slash and burn agriculture at Nkandla forest have been completed. Other new projects include the biogeography of forest fauna in KZN and the Northern Province, the putative effects of climatic extinction filtering on community structure and composition and the role of *Isoglossa* in the ecology of coastal dune forest. Today, the use and regeneration potential of high-value tree species in Eastern Cape forests is also being investigated.

Ongoing studies include the effects of forest fragmentation and matrix type on community structure in birds and epigaeic invertebrates, the influence of life-history traits on metapopulation persistence of forest birds and mammals within fragmented landscapes, dioecy in the coastal forest tree *Drypetes natalensis*, and the sustainable use and value of indigenous forest resources to rural communities in the Eastern Cape and KZN. Much about this is found in the following website;<http://www.botany.unp.ac.za/Staff/Lawes/forestbio.htm>

4.9.4 MANAGEMENT OF CHROMOLAENA ODORATA IN A PARK AND SURROUNDING AREAS

But for a few exceptions, experts seem to find insufficient attention given to developing an effective *strategy* for controlling the spread of alien plants. Instead, current practice emphasizes *tactics* for controlling invasions locally, i.e. the specific procedures used to remove alien plants (Moody & Mack, 1998) cited by Foxcroft (2001). In order to successfully plan and implement a control strategy, consideration needs to be given to factors such as

setting objectives, prioritizing management strategies, control techniques, monitoring, evaluation, and follow-up, programme management, securing resources and stakeholder involvement and training.

Chromolaena odorata was first recorded in the KZN Province during the late period of 1997 by the KZN Alien Plant Working Group. Since then, large infestations were found in the Lows Creek area and in the mountainous areas bordering Swaziland. Prior to that (1995) surveys were carried out in Swaziland to map distribution and density of *Chromolaena odorata*. In November 1993 *Chromolaena odorata* was also recorded in the Hazyview area, (Foxcroft, 2001). Plants then were found regularly from 1997 onwards in the Malelane area, threatening to invade the Crocodile River. Plants were shortly found in the Sabie River as far into the KNP as the Kruger Gate bridge, (Foxcroft, 2001). Isolated plants were then recorded along the Sabie River, from Hazyview to Kruger gate. Following a large awareness campaign, a few specimens were recorded in the Letaba River near Letaba restcamp and with special control teams, large numbers of plants were then recorded. Numerous other records of *Chromolaena odorata* have been made in the Lowveld area, and in many areas growing at a rate exceeding that of control actions.

The objectives for controlling *Chromolaena odorata* (long – term, short or medium term) are simple:

- Biodiversity issues (physical exclusion of indigenous plant species, competition, allelopathy, loss of associated species due to change in habitat);
- Hydrology (increase in water use, clogging of water ways by densification, destabilizing banks, changing water nutrients and chemical properties).

Foxcroft (2001) warns that management plans for *Chromolaena odorata* must be seen as an ongoing, long-term programme, with an annual review of progress and problems to update and review the planned strategy. This should be the case as well for *Acacia* species.

4.9.5 MANAGEMENT PLAN FOR THE CONTROL OF CHROMOLAENA ODORATA

Prevention is generally far more cost effective and environmentally desirable than measures taken following the introduction of an IAS. Priority should be given to prevention of entry of IAS. If entry has already taken place, actions should be undertaken to prevent the establishment and spread of alien species. The preferred action would be eradication at the earliest possible stage. In the event that eradication is not possible/feasible or is not cost effective, containment and long-term control measures should be considered.

Eradication: Where feasible and cost effective, eradication should be given priority over other control measures to deal with established IAS. The best opportunity for eradicating IAS is in the early stage of invasion, when populations are small and localized.

Containment: When eradication is not appropriate, limitation of spread is an appropriate option where the range of the invasion is limited and containment within defined boundaries is possible. Regular monitoring outside the control boundaries is essential, with quick action required to eradicate any new outbreaks.

Control: Control measures should focus on reducing the damage caused and the long-term reduction in density and abundance to go below a pre-set acceptable threshold. Effective control will often rely on a range of integrated techniques. Most techniques will need to be regularly applied, resulting in a long-term operating budget and the need for long –term commitment to achieve and maintain results. Biological control, integrated into other control techniques will often form a long-term low maintenance control option, provided certain requisite conditions are favorable (i.e. plant density, safe areas).

Cases for eradication: Foxcroft (2001) cites the Hans Merensky Country club – to have localized, small, fairly young infestations. Possible seed sources for the entire region (also down Tsutshe spruit into Olifants river). Also a fairly large infestation was localized / isolated, and it appeared to be a source of infestation for the Phalaborwa region. Situated in a small valley, is surrounded by mining activity, except for the one side where the river leads to the Olifants river.

Containment and control: The majority of areas infested by *Chromolaena odorata* should be controlled with the aim of containment and limiting further spread of the plants, Foxcroft (2001).

Areas include:

- Tzaneen leading down Letaba River
- Blyde river catchment (infestation confirmed yet?)
- Hazyview
- Crocodile River area (River side farm)
- Upper Levuvhu river area (infestations confirmed?)

Some of these areas have been earmarked for biocontrol.

Control methods

In the KZN province, it is widely assumed that control methods are generally not well known. The use of integrated control options, namely chemical, mechanical and biological with the use of a correct planning can provide successful results. Important issues are the correct use of the techniques in a specific situation. Furthermore, the assigning of a specific technique should fit the objectives and the desired outcome of the area to be managed.

Actions as proposed by Foxcroft (2001):

- Prioritise the *Chromolaena odorata* situation, according to recognised principles, and the desired outcomes.
- Draft formal strategy to determine areas for control, methodology and time schedules.
- Monitor (according to defined time and other objectives), the efficacy of the implemented control programmes as well as scientific monitoring of defined areas to determine density and other vegetation changes.
- Evaluate against defined criteria and determine if any actions are behind, lacking or not achieving the goals as defined in the strategy. This evaluation should be done annually by a designated person/organisation, perhaps those responsible for their area of work and fed into a central point to be analyzed. Monitoring methods need to be

determined. For areas under intensive control / eradication attempts, monitoring will be required to be equally as fine / thorough and on a more frequent basis, to allow for more rapid action in terms of escaping or missing seed producing plants.

Some of the principles of planning IAS work as outlined by Foxcroft (2001) include:

- Clear light areas first and maintain them.
- Protect areas of special significance: high botanical sensitivity
- Prevent re-introduction of *Chromolaena odorata* from outside areas.

Legislation and guiding policy

In this respect, the recently amended CONSERVATION OF AGRICULTURAL RESOURCES ACT, 1983 (ACT No. 43 OF 1983) includes *Chromolaena odorata* as a declared weed (category 1).

Therefore, Category 1 plants (*Chromolaena odorata* inclusive) may not occur on any land or inland water surface other than in biological control reserves. A land user shall control any category 1 plants that occur on any land or inland water surface in contravention of the provisions of sub-regulation by means of the methods prescribed in regulation 15E. Also, no person shall, except in or for purposes of a biological control reserve shall – (a) establish, plant, maintain, multiply or propagate category 1 plants; (b) import or sell propagating material of category 1 plants or any category 1 plants; (c) acquire propagating material of category 1 plants or any category 1 plants.

The KZN province also recognises that IAS (invasive alien species) are the greatest threat to its biodiversity goals and therefore recognize the importance of control measures to mitigate the impact of IAS in the KZN.

Mapping distribution and density of *Chromolaena odorata*

To fully ascertain whether containment and eradication measures are successful, ongoing mapping exercises need to be maintained. These maps will have to provide an indication of the range of expansion with time and provide a measure of density in the known infestations.

This will reveal, to an extent, the efficacy of the implementation (containment and eradication) strategies.

Rehabilitation aspects

In the disturbed areas where *Chromolaena odorata* is seemingly under control, the possibility of rehabilitation of the areas needs to be explored, thereby providing a measure of competition and possibly introducing / allowing for other control options to further the integrated approach e.g. burning. As Foxcroft (2001) puts it, such areas that may benefit from such an approach are the mining areas, where the *Chromolaena odorata* infestation occurs in an altered and unnatural system already. Rehabilitating the area or developing a management practice that will compete with the weeds may assist the maintenance of the long-term control programme.

Research

Research into the most effective control strategies in different situations and climatic conditions needs to be determined. This may only entail a literature search or input from various persons of latest known research outcomes or technologies. Other research objectives may be to determine areas of different levels of potential impact, i.e. the sensitivity of certain areas to invasion by *Chromolaena odorata*, as this may provide input to future planning of control strategies.

Interested and involved partners include:

- KZN Conservation Services: Environmental Management Unit: Alien Biota Section; Section Rangers
- PPRI
- KZN Alien Plant Working Group
- KZN Working for Water Project and those of other provinces like the Northern Province and Mpumalanga have to work hand in hand.

Biological control

Developments presently (current situation) in this regard have not been promising. Thus, future options are open, with the integrated approach being favoured most. Still in the biocontrol domain future prospects: (unproven insects, difficulty in rearing) and release sites and safe nursery areas have been the main issues yet to be ironed out.

Despite all these, a relatively good knowledge of the distribution of *Chromolaena odorata* is known, if the actions are to be successful, extremely fine distribution and density details are required of the infestations (otherwise it will be like jumping after veld fires which keep flaming up behind one's back).

4.10 THREATS TO BIODIVERSITY IN THE GAUTENG AND KWAZULU NATAL PROVINCES

Unfortunately the immense natural wealth in this two provinces of South Africa and other parts as well is under extreme pressure resulting from human demands placed on the environment through economic development, agriculture and urbanisation. Invasive alien vegetation and the trade in wildlife also contributes to the problem.

Apart from the poor conservation status of the Succulent Karoo and Lowland Fynbos vegetation types (less than 3% conserved (Rebello 1997, Cowling & Hilton-Taylor 1994)), a high proportion of the terrestrial vertebrate fauna and the flora of South Africa is preserved in nature reserves in the form of breeding populations. There are however 582 protected areas in South Africa (160 private reserves and 422 areas under national, provincial or local authorities).

It is important to note that in the concerned provinces of South Africa, severe inroads into natural vegetation have been created by invasive species, an estimated 8% (10 million hectares) of South Africa have been invaded to some degree by a wide range of alien species (Versveld *et al.* 1998). Alien plant invasion is occurring in all seven of South Africa's biomes. Infestations are dense in most biomes. Significant plant invasions are noted for each of the other six biomes, but comparable estimates of spatial extent are not available. This and more makes management practices so difficult. The following table shows estimated values of

the actual plant biodiversity loss in South Africa. It gives a perfect picture of how a daunting task it has been for those involved in biodiversity efforts in South Africa with limited success.

TABLE 31: ACTUAL AND POTENTIAL PLANT BIODIVERSITY LOSS

Numbers of Threatened Taxa	1980	1995
Extinct	39	56
Endangered	104	241
Vulnerable	165	422
Rare	521	1322
Indeterminate	259	378
Insufficiently known	805	849
Total threatened taxa	1893	3268

(Source: C. Hilton-Taylor 1996 cited in the DEAT (1999))

Explanation: Table 36 shows estimated values of plant biological loss in South Africa.

CHAPTER FIVE

CONCLUSIONS AND RECOMENDATIONS

5.1 SUMMARY

The South African Government has three overriding priorities:

- the eradication of poverty;
- the sustainable development of its economy; and
- the social development of its people.

These priorities, together with the national environmental policy presently being formulated, provide the context within which consideration will be given to achieving the three objectives of the Convention on Biological Diversity:

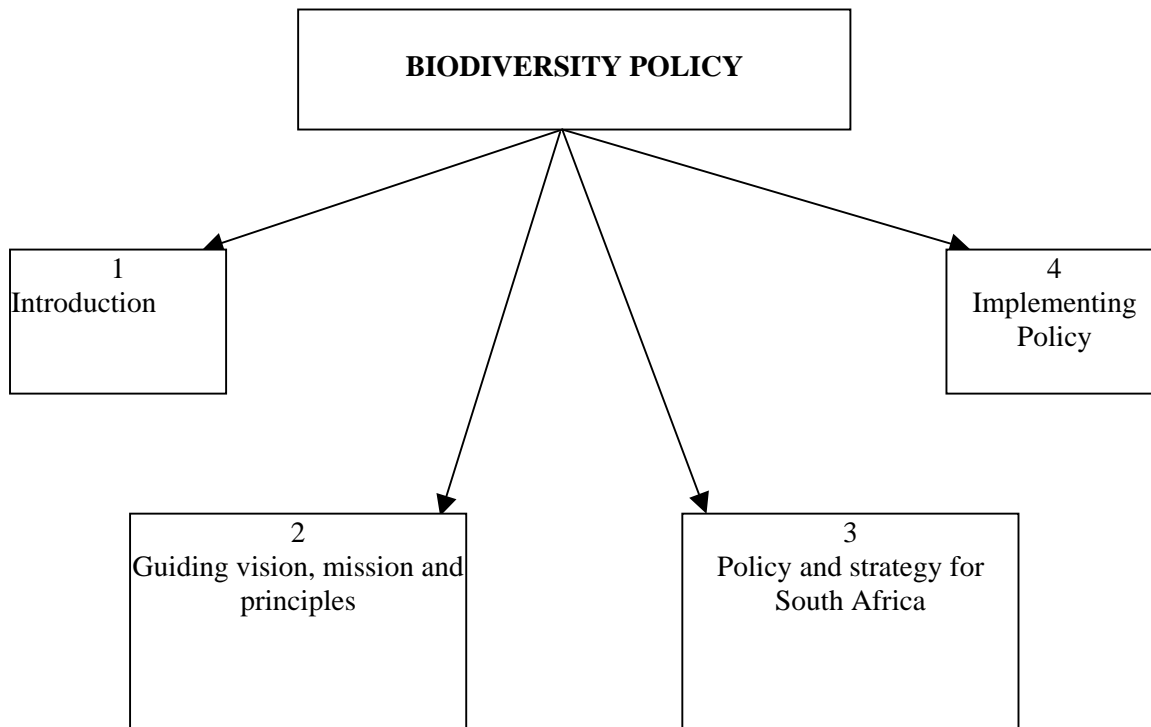
- the conservation of biological diversity;
- the sustainable use of biological resources; and
- the fair and equitable sharing of benefits arising from the use of genetic resources.

In addition to fulfilling these objectives, the South African Government has committed itself to a biodiversity policy and strategy that will promote the reconstruction and development of South Africa through:

- ensuring provision of the essential ecosystem services and biological resources required to meet basic human needs;
- not restricting economic development unnecessarily;
- enhancing the provision of jobs related to the conservation of biodiversity and sustainable use of biological resources;
- redistributing income and opportunities derived from the conservation of biodiversity and sustainable use of biological resources in favor of the poor;
- enhancing the development of human resources necessary to conserve biodiversity and use biological resources sustainably; and
- increasing participation in the institutions of civil society engaged in conserving and using biodiversity.

The upcoming chart (Figure 16) gives an overall picture of the considerations taken in formulating a national policy.

FIGURE 8: STEPS IN THE POLICY FORMULATION PROCESS



(Source: Author's own)

Explanation: This illustrates the logical steps taken into consideration when formulating a national policy.

For a policy to be formulated, as was the case of South Africa, those directly concerned had to ensure that;

- what was being designed was within the context of international policy,
- the history of South Africa's biodiversity was important, it is a 'living heritage' that cannot be ignored by any expert,
- the scope of South Africa's biodiversity policy needs to be weighed,
- major concerns must be expressed

There is no doubt that the vision, mission and principles' guiding a biodiversity policy as that of South Africa encompasses aspects of the constitution. Implementing policies has not been an easy thing, a view shared by many experts. At such a stage, roles of all key players partaking in this important piece of work need neither to conflict nor to clash. They must be

specific and clear to the point. Institutional changes, funding and priority action at this critical stage of the policy process are supposed to be carefully handled.

South Africa's policy and strategy for biodiversity conservation lies in the context of the Convention on Biological Diversity. The CBD is a landmark on its own, not only because of the fact that for the first time a global agreement exists to conserve biodiversity, but because it reconciles the need for conservation with the concerned for development. It is also based on considerations of equity and shared responsibility, emphasising that natural resources are the property of individual countries. It is for this reason that each country does its best to come up with its own policy and strategy of conserving its valuable biological (natural resources). For the case of South Africa, we have seen how laid down it is. But then, what is put on paper needs to be carried out in the field. This research study is about this aspect too, the practicality, will and abilities of protecting biodiversity. In South Africa the policy is well disseminated though much still needs to be done.

There are a number of organisations involved in the process of policy implementation viz a viz conserving the country's biodiversity, by way of enforcing the necessary environmental laws or being actively involved in the field, hence contributing in the latter. Some of these organisations include:

- The Agricultural Research Council,
- The South African National Seed Organisation (SANSOR),
- The CSIR (CSIR's activities are broad and include a variety of sectors indirectly or directly involved in biodiversity prospecting activities),
- The Medical Research Council (MRC),
- The National Botanical Institute (NBI), and
- Universities and Other Research Institutions

Several government departments are directly involved in issues raised by biodiversity. At the provincial as well as national levels these include Departments of Nature Conservation, Economic Affairs, Agriculture, Environmental Affairs, and Health.

Above all, some of the National Legal Instruments Governing the Use of Biological Resources in South Africa include: Environment Conservation Act 73 of 1989, Department of Environmental Affairs and Tourism, National Parks Act 57 of 1976, National Parks Board,

Conservation of Agricultural Resources Act 43 of 1983, Department of Agriculture, Plant Breeders' Right Act of 1976, Department of Agriculture, Plant Improvement Act of 1976, Department of Agriculture, and the Department of Water Affairs and Forestry.

The policy and legislation of South Africa was designed to improve on the nation's biodiversity conservation status, which equally makes use of all legal instruments and channels. Above all, this writer and other experts strongly believe it cements the development route for access of legislation thereby creating a national sovereignty and authority to determine access to genetic resources; confirming that countries providing genetic resources are entitled to benefit from the commercial use of such resources. As a matter of fact the various instruments put in place within the confines of the South African constitution seek to achieve all the goals of the nation's biodiversity policy in an effective manner.

This study has in a very succinct way brought to the open the realities of the problems brought about by alien species (Acacia species and *Chromolaena Odorata*) unto the biodiversity of Gauteng and KwaZulu Natal provinces in particular, and South Africa at large.

Throughout the various Chapters the discussions weigh much more on the impacts of these species to the biodiversity in the country, how these species have come about into the region, how they are spread and the threats they hold for the rest of the continent. Based on the background information done by this writer, literature review on the field of study, Survey of the past and present biodiversity management practices of invasive alien Acacia species and *Chromolaena Odorata* in the Gauteng and KwaZulu Natal provinces was essential. This was done with particular emphasis on the impact of the introduced plant species with resolve of the recovery rates of biodiversity after bio-control and other measures have been put in place.

In this study / report, the need to rationally elaborate or discuss on the research methods and approaches used in deriving the necessary data and findings was necessary to further highlight the depth of the problems. Also the complexities and *melange* of the research methods shows to what degree, adequate, proper and refined data needed to have been generated. The relevance of detailed information on the role of governmental and non-governmental institutions and organizations in conserving the biodiversity of the Gauteng and Kwa - Zulu Natal provinces, coupled with specific knowledge on the political, cultural and socio-economic obstacles to sustainable biodiversity use in South Africa (mainly the two provinces

of concern) was appropriate in canvassing a broader framework of the issues of concern to this writer and other concerned parties.

The justification of the study stems from the connectivity to the previous research study carried out by this writer almost two years ago which now shifts from a broader scope to a more specific one, capitalising on two specific species but with a different emphasis – impact on biodiversity. Equally, the present urgency of the need for solutions to the problem invasive species posed on the biodiversity of the region makes this piece of research work a unique study and thus a reference index for subsequent ones to follow within the continent and beyond.

The research in terms of its contributions (original in nature) focuses on the ways of approaching the problem of land infestations by aliens such as those investigated in this study. At each stage of the research / report there is that attempt to draw some thematic concepts, recent findings and original information generated to the change in the body of knowledge within this field of study. Despite some limitations, the centre of focus in the research did not shift either. Attempts in this study to analyse biodiversity management practises in South Africa, and related problems faced in this part of the world in retaining the bio – diversity richness of the country remains essential in the decision making process on how to make use of the research findings presented herein.

5.2 MANAGING BIODIVERSITY

This was equally well dealt with in almost every chapter. It did not only reveal the weaknesses of South Africa's efforts so far but served as a pointer on to potential approaches in dealing with the situation at hand.

5.2.1 THREATS TO SUSTAINABLE BIODIVERSITY MANAGEMENT

Much of this has been analysed in the previous chapters and to a greater extent. The discussion waged did cut across the intricacies of biodiversity management viz a viz sustainability – as a catch phrase.

5.3 CRITICAL REVIEW OF RESEARCH METHODS USED IN THE FIELD

The research methods that were followed made use of the *paradigm of choices* (i.e., using / selecting a number of different research methods). Questionnaires, interview schedules, just to name a few are some of the methods used by the researcher. Anticipated by the researcher is that, success of the research study is dependent on the mastery of the nature of the research design followed. The nature of the design (analytical) permitted the researcher to reflect on each step in order to improve on the next step (Cohen and Manion, 1995).

This study made use of both the qualitative and quantitative *research paradigms*. Rather, the *paradigm of choices* was the one followed which involved the use of a combination of several research methods. In the case of this research study these methods will comprise: interviews, questionnaires, field measurements (using the PCQ and transect methods) and also a monitoring approach. Use of these methods is necessary to achieve triangulation of the information gathered. According to Mathison (1988) triangulation is a strategy to increase the validity of evaluation and research findings. Through triangulation, we expect various data sources and methods to lead to a singular proposition about the phenomenon being studied (Mathison, 1988).

As clearly seen in the research methods chapter, numerous approaches can be used for vegetation surveys. Giving a second thought to some and trying some in the field for the sake of clarity and anticipating possible adaptations within them or amalgamating them to others was necessary for elimination purposes. At the end, a good number of research methods were ruled out, and just a few found useful for the investigations. Some of those entirely rejected on the grounds that they never tied to the demands of the study aims were: - Rutherford's (1979) method to determine available leaf material; Biomass Estimates from Canopy Volume (BECVOL); Stem diameter method; and Stem count methods just to name a few.

The BECVOL is a computer-based programme which is aimed at describing the woody component of savannah quantitatively by determining the leaf volume and leaf mass of individual trees. Though the method is applied to determine density of woody species as well as to analyse the structure of vegetation, the necessity for it was replaced with the other methods directly used for the study. The CLIMEX software and other methods such as the transect methods replaced the need for the BECVOL. Despite the fact that this method could reveal much but then the direct need to generate the data required would remain remote in the sense that it demanded so many measurements per tree, hence costly. Also, the fact that it

makes use of primary and secondary calculations gave the impression that plenty of time was required for this approach. Hence was not worth using.

Apart from the PCQ and transect methods used, monitoring approaches, interviews, questionnaires and so on centred on the fore front of the investigation strategy. In all, reconnaissance of the area – maps of topography, soil, geology, land types and aerial photographs; plant collection and identification; stratification of the area into homogeneous habitat units; determining plot size, shape and number; random location of plots; survey and description of physical environmental factors; data processing and analysis; identifying the vegetation types, naming and describing them was essential. The most lacking aspects here was that the vegetation maps used for the purpose of this study were those provided in state libraries. The naming and description of the vegetation types was not on focus as they existed already. Nonetheless, the lack of aerial maps for some sites in KwaZulu Natal province also made the investigation a bit hard to figure out some uncertainties.

5.3.1 STRENGTHS OF INSTRUMENTS AND METHODS UTILIZED IN THIS STUDY

The use of the PCQ, transect methods, monitoring techniques, questionnaires, interviews and observation schedules drew strength in the findings derived.

PCQ method

- It is less complicated in field applications derives greater information value per sampling Point,
- It is more reliable than the random pairs methods,
- The quadrats (contiguous) ease quantification and explanation of changes between temporal observations, and
- As an advantage, using the PCQ method accuracy increases with the number of sampling points (minimum of 20 points is recommended), (Cottam & Curtis, 1956) cited by Dumbois (ND).

Transect method

- Useful in classifying vegetation types, to describe relationships between vegetation and environment to illustrate the vertical structure of the vegetation,
- Useful to calculate the frequency, density and dominance of woody plant species.

Monitoring techniques

- Some sites visited have baseline data for which certain differences could be identified,

- The intensity of sampling at the various sites eased the evaluation of the variability of the changes over the recent past especially along the Elands River,
- With this technique, the ecological importance of the species within the transects could be easily interpreted, and
- Data obtained was robust as they could be analysed in different ways using different methods.

Questionnaires

- Questionnaires are data-gathering instruments used to obtain factual data, opinions and attitudes (Galfo, 1975),
- Using questionnaires in this study enables this writer to attain a large sample conveniently,
- It was realised in this study that questionnaires are much more simpler and easier to analyse,
- It is a quick method to obtain information,
- As this researcher faced financial constraints, the cost of administering questionnaires was lower as compared to other methods. Sanders (1995) and a host of researchers hold this same opinion,
- With questionnaires, if pilot tested as in the case of this study, it gives an idea to the researcher of how long it will take recipients to complete the actual questionnaires. Same is an advantage for interview schedules. Furthermore, the clarity of the questions and instructions are duly checked after the piloting stage

Interviews

- In this study the interview schedules gave openings for probing, which this writer explored to follow-up potential leads. Borg & Gall (1983) agree that this is possible, in the case of a semi-structured interview schedule, and
- Interviews bring about a face-to-face encounter, and both the interviewee / interviewer stand a chance of asking for clarifications of responses or questions.

5.3.2 WEAKNESSES OF INSTRUMENTS AND METHODS UTILIZED IN THIS STUDY

Some of the problems of using the above methods are outlined below:

PCQ method

- An individual must be located within each quarter,
- an individual must not be measured twice,
- also, stands with wide spacing of individuals present a problem in using this method.

Transect method

- Field procedures require exact repetition to ensure comparability between successive sets of data, and
- One other problem associated to the transects (especially in the coastal areas of the KwaZulu Natal province) is the inherent heterogeneity of the sample area, being narrow and long, in confounding the vegetation – environment relationship.

Monitoring techniques

Monitoring exercises were carried out to collect information. The initial round were to familiarize ones self with the terrain, especially in KwaZulu Natal Province. Follow-up rounds were more in-depth and aimed at producing succinct data. The data obtained from the monitoring exercises were taken down in the form of field notes. This was essential in helping the researcher compare information (data) derived with those of other responses obtained from interviews and questionnaires. Despite all these the following weaknesses were observed:

- With control sites not numerous and directly included in the study report, the study may yield to a limited extent useful data for long-term. Additional knowledge on variations of *Chromolaena* thickets to alternative states would be helpful in shading light on successional dynamics, and
- Conclusions about species richness and sample size were not adequately established using this method.

Questionnaires

- Time consuming,
- Probing is not possible,
- Costly, etc, etc.

Interviews

- Unnecessary arguments could erupt,
- Interviews could be interrupted, ETC, ETC.

5.4 PROPOSED CONTROL METHODS FOR ALIEN INVASIVE SPECIES

5.4.1 WATTLE CONTROL

In certain situations, wattle may be sold or used as firewood, charcoal, fence droppers, building material, wood chips, pulp wood, mine props, wattle flowers (export market), and bark (black wattle is extensively cultivated for the tannin industry).

In the eyes of some experts utilising wattles in this manner it was thought to help partially to offset the high costs of control. However, in many situations, the sale of wattle plants is not practical. A common reason is the high transport costs involved. As revealed in this writer's literature survey, and formal chats, there exists two major invader wattle species; black wattle – *Acacia mearnsii* & silver wattle – *Acacia dealbata*.

GENERAL DIFFERENCES IN WATTLES

Silver wattle (*Acacia dealbata*)

- useless for extraction of tannin
- flowers from July to August
- coppices vigorously from stumps
- nectar glands are only at the junction of the pinna and leaf midrib
- leaflets are short (1 – 2 mm)
- Stem ridges are poorly developed

Black wattle (*Acacia mearnsii*)

- grown commercially for tannin in the bark
- flowers from September to October
- immature pods occur on the tree most of the year
- mature trees do not coppice from stumps
- nectar glands are found along the entire length of the midrib
- leaflets are short (1- 2 mm)
- stem ridges are prominent but not wing – like

Green wattle (*Acacia decurrens*)

- can be considered for extraction of tannin by negotiation with the extract factories

- flowers from august to september
- coppices from stumps
- nectar glands are only at the junctions of the pinna and the midrib
- leaflets are long (up to 1 cm)
- stem ridges are pronounced giving branchlets an angular, wing – like appearance

Wattle is costly because infestations; kill grass and indigenous vegetation, increase erosion on slopes, decrease water supply.

Successful wattle control is no doubt long term because of; vigorous coppice regrowth from stumps (larger black stumps do not coppice), vigorous suckers from roots (black wattle is less vigorous), large numbers of long lived – seeds, and very few natural enemies are present in the case of South Africa to curb growth and reproduction. The suggested control approaches of wattle species discussed in this thesis is based on the SAWGU (South Africa Wattle Growers Union) initiative. The SAWGU proposal on combating the spread of wattles specifically is quite sound but needs further modifications especially in terms of the integrative aspects. Overall this author embraces the concept in principle whilst putting in place suggestions to beef up the efficiency of such a plan.

STRATEGY FOR SUCCESSFUL WATTLE CONTROL

It has been established within the scientific community that there are three levels of control necessary to achieve progress which are as follows:

Initial control – This implies drastic reduction of the existing wattle population i.e. this involves clearing wattle.

Follow – up control – It involves removal of seedlings, root suckers and coppice regrowth i.e. mainly involves treatment of regrowth.

Maintenance control – It brings about sustained or reduced wattle numbers / density with low annual control costs. This is to prevent invasion or densification of wattle. At this level, wattle is no longer considered a problem. This writer has also gathered that monitoring the situation yearly to avoid wattle spread and densification, with increased control costs is absolutely necessary. The aim as is generally agreed amongst alien invasive control experts is to reach the maintenance level of control, and then rehabilitate land that has been seriously infested by wattle. For example by use of grass species to cover and bind bare soil or convert unwanted wattle jungle into plantation.

Successful wattle control requires good planning

Clearing wattle from your property can take 5 to 20 years. This depends on the extent and density of the wattle infestations, and how much you can afford to spend each year. It is important to make steady progress with control, thus systematically reducing the extent and impact of the infestations.

There are three rules to follow:

- 1- Do not try to control too much in one year.
- 2- Start with light infestations first because these are likely to increase and are relatively easy and cheap to control. Dense infestations have already reached their peak.
- 3- Do not begin initial control of a new infestation unless all follow – up and maintenance control has been completed in areas already treated.

The Planning method

- Divide your property into control areas, using convenient boundaries, e.g. fences, roads, streams. Number these areas for record purposes.
- Rank infestations or areas into high, medium or low priority for control. Number these infestations for record purposes.
- Describe the infestations: Record the type of growth, e.g. trees, saplings, coppice and seedlings.
- Estimate the % cover as a measure of density, e.g. 75 – 100% cover is very dense, 50-75% is dense, 25 – 50 % is medium, 5 – 25 % is sparse and 0 – 5 % describes a scattered infestation.

For each high priority area or infestation:

- List the required resources, e.g. labour, herbicides, equipment, transport.
- Select appropriate control methods, using registered herbicides.
- Select appropriate rehabilitation methods to establish a ground cover. Aim to stabilize / bind bare soil after wattle control to prevent soil erosion and re-invasion by wattle.
- Determine your annual funds for wattle control: The rate and scale of progress with the control work should be based on the available funds.
- Calculate the budget of the first year according to the funds available, e.g.:
- 75% for follow – up control work and rehabilitation of previously cleared areas
- 20% for initial control of a new area,

- 5 % for an emergency ‘fire fund’, used for seedling control after runaway fires or a “flood fund”, used for replanting grass where seeds have washed away during heavy rains.

Identify areas of potential income to help offset the costs of control. E.g. wood lots, and also any areas that can be converted into pastures, natural veld or annual cash crops.

It is important to keep simple records of daily operations, e.g. record the labour days, herbicide volumes, and equipments used. This is helpful in establishing standards / norms and therefore sets realistic targets for the control work. At the end it is ideal to include these records into the budget for the second year. for follow – up control of regrowth.

GENERAL RULES FOR CONTROL

- Herbicides should be applied when plants are actively growing.
- Use only herbicides that are registered for wattle control. Follow label instructions carefully.
- Test alternative treatments on a small scale before applying them to a large area, as there is no guarantee of success.
- Start control work at the top end of water courses, and progress systematically downstream.
- Sparse to medium infestations along water courses can increase in density and extent and have a future increased impact on water flow. A small separate labour team can work rapidly in these areas while the main team works in the dense areas.

Confine large dense infestations: It is advisable to start at the outer edge of large infestations and work inwards. Thus, each year, control all trees, saplings, coppice and seedlings in a 5 to 10 m – wide strip on the edges of infestations. This confines infestations by preventing spread to neighbouring areas. Confining infestations has high control priority as this maintains progress with the control programme.

Confine large infestations: This works systematically inwards

Thin out large infestations: Thinning out large medium-dense infestations by controlling low-density / sparse wattle growth inside the area. This encourages and protects grass growth and breaks up the infestations into smaller units that are more easily controlled. The timely control of sparse growth also prevents densification of the infestation.

The Control of costs

Any given cost of control are likely to be inaccurate. This is on account of inflation, annual and regional differences in costs of herbicide and labour, and differences in terrain and both density and extent of the infestations.

For this reason, resource requirements for the different methods are given as guidelines, in terms of time (man days per 1 000 stems) and volume of the products used (L herbicide mix per 1 000 stems). Man days = the number of days for one worker to complete the task (Man days = labour days = shifts). Above all, it is widely estimated that, for 14 man days per 1 000 stems; 1 man takes 14 days for the task or 14 men take 1 day for the task or 7 men take 2 days for the task.

TABLE 37: INITIAL CONTROL OPTIONS FOR WATTLE

Control option	Situation
Threat standing trees: A. Basal bark (mix herbicide in diesel) B. Strip bark C. Stripbark + Basal bark (mix herbicide in diesel) D. Frill (mix herbicide in water)	Trees unsuitable for utilization - stems less than 10 cm diameter, avoid high stem densities near water course - stems more than 3 cm diameter, no crevices in bark - stems more than 10 cm diameter, with crevices in bark and / or exposed roots - stems more than 3 cm diameter, stems are accessible to make downward slanting cuts, no crevices in bark for total frill
Cut stump treatments: E. Stripbark stumps F. 2% Tordon 101 (mix herbicide in water) F. 3% Timbel (mix herbicide in water) F. 20% Mamba (mix herbicide in water) F. 10% Chopper (mix herbicide in water) F. 1.5% Access (mix herbicide in water) G. Fungus (mix fungus in sunflower oil) H. 1% Tordon super (mix herbicide in diesel) H. 2% Garlon 4 (mix herbicide in diesel)	Trees suitable for utilization - slow work, requires much labour - safe for stumps in grass, avoid drift, avoid contamination of waterways - safe for stumps in grass, safe for use in waterways - avoid overspraying on to grass, safe for use in waterways - avoid spillage on grass, avoid contamination of waterways - safe for stumps in grass, avoid contamination of waterways - safe for stumps in grass, safe for use in waterways - safe for stumps in grass, avoid spillage into waterways - safe for stumps in grass, avoid spillage into waterways.
Fell + burn treatments: * Follow burning regulations. I. Fell, stack brushwood burn J. Fell, spread brushwood, burn	Disposal of brushwood - stack small amounts in rows or heaps, control large trees standing, burn where safe - spread brush evenly over a large area, control large trees standing, burn where safe

(Source: SAWGU with some slight modifications by author)

Explanation: Table 37 shows different control options applicable to different situations. It highlights the varying strategies ideal for successful wattle control.

TABLE 38: FOLLOW-UP AND MAINTENANCE CONTROL OPTIONS FOR WATTLE

Control option	Situation
Mechanical treatments: A. Hand pull seedlings	Sparse stem density - where labour is easily available, seedlings are sparse, soil is wet
D. Fire: burn high fuel loads of grass	- take precautions to contain the fire, follow burning

	regulations
Cut stump treatments: B. Cut plants + treat stumps (refer to the initial control options)	Sparse to medium stem density - suited for rough terrain or where there are large distances between plants
Foliar treatments: C. Spotspray 0.75% Garlon 4 (mix herbicide in water). This treatment has been reduced to 0.25% for seedlings (not coppice) less than 0.5m in height. C. Spotspray 0.5% Torlon 101 (mix herbicide in water) C. Spotspray 1.5% Roundup (mix herbicide in diesel) or Use similar products, for example - Mamba 360 SL or Glyphosate 360 C. Spotspray 1.4% Touchdown plus	Plants less than 1m tall - safe on regrowth where grass is present, safe for use in waterways - safe on regrowth where grass is present, take precautions against drift, avoid contamination of waterways - avoid treating wattle where grass is present, black wattle only, safe for use in waterways, protect desirable species -avoid treating wattle where grass is present, black wattle only, safe along waterways, protect desirable species
Coppice treatments: Cut plants, with foliar application to coppice regrowth (use foliar treatments C)	Plants taller than 1 m

(Source: SAWGU with some slight modifications by author)

Explanation: Table 37 shows different follow up control options applicable to different situations in the fight against the spread of wattles. Varying strategies are presented in the above table including maintenance options.

MAINTENANCE CONTROL METHODS

A low annual input is often required to maintain the veld in good condition. If this is neglected, experts believe that the veld will revert to the follow-up level of control, with denser patches of wattle and higher control costs. Control options for maintenance control are the same as those for follow-up control. According to conservationists in the field, at maintenance control, wattle is no longer considered a problem.

REHABILITATION OF WATTLE JUNGLE INTO PLANTATION

If access to any of the markets mentioned in the introduction is feasible, it is worth turning the problem into opportunity.

What appears to be a dense jungle can be thinned out yielding lathes, building poles and firewood initially. Trees that are less than 5 years will respond with increased growth after thinning, and after a further 3 years, an improved yield of pulpwood or charcoal will be achieved. Older trees are less likely to respond.

Trees that have black and / or corky bark are less likely to have the bark easily stripped, so these trees should be removed during thinning operations for firewood. Trees older than 15 years are usually not readily stripped.

The ideal stocking is 1 600 trees per hectare. A jungle could be thinned to leave as many as 3 000 trees per hectare and give an acceptable size of tree or pole to handle. Thinning can be done in two ways:

either

mark out rows spaced 3 metres apart removing everything in the interrow, and then on the row thinning inferior trees leaving the most vigorous, better shaped, desirable trees between 1.3 to 2 metres apart.

or

do a scattered thinning throughout the area without rows making sure that remaining trees are between 1 and 1.4 meters apart in all directions.

REHABILITATION OF BARE SOIL BY PLANTING GRASS

After removal and control of the wattle, it is generally advised that one should plant suitable grass species. The addition of fertilizer aids rapid establishment of grasses but is often omitted if the aim to get back to natural veld.

In selecting species suitable for your area and according to the land management aims, consider the following grass characteristics:

- pioneer species with rapid establishment,
- good erosion control, especially on medium to steep slopes,
- grass species can produce high fuel loads and has good recovery after fire, where burning to control wattle is required,
- good palatability, where grazing by livestock is required,
- indigenous species, where increased by livestock is required,
- annual or weak perennial species with limited life span, where neighbouring slower – growing grass species will eventually colonize the planted area.

The correct use of fire and / or correct stocking rates keep the grass sward healthy and controls wattle seedlings.

THE SUPPRESSION OF WATTLE SEEDLINGS AND ESTABLISHMENT OF GRASS IN AREAS WITH NO BRUSHWOOD AND LITTLE OR NO ORGANIC MULCH

Experts do warn that such a strategy requires intensive management and close supervision. The herbicide Lontrel is well known to be registered for the suppression of wattle. The growth of treated plants ceases for a period of up to six months. Up to 60% of the treated plants die, with the remaining stressed 40% usually killed by winter frosts.

Stressed wattle saplings can aid grass establishments:

- the plants disperse / break up the energy of the rain drops thereby improving rain infiltration and reducing runoff
- the roots help hold the soil
- the stressed plants provide some shelter from wind and heat to planted grass seedlings and help retain moisture in the soil
- the stressed plants allow the building up of organic material and prevent it being washed away during heavy rains. The organic material already present is held, and material e.g. dead grass and brushwood is washed into the sprayed area and trapped by the suppressed seedlings.

Planting of grass among the suppressed seedlings, to take advantage of the built – up organic mulch to aid establishment is also called for.

In terms of follow-up control, efforts should be done once the grass is established, using a registered selective herbicide to kill the wattle saplings. To enhance effective control measures, it is instrumental that all concerned parties be able to differentiate between all the acacia species. Thus, knowing wattle differences is vital.

ESTIMATING WATTLE SEED NUMBERS IN THE SOIL

Seeds of wattle are long-lived, and may remain dominant in the soil for up to 100 years. This dormancy may be broken when the veld is burned. The seed coat cracks, and the seed germinates during the following rains.

TABLE 39: ESTIMATED NUMBER OF WATTLE SEEDS IN THE SOIL

Number of stems / ha	Mean stem diam.	Range seed numbers in 1m x 1m x 6 cm	Maximum seed numbers (1 ha x 6 cm)
5 000	5 cm	2 000 – 63 000	600 million
13 000	5 cm	1 000 – 150 000	1 500 million
2 300	9 cm	7 000 – 540 000	5 000 million

(Source: Author’s own)

Explanation: Table shows estimates of wattle seeds in the soil per given area of land. For example in an area having 5 000 stems per hectare the maximum seed numbers in the soil could attain six hundred

million.

Research experts in South Africa claim that approximately 70% of the seeds are found in the top 6 cm of soil. This is the zone where fire is most effective either to kill the seeds or to stimulate germination.

BIOLOGICAL CONTROL PROSPECTS FOR WATTLE SPECIES

Insects have been used in this endeavour by South African researchers. A seed – attacking weevil, (*Melanterius maculatus*), which feeds and lays eggs on developing green pods of black wattle, has been released and is established in parts of the S.W Cape. It is now known that the effect of this weevil is being monitored. It is also intended to introduce two more *Melanterius* weevils from Australia to limit seed production of silver and green wattles. Use of additional seed-reducing insects (midges and seed wasps) is being evaluated for black, silver and green wattles. Biological control confines infestations by reducing viable (live) seed numbers on the plants and thus preventing further spread. The insects will not affect plant growth nor reduce the soil seed bank.

Conventional methods, using registered products for control of wattle trees and soil seed bank, must therefore be used in combination with any seed attacking bio-control agent.

Fungus for control of wattle

A wood rotting fungus (*Cylindrobasidium laeve*), which occurs naturally in South Africa, was isolated some years ago from wattle stumps and is registered as a fungi inoculant for the control of regrowth in black and golden wattle. This product Stumpout, containing live pores of the fungus *Cylindrobasidium laeve*, and is diluted with sunflower oil as specified on the labels, and painted onto the felled tree stumps.

For the effective use of this inoculant, it is required to fell the wattle trees at ankle height above ground level, and apply the inoculant as soon as possible after felling. It is worth noting that treatment is best when each stump is treated individually with the fungus.

Treated stumps may sometimes produce regrowth. However, the stump plus regrowth will be killed within a period of nine months to a year. No follow-up treatment is necessary here. The fungus is safe near water courses and in other sensitive areas and is best used in light to medium density infestations, where the product is highly cost effective. As this is a living product, care needs to be taken in handling and storage of the fungus that will kill the stumps more rapidly.

It is evident that there are several registered herbicides used for black wattle, and also silver control in South Africa. Some of these herbicides have active ingredients such as glyphosphate 360, triclopyr, clopyralid, bromacil, and tebuthiuron just to name a few. Already recent developments prove that the ultimate solution to wattle control is the use of integrative approaches.

5.4.2 CHROMOLAENA CONTROL

Chromolaena odorata is a self-propagating American weed plant (from Paraguay to Florida). This weed was first observed in **Ghana** in February 1969 at the Legon Botanic gardens (Hall et al., 1972) cited by Timbila (ND). Since 1937, when the first introduction of *C. odorata* into Africa was recorded in Nigeria, the weed has invaded most of West and Central Africa and continues to spread into new areas; particularly in Africa. Zebeyou (unpublished report, 1996) cited by Timbila (ND) reported that the normal altitude of 1,200m has been exceeded as *Chromolaena odorata* was collected in Bafoussam in **Cameroon** at an altitude of 2,000m. In addition to this *Chromolaena odorata* was also recorded in Chad (a neighbouring country to Cameroon), where the rainfall is only 600 mm per year as opposed to the normal rainfall requirement of 1,000-2,000 mm per year. This limit is further exceeded as *Chromolaena odorata* is reported to grow in arid bushveld vegetation with annual rainfall less than 500 mm in South Africa (Goodall and Erasmus, 1996) cited by Timbila (ND).

These reports give further evidence to the predictions regarding the potential distribution of *C. odorata* in most countries between the Tropics of Cancer and Capricorn including South Africa (Gautier, 1992; McFadyen and Skarratt, 1996) cited by Timbila (ND).

In South Africa, Timbila (ND) claims, a number of National Game Reserves have been infested by this weed. More recently in 1991 it was observed near Phalaborwa on the western border of Kruger National Park (Erasmus and Goodall, unpublished data) cited by Timbila (ND). Indications are that the weed is fast replacing fodder for game animals in the Kruger National Park (R. E. McFadyen, personal communication, 1996) cited by Timbila (ND). Thus, further spread of this noxious weed is a threat to game animals.

The introduction of *Chromolaena* into Africa has given rise to the pestilence of *Zornocerus* grasshoppers as a result of a non-nutritional relationship existing between the weed and the insect (Boppre, 1991; Timbilla and Braiman, 1996) cited by Timbila (ND). On the other hand *Chromolaena odorata* is claimed to have some useful attributes in checking erosion, reducing

fallow periods and improving soil fertility (Timbila, ND). These attributes of the weed have often generated a conflict of interest regarding the control of the weed in some countries. There is no controversy about the weed status of *Chromolaena odorata* in South Africa since 1983. Timbilla (1996) and Timbilla and Braimah (1996) quoted oncemore by Timbila (ND) are, however, of the view that there is need to look at the pestilence of *Chromolaena odorata* in an ecological context. In South Africa, *C. odorata* is known to decrease the carrying capacity and species diversity in both grassland and forest (Pickworth, 1976, Liggitt, 1983; MacDonald, 1984; Erasmus, 1985; ByfordJones, 1989; Erasmus, 1991) cited by Timbila (ND). This situation is not different in Ghana and other infested parts of Africa, Cameroon not excluded.

Realizing the constraints of the weed to agricultural production in Ghana, a biological control programme using the arctiid moth, *Pareuchaetes pseudoinsulata*, was initiated in 1989 in a pilot project in the Ashanti region, reports Timbila of the Crop protection unit in Kumasi. Following two years of preliminary investigations, field releases were made between 1991 and 1993 and subsequently the insects established in 1994. By the end of 1995, Timbila (ND) acknowledges that a dramatic damage was recorded up to 45 km from the release site (see Timbilla, 1991; Timbilla, 1996; Timbilla and Braimah, 1996).

Timbila's findings, **though preliminary** as he acknowledges, raised hope for mitigating the menace of *Chromolaena odorata*. The use of other bio-agents in addition to *P. pseudoinsulata* is thought would speed up control of this noxious weed. Timbla's suggestion is that biological control is the most viable, modest and environment friendly way of salvaging the further spread of *Chromolaena odorata*, and should be seriously considered in a global perspective since the weed cuts across many boundaries. But this can be disputed. In many other parts of the world, South Africa included, a country known to be the champion of bio-control efforts in the African continent has realised in some of its projects a failure in this approach thus driving back to the '*integrative concept*' which this writer and many others believe is the best, especially when the infestation is dense. There lies the thrust of this argument if concerned parties really wish to achieve successful control in a long-term.

EFFECTS OF CHROMOLAENA ODORATA IN SOUTH AFRICA

Chromolaena odorata invades coastal grasslands and replaces species – richness communities with mono specific thickets in a short time. Research suggests that root competition (Slaats

1995) allelopathy (Hamilton et al. 1993) and shading (de Foresta & Schwartz 1991) by chromolaena are the main factors causing undesirable changes in natural vegetation.

THREATS TO GRASSLANDS

As a result of alien infestations, transformations – plantations, fires and other destructive processes that have taken place in the grasslands, especially the coastal parts which harbours the KZN province, very little is left of the vegetation. There is no data available on how much coastal grassland remains in this province of South Africa, their respective conditions, management and protection. The greatest threat to remaining habitats is development.

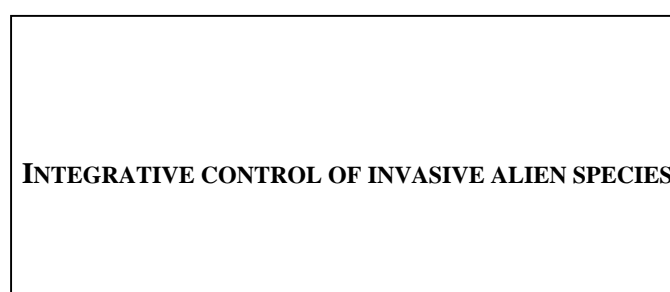
The association between threatened plants and ecosystems in KZN (Scott – Shaw 1999) cited by Godall (1999) shows disproportionately high representation in grassland (58%) compared with forest (16%). Drakensberg alpine tundra (11%), savanna (10%), fynbos (3%) and valley bushveld (2%). Grasslands are vulnerable to all forms of land conversion. Coastal grasslands in KZN account for 14% of the threatened species in grasslands, excluding Pondoland ecotourism development, unsustainable agricultural expansion, exploitation of forest resources and permanent heavy grazing are threats to coastal grasslands and estuaries in the Pondoland region of the Eastern Cape (McKenzie 2000) cited by Godall (1999) and in KZN.

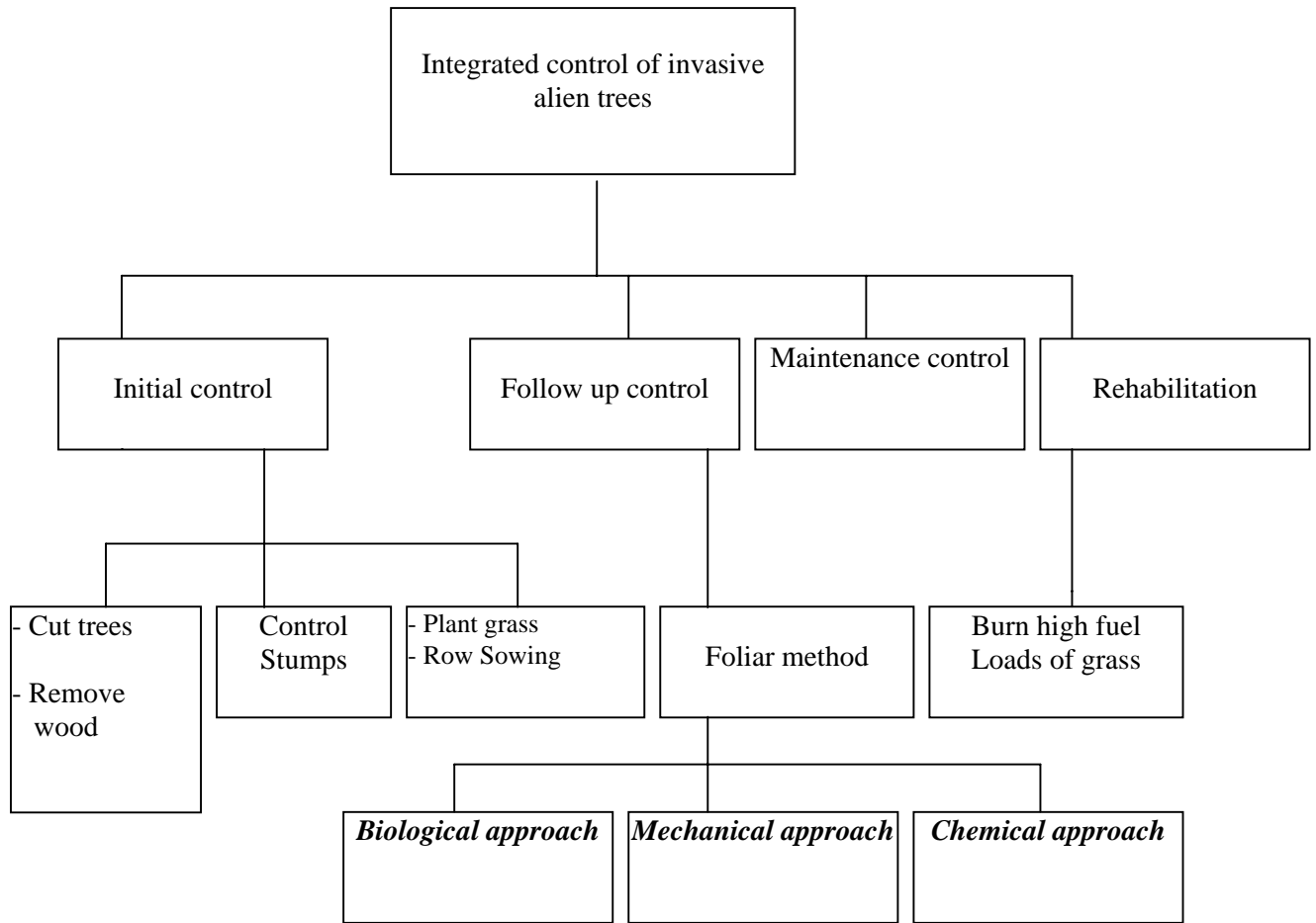
Integrated control approaches are the tools of today that managers need to use to manage vegetation as grassland or forest and these include fire, chemical control and mechanical control, although it is still believed by some schools of thought that grassland states can only be managed with fire.

Despite statistical limitations, this study contributes to the holistic management and conservation of grasslands in Africa. The integration of fire and invasive plant management practices (biological, chemical, and mechanical control methods) are crucial for retaining the natural vegetations, hence grasslands. Therefore, the following recommendations apply to the alien invasive species found in the grassland regions of South Africa and the rest of the continent.

FLOW CHART INDICATING ALTERNATIVE APPROACHES TO ALIEN INVASIVE PLANT CONTROL

FIGURE 9: CONTROL OF ALIEN INVASIVE SPECIES

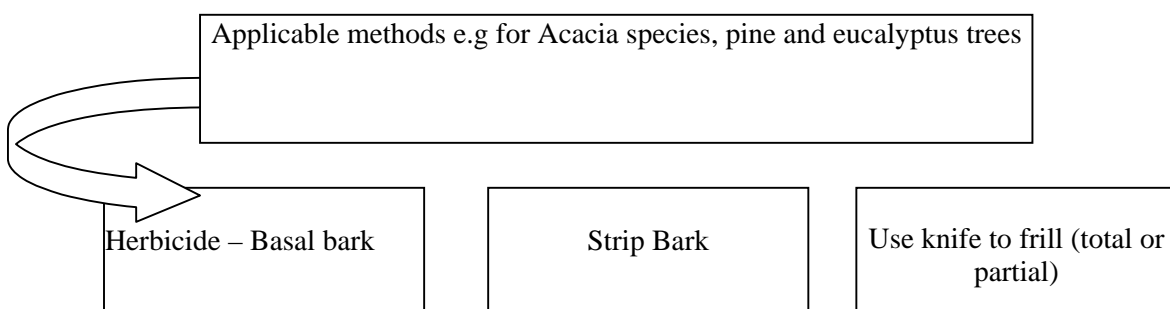


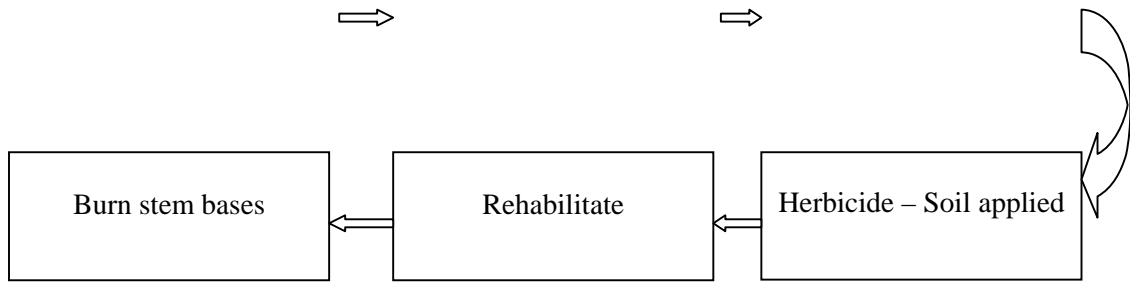


(Source: author's own)

Explanation: This illustrates alternative approaches to controlling alien invasive species. It involves a combination of the most suitable control methods for a species in a particular situation.

FIGURE 10: STRATEGIES AIMED AT CURBING THE SPREAD OF ALIEN INVASIVE TREE SPECIES (INITIAL OPTION)

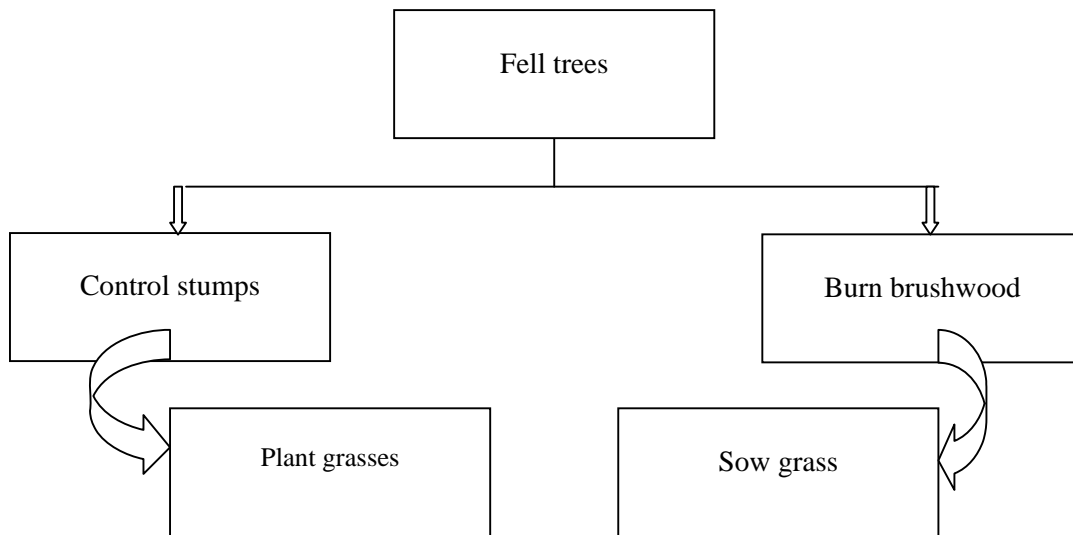




(Source: author's own)

Explanation: Initial options useful to controlling the spread of foreign invasive species. This approach is simple and cheap. Following this process trees could take about 16 –18 months to die depending on the size and species.

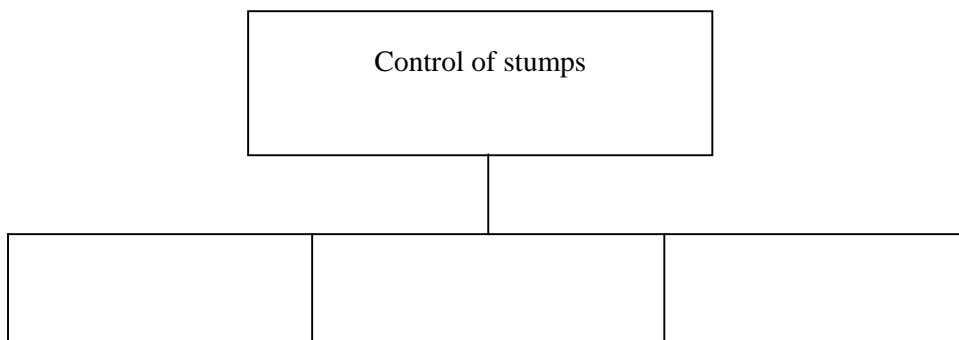
FIGURE 11: ALTERNATIVE CONTROL ROUTES FOR WATTLES, GUM OR PINE TREES (GENERAL)

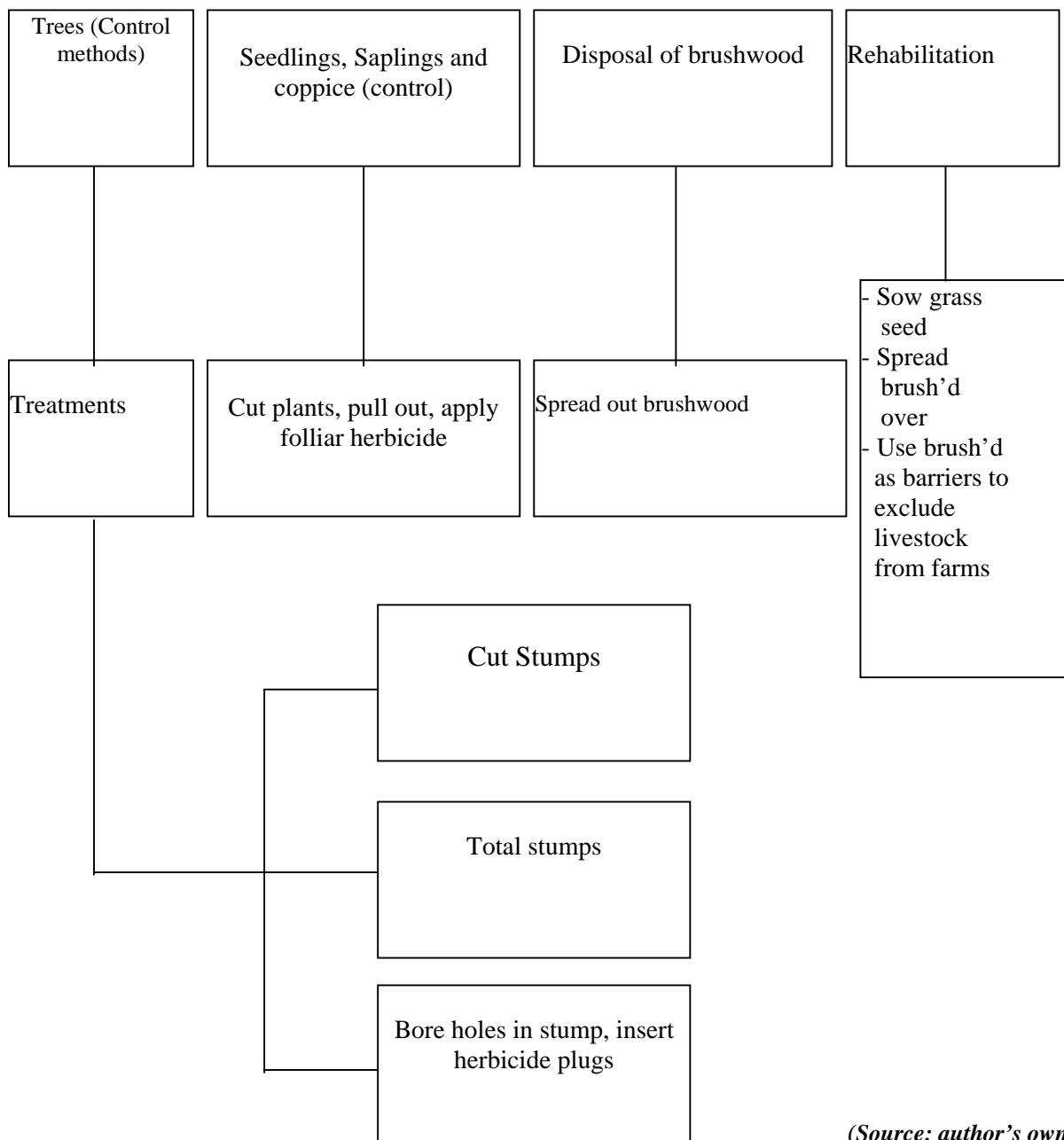


(Source: author's own)

Explanation: Trees such as wattles, gums or pines can be controlled as illustrated above. Control can be achieved by taking out stumps or burning brushwood, then followed by planting of grass or sowing grass if the initial step involved burning of the brushwood. This is suitable where infestations are easily accessible and can be harvested.

FIGURE 12: STEPS FOLLOWED FOR THE CONTROL OF STUMPS

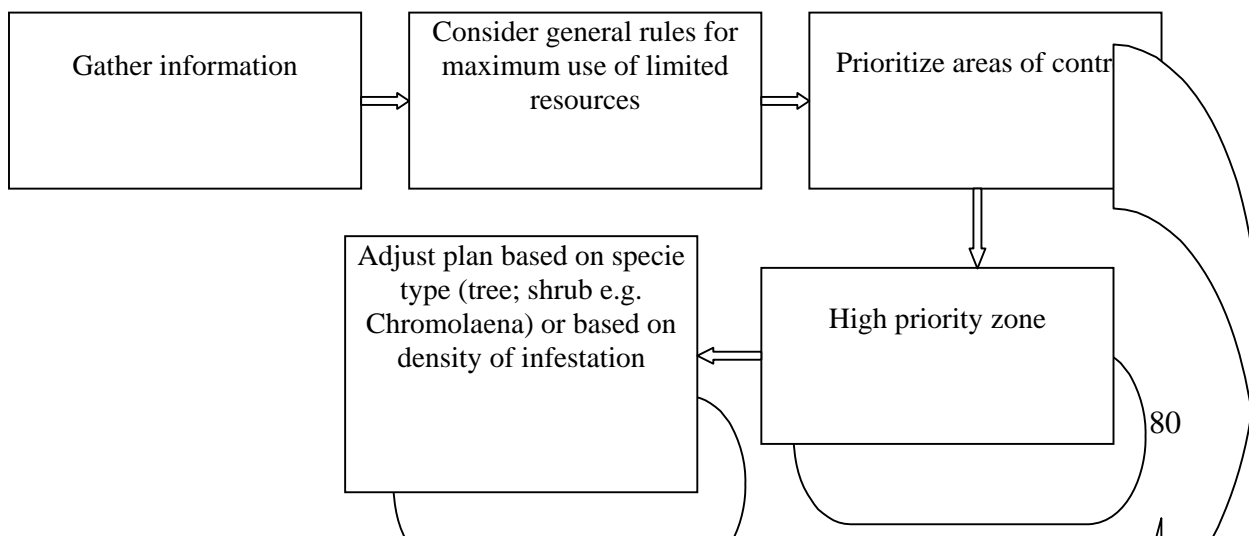


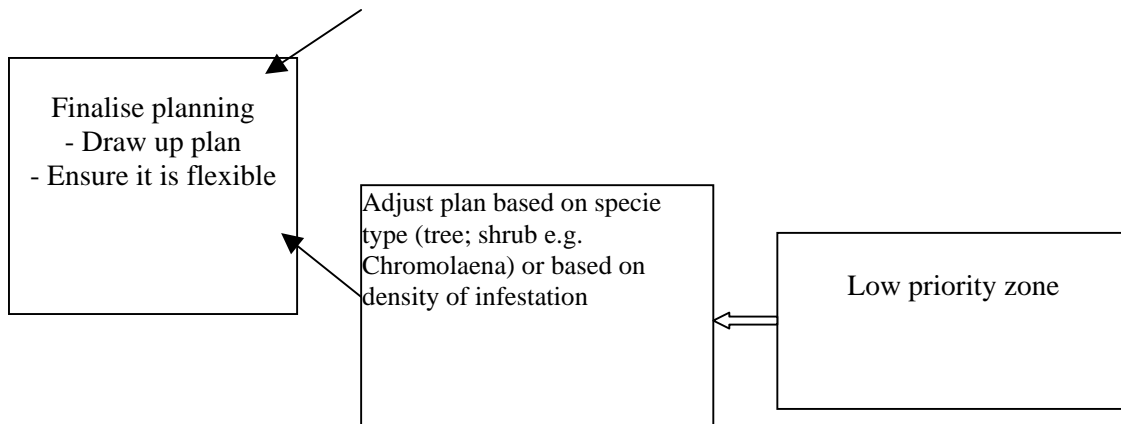


(Source: author's own)

Explanation: Figure 20 gives us a clearer picture as to how to proceed with control of stumps. With this approach individual stumps could be neutralized at the end by inserting herbicide plugs in them.

FIGURE 13: CONTROL PLAN OF INVASIVE ALIEN SPECIES (INTEGRAL CONTROL OPTION)

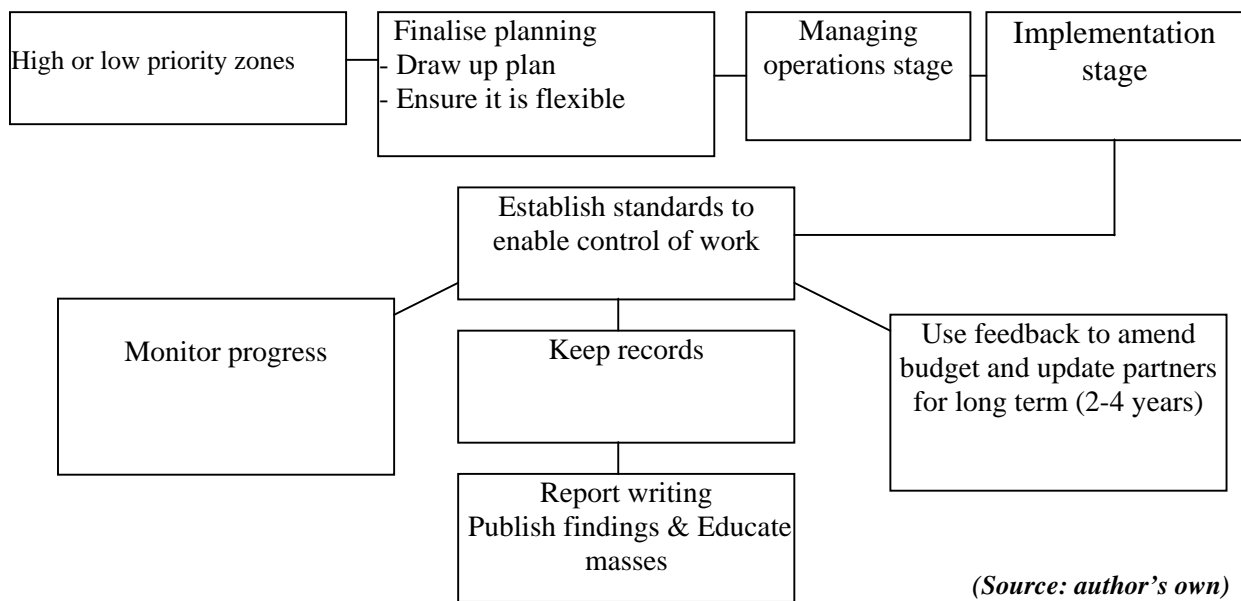




(Source: author's own)

Explanation: A concise approach to planning the control of IAS through an integrated route is highlighted above. Removing alien vegetation is an initial objective here. As soon as this is done a land use plan and objectives must be clearly defined. This determines how the area is rehabilitated and returned into production.

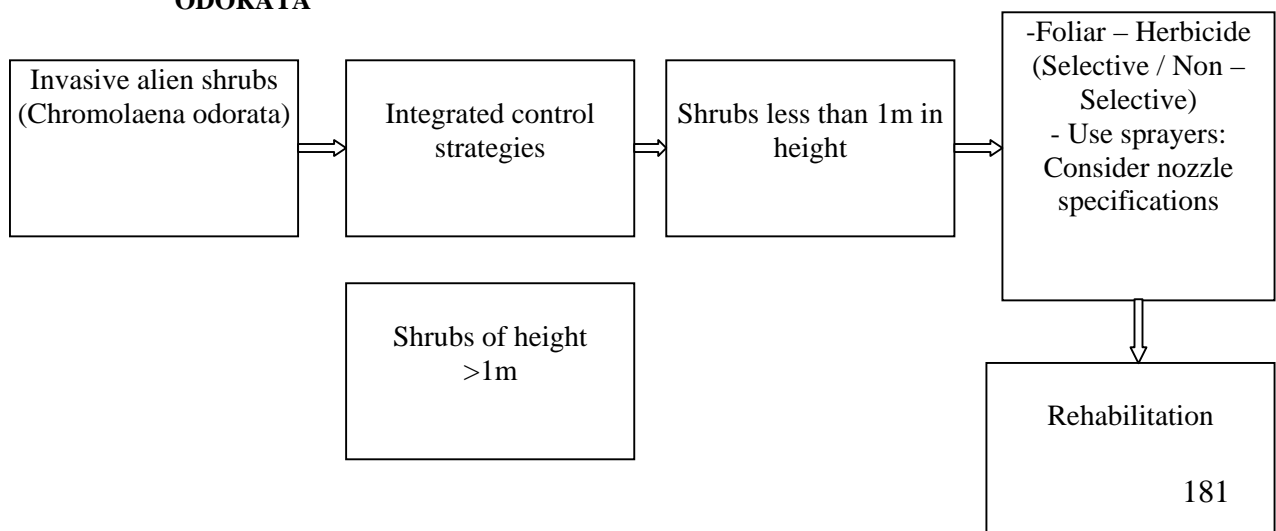
FIGURE 14: PLANNING TOWARD IMPLEMENTATION

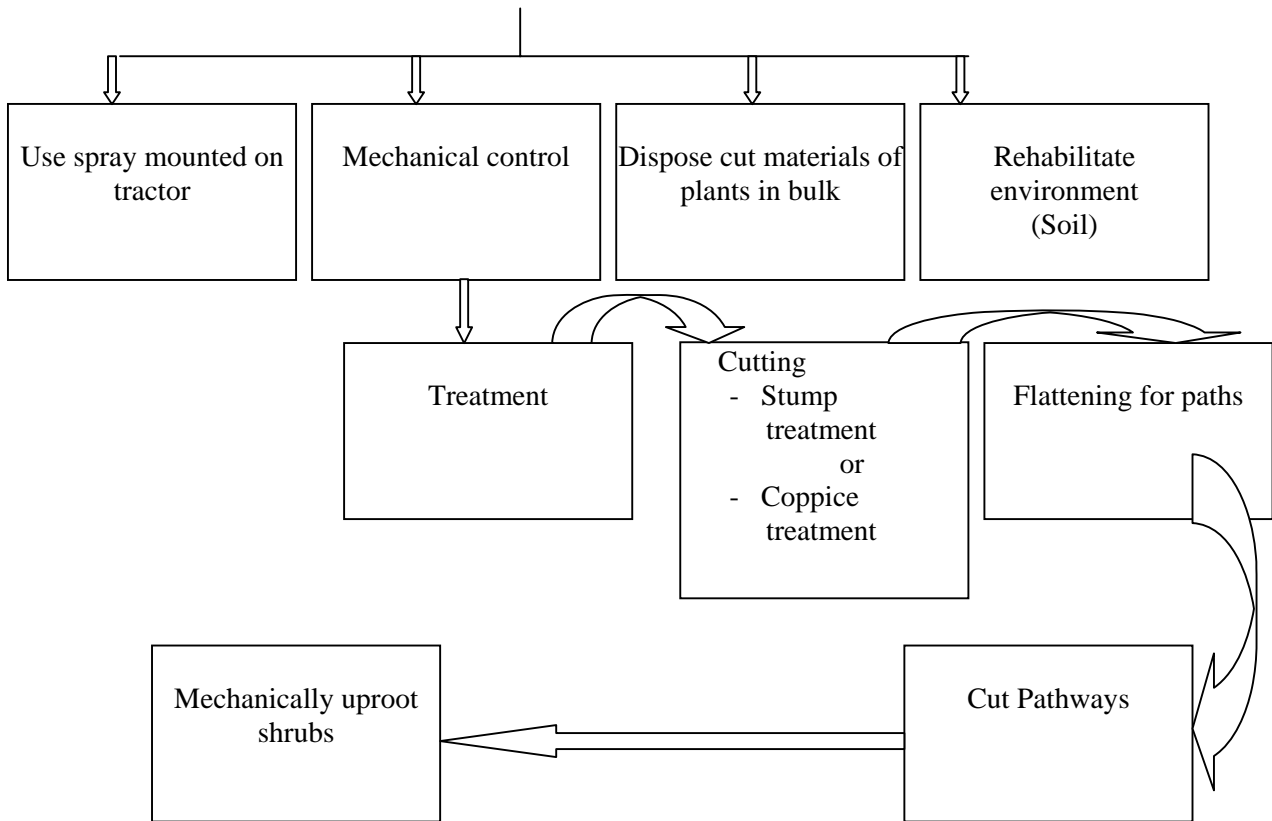


(Source: author's own)

Explanation: Finalizing planning is essential in order to make use of available resource. Figure 22 shows that final planning is crucial once a decision has been made for a commitment to alien plant control.

FIGURE 15: INTEGRATIVE CONTROL APPROACH IN THE CONTROL OF CHROMOLAENA ODORATA





(Source: author's own)

Explanation: The above shows a combination of methods brought together in order to tackle alien shrubs. The strategy involves mechanical, chemical, and biological control methods.

A good control programme for alien vegetation must include three phases; the initial, follow – up and maintenance control approaches. The charts just seen follow the same pattern and apply also for the control of *Chromolaena odorata*.

Initial control:

This involves drastic reduction of the existing population.

Follow – up control:

Control of seedlings, root suckers and coppice regrowth.

Maintenance control:

Sustain low alien plant numbers / density with low annual control costs. At this phase, alien plants are no longer considered a problem.

Each control operation requires a number of recommended control methods to achieve a reduction in the alien plant population. A recommended control method should always be a *tried and tested method* that when it is used correctly will be effective at the initial, follow – up and / or maintenance control levels.

CONTROL STRATEGY

Below is a tabulated example of an integrated control strategy made up of a number of methods suitable as well for curbing the spread of *Chromolaena odorata*. It conforms with the pattern of the chart in the previous pages of this study / report.

TABLE 35: CONTROL STRATEGY

Cut trees. Remove wood.	Method 1	Initial control (I.C)
Control stumps	Method 2	I.C
Plant grass. Row sowing	Method 3	I.C
Foliar	Method 4	Follow – up control
Burn high Fuel loads of grass	Method 5	Maintenance control

(Source: Author's own)

Explanation: Table 40 highlights an integrated control strategy made up of a number of methods suitable for a particular situation.

5.5 CONCLUSIONS

5.5.1 RAMIFICATIONS OF THE SPREAD OF ALIEN INVASIVE SPECIES IN SOUTH AFRICA, AN ON - GOING SAGA.

The control of weeds is regulated by the Agricultural Resources Act (Act 43 of 1983). In terms of this act, species are declared either as weeds or as invaders. The presence of declared weeds is no more condoned. As a matter of fact, where they occur, they are to be either eradicated or effectively controlled by the landowner. Strict prohibitions have been laid on the unauthorized dispersal and trade in weeds and seeds of weeds. Lists of declared invasive species are revised from time to time. Also the Agricultural Resources act is further enforced by other Acts such as the forest Act (Act 122 of 1984), Water Act (Act 36 of 1998).

South Africa as a signatory to the Biodiversity convention is obliged to prevent the introduction of alien species that threaten ecosystems, habitats or species. This is costly, (especially control) and requires time for significant achievements to be made.

On the other hand one may have to come to terms with certain issues here. None of the alien invasive species present in South Africa are a threat in their countries of origin. This is so because they come from parts of the world with:

- similar climate.
- similar soils.
- similar ecology.

Thus, they become well adapted to grow in their new environment, and preadapted to areas prone to fire.

Also many species become invasive because they:

- have the ability to produce large numbers of viable seeds, and the ability to grow fast and reach a mature age very quickly.
- have seeds that can be easily spread by wind, birds or water.
- are released from the pressures of a host of insect predators and other pathogens which monitor them in their various homes / countries.

It is very possible to identify, hence avoid invasive species for the simple fact that they need to meet most of the above criteria.

5.5.2 IMPACT OF ALIEN INVASIVE SPECIES ON WATER SYSTEMS

It is now well recognized that invasive alien species, particularly tree species, often have much increased water usage as compared with native vegetation.

Perhaps not quite understood are the reasons for this increase in the use of water and whether such an increase should be expected from all species of invading alien trees under all environmental conditions. However, not all alien plant infestations use more water than the natural vegetation that they replace but, as a general rule, trees tend to use more water than grass or shrubs. The greatest impacts occur when evergreen plants replace seasonally dormant vegetation. Thus, where alien trees invade grasslands or fynbos shrublands, the overall water use by the vegetation increases, leaving less water for the streams.

In several research sites (for catchment experiments) in S. Africa, catchments in grassland were afforested with pines, and in some cases eucalyptus. For example an 82% in streamflow was observed in KZN Drakensberg 20 Years after the planting of pines took place. Experiments of this magnitude were likened to invasions by alien trees whereby the end result was same - replacement of a grassland area with a tall woodland or forest. It is worth noting that, most of the streamflow in S. Africa is generated from upper catchments, and these are

the areas that are most at risk from invasion. Such areas are likely to become fully invaded if they are not managed.

Also in this regard, riparian zones (the strips of land along rivers) are of special concern. Here plenty of water is available and alien species use this water whenever it is available. The water used - up by trees in riparian zones tend to double that of similar / same trees growing away from rivers. As a result of this riparian zones are not planted by formal forestry, but nonetheless become invaded and have to be constantly cleared to prevent these impacts. Increases in streamflow can therefore be reached if the riverbanks are cleared of invasive species. Meanwhile, the effects of invading alien plants on floods have not been well studied.

Water use so far by pines, eucalyptus, poplars, and wattles has been well measured in S Africa. As concerns other species there is no available data yet. Current national estimates indicate that invading aliens cover 10 million hectares, and use 3.3 billion m³ of water in excess of that used by native vegetation every year. This estimate is based on models which make a number of assumptions hence, could be regarded as only preliminary. However, these reductions are significant, thus, indicating the urgent need for intervention of sorts. South Africa like many other countries cannot afford such losses. Nevertheless, these losses may be aggravated if alien plants invade other areas left uninvaded. In a nutshell, a lack of prompt action would therefore be one of the most serious threats to the sustainability of water yields from S. Africa's catchments.

- Should alien plants become an integral part of a catchment management agency's responsibility? Yes

The reason for alien plants being so thirsty is that, the faster a plant grows, the more water it uses. This is the case of alien plants - especially trees. They are deep-rooted and able to transpire even during the dry season.

5.5.3 ROOT SYSTEMS OF INVASIVE TREE SPECIES

A majority of a tree's roots are situated within the first 0.5m below the soil surface. The remaining portion of the roots (sinker roots) penetrates into the lower soil layers and may be critical for a plant's survival during periods of drought.

Alien plants grow rapidly and some establish deep sinker roots while still young. Eucalyptus for example establishes deep sinker roots while young, even when the upper soil profile is able to provide all the water the tree needs. Acacia plant roots reach depths of up to 20m,

hence making maximum use of water like all other alien species. While it is available, with dire consequences for streamflow and groundwater levels.

On the other hand, it is quite evident today, that man's dependence on biodiversity, and therefore its value, comes in the form of free ecosystem services including food, wood, water, clean air, soil retention, pollination, decomposition of waste products, recreation, ecotourism and medicine.

In essence, biodiversity is the ultimate basis for life on earth and is therefore a resource to be used and preserved. The on-going rate of biodiversity is one of most serious and alarming environmental problems of the modern era. South Africa is endowed with more than its fair share of the biodiversity. Within South Africa's borders, we have eight biomes, each with its own distinctive fauna, flora and ecological functioning. There are several reasons that warrant South Africa to be considered as one of the megadiversity countries in the world. It holds extraordinary levels in biodiversity. It has twice as many amphibians, six times as many reptile species, six times more mammals, eight times more breeding birds and nine times as many more plants than the mean for all countries.

Invading alien species are widely regarded as the second largest threat to biodiversity after direct habitat destruction. Principal negative impacts of alien plants on biodiversity include:

- Displacement by direct competition,
- Reduced structural diversity,
- Increased biomass and disruption of the prevailing vegetation dynamics.

Invasion also has an impact on the fire regime (due to increases in fuel loads), on hydrology and on nutrient cycling. Evidence has emerged over the years to prove that current rates of extinction and therefore loss of biodiversity, are thousands of times higher than the natural rate of extinction (normally one or two species per year). Current conservation estimates put the annual global loss of species at around 27 000 per year. Whilst past extinctions have been balanced by the evolution of new species, the current rapid rate of extinction happens almost exclusively as a result of the activities of man. An alien plant invasion, instigated by humans is one of such activities.

There are only a handful of proven cases where alien plant invasions have resulted in the extinction of species in S. Africa. The loss however of keystone species is of particular concern. Each species contributes more than others to the ecological processes in an ecosystem. Their absence from a system results in losses of other species dependent on the

keystone. For example, birds pollinate certain plant species. These pollinators are keystone species and should they disappear through habitat elimination by invading plants, it would have an impact on several hundreds of plants, many insects and other species that depend on those plants. These are typical "cascade" effects, which will start to become more and more evident as alien plants replace natural communities.

5.5.4 THE ECONOMIC RAMIFICATIONS OF WATER LOSSES

Reduction of ground water supplies, and streamflow from catchment areas by invasive alien species affects the economy of South Africa in several perspectives some of which are:

- Decline in ability of existing water supply schemes to deliver sufficient water to meet demands. Worse still, in dry periods of the year, alien plants spread and for that reason, their impact expands and rapidly too if not checked. In economic terms this becomes a negative impact; demand rise vis a vis need for building bigger schemes.
- Fall in the total amount of water available for human consumption. Unfortunately this is a limiting resource for economic development, hence, without this valuable resource the scope for development is diminished.

Other aspects from related studies:

- Clearing alien plants from catchment areas = more water at 14% of the cost associated with building a dam scheme.
- Early investment in clearing = cost effective.
- Increase in cost = decrease in yields: the longer the catchment is left invaded.

5.5.5 EMERGING AND CONFLICTING ISSUES CONCERNING ALIEN INVASIVE SPECIES

Some alien invasive species do have considerable value, and thus some form of benefit associated with them. Others have negative impacts, unfortunately a growing number. As a result, conflicts of interest surfaces time and again. They include:

- Where invasive plant species underpin commercial activities, such as plantation forestry.
- Cases where alien invasive species (such as the black wattle) are used as firewood (a third world phenomena).
- Situations where they are considered as holding some aesthetic value (Jacarandas in Pretoria) or utilitarian value... e.g. pines as windbreaks among orchard. With all these issues, how do we deal with them in a sensible manner if meaningful progress has to be made in minimizing the negative effects of these 'species'? Perhaps in the following ways!:

- Educating people about dangers and costs of invasive species.
- Encouraging the use of alternative non - invasive species for ornamental and utilitarian purposes.
- Recognizing potential ‘enemies’ - invaders early and doing what it takes.
- Using a non lethal approach (for example the biological control methods) in order to scale down the invasive potential of otherwise useful species.
- Using non-invasive species wherever possible.
- Recognizing the value of a vibrant forest industry and actively managing the spread of plantation trees. It is evident in literature (at the time of putting up this paper) that the forest industry has adopted a policy to deal with this in South Africa.

5.6 GENERAL RECOMMENDATIONS FOR THE CONTROL OF ALIEN INVASIVE SPECIES

The issue is, how do we deal with the problem. Achieving full control of invasive alien species is imperative in order to prevent an environmental catastrophe. The most reliable of methods may just be the integrative approach. But how integrate? For which plants? To what extent? ...

The integrative approach entails combining a host of methods; biological, chemical, mechanical and cultural approaches. It varies for different species and regions of the country, but may as well have some problems hanging around them. These to the best knowledge of this writer and based on the findings on his study on invasive species is the only way to achieve a long-term successful control. Even though much is still to be learnt in the field on integrated control of invasive alien species on a large scale, it remains the best approach deemed effective enough to control alien invasions. However, at the moment problems encountered are:

- Identifying environmentally safe and effective herbicides for large scale control operations.
- Public ignorance, which needs to be overcome on a wide scale.
- Recruiting and forming individuals with the capacity to deal with the problem nationally.
- Identifying, transferring and establishing effective bio-control insects and diseases that will provide effective control or prevent re-invasion of cleared areas and the spread of invading plants to newer areas.

Several programs and departments managed by the government of S. Africa have taken the challenge to effectively deal with these problems. Most of the programs operate hand in hand with all the government branches concerned, and NGO's as partner organizations, individuals and other concerns. This has opened the doorway for more employment opportunities. In all of South Africa's province's several programs are underway, a good number not effective as a result of the '*stupidest of reasons*' - "lack of funds". However, in total, programs aimed at combating the spread of alien invasive species are more than 200.

So far, the impact of Acacia species and Chromolaena odorata on biodiversity in South Africa and in other parts of the African continent has reached alarming proportions. Thus;

- Much should be done to combat this invasive species. If not, soil and water systems will be negatively affected as these species do have high water consumption rates.
- The spread of these invasive species should be halted at all cost and sooner other wise their spread will continue to adversely affect our biodiversity and hence destabilize our natural ecosystems.
- Based on this study the **integrative control method** remains the best option for curbing the spread of alien invasive species.
- Discontinuing the use of single control approaches – e.g. chemical approaches which contaminate our environment is worth enforcing.
- Policy makers and other experts across Africa should work hand in hand and in harmony to achieve effective control of all exotic species especially Chromolaena that is gradually making headway into other parts of the continent at an alarming rate.
- Apart from the fact that environmental research projects should be continuously supported financially and otherwise, environmental education programs as well should be intensified across S. Africa and in other countries. It is the prerogative of local politicians, conservationists, environmentalists and other experts alike to as a matter of fact through their leaders ensure that the issue of combating alien infestations be included as one of the priorities for the newly created African Union.

Meeting up with these recommendations seems to be the ideal step for us all and most especially for South Africa to take toward ensuring progress in the attempts / efforts to maintain a healthy environment, biodiversity wise.

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APPENDIX

APPENDIX A

**FORMATS OF THE DATA SHEETS USED IN THE COLLECTION OF FIELD
DATA.**

DATE: _____ BEARING: _____ Start: ___° ___' ___"S ___° ___' ___"E Transect: _____

Names: _____ End: ___° ___' ___"S ___° ___' ___"E

Aspect: _____

	↑
4	1
3	2

Sampling Point	Quarter No.	Distance (m)	Species (A)	Diameter at base (cm)	Species (B)	Diameter at base (cm)	Distance A - B (m)	Height Class
	1							
	2							
	3							
	4							
	1							
	2							
	3							
	4							
	1							
	2							
	3							
	4							
	1							
	2							
	3							
	4							
	1							
	2							
	3							
	4							

APPENDIX B

INTERVIEW QUESTIONNAIRE FOR RESEARCHERS IN SOUTH AFRICA.

RESEARCH QUESTIONS ON BIODIVERSITY

TOPIC: The impact of alien plant invasions on biodiversity in South Africa. The case of alien Acacia species in the Gauteng and Chromolaena odorata in the KwaZulu Natal provinces.

INTERVIEW QUESTIONNAIRE FOR RESEARCHERS IN SOUTH AFRICA.

Your contributions to this interview session will ease this researcher in assessing the extent of the existing biodiversity problems of South Africa. It will seek to scheme the views on the impacts of alien plant invasions in the Gauteng and KwaZulu Natal provinces of South Africa. Not only that, but your perceptions of how you weigh the present biodiversity status of South Africa will bring light to much of the questions being brought forth.

Your sincere contributions will be very much appreciated, as the compounding results will serve to identify weaknesses, bring forth suggestions for strengthening and improving the biodiversity of this part of the world.

Questions

1. What exactly is biodiversity?
2. Why is biodiversity important for South Africa?
3. Why is there growing concern over the loss of biodiversity in the Gauteng and KwaZulu Natal provinces?
4. How is biodiversity protected in South Africa?
5. What is the meaning of “endangered,” “threatened,” and other terms applied to species in the Endangered Species Act?
6. Which are most endangered and threatened species in South Africa?
7. Are some of the most endangered and threatened species located in the Gauteng and KwaZulu Natal Provinces?
8. Where is most of the biodiversity of South Africa located?
9. What are the threats to biodiversity in the Gauteng and KwaZulu Natal provinces?
10. Why should we conserve biodiversity in South Africa?
11. What could ordinary South Africans do to help conserve biodiversity?
12. Where could South Africans go for more information on biodiversity?
13. Why is it important to remove invasive exotic (non – native) plants from public lands?
14. Are all terrestrial plants in South Africa weeds?
15. Does the department spray native plant species as well as exotics?
16. In a few words could you explain why are invasive plants managed?
17. What does maintenance control mean?
18. What has been done about South Africa’s ”exotic species” problems?

19. What could you advise people do to help stop the spread of exotic species?
20. Are herbicides safe to use?
21. Does the department of environmental affairs in South Africa or any of its affiliated agencies (organizations) have a chemical quota to fill per annum?
22. Why doesn't the department use mechanical methods exclusively to control invasive species – such as *Chromolaena odorata* and *Acacia* species, since labour is cheap in South Africa?
23. Is the extensive spread of *Chromolaena odorata* and *Acacia* species in most Grassland and Savannah areas of South Africa the result of poor plant management programs?
24. Do you in anyway envisage or predict the spread of *Chromolaena odorata* across Africa. If yes, why?
25. Have bio - control methods lead to any successful recovery rate of biodiversity in South Africa. Where? Could you kindly provide any statistical records to substantiate your facts?
26. What role has (is) government and the non – governmental institutions played (playing) in conserving the biodiversity of the Gauteng and KwaZulu Natal provinces?
27. Are there any specific political, cultural and socio – economic obstacles to sustainable biodiversity use in South Africa? If so, what measures have (are) been taken to counter such obstacles?

APPENDIX C

QUESTIONNAIRES USED IN SOUTH AFRICA, CAMEROON AND GHANA

QUESTIONNAIRE ON BIODIVERSITY

TOPIC

The impact of alien plant invasions on biodiversity in South Africa. The case of alien Acacia species in the Gauteng and Chromolaena Odorata in the KwaZulu Natal provinces.

QUESTIONNAIRE FOR RESEARCHERS, FIELD OFFICERS, SPECIALISED WEED INSPECTORS, AGRICULTURAL / LAND RESOURCE MANAGERS, NATURE CONSERVATION OFFICERS, NATURE CONSERVATION PARK OFFICERS, AND WORKING FOR WATER OFFICERS OF KWAZULU NATAL AND GAUTENG PROVINCES IN SOUTH AFRICA.

This questionnaire will go a long way to assess the extent of the existing biodiversity problems of South Africa. It will seek to scheme the views on the impact of alien plant invasions in the Gauteng and KwaZulu Natal provinces of South Africa. Not only that, but your perceptions of how you weigh the present biodiversity status of South Africa will bring light to much of the questions raised.

Your sincere contribution will be very much appreciated, as the compounding results will serve to identify weaknesses, bring forth suggestions for strengthening and improving the biodiversity of this part of the world. In this questionnaire, meanings of the following SA, A, D, SD are as follows: (SA; strongly agree, A; agree, D; disagree, and SD; strongly disagree).

Kindly answer the following questions by ticking in the appropriate box, except where other wise stated.

1. Biodiversity is important for South Africa.

SA A D SD

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2. The loss of biodiversity is important for the growth of the South African touristic industry.

SA A D SD

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3. There are good reasons for the protection of the earth's biodiversity.

SA A D SD

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Why?

4. The biodiversity of:

(a) Gauteng province are seriously under threat by alien Acacia species.

SA A D SD

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(b) KwaZulu Natal province is not hampered by Chromolaena Odorata.

SA A D SD

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5. Chromolaena Odorata is a major invasive specie in the KwaZulu Natal province.

SA A D SD

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6. Sensitization about the need to conserve South Africa's biodiversity has not been sufficient.

SA A D SD

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7. There are more invasive species (problem plants) in South Africa than native species.

SA A D SD

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8. Chemical methods of controlling invasive species are not adequately used.

SA A D SD

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9. Successful bio – control is not favored in the fight against exotics in South Africa.

SA A D SD

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10. The use of a combination of control methods to fight invasive species is ideal in the Gauteng and KwaZulu Natal provinces of South Africa.

SA A D SD

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11. The spread of Chromolaena Odorata is fast gaining grounds across the Southern African region.

SA A D SD

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12. What is the extent of the impact of alien plants on species diversity in the Gauteng and KwaZulu Natal provinces?

13. How are the environmental policies being put in place to deal with this dilemma?

14. Is implementation of those policies effective enough?

If so, why?

15. How best could South Africa tackle the problem of land infestations by *Chromolaena Odorata* and other alien species such as acacia species?

16. A lot of sensitization has been carried out to educate the public on the risks of the spread of alien plants.

SA A D SD

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17. Is biodiversity conservation a “successful story” in the Gauteng and KwaZulu Natal provinces?

SA A D SD

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If so, why?

18. In the fight against alien infestations (invasive species) the following is the best approach:

(i) In the case of *Chromolaena Odorata*

- Mechanical control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Chemical control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Biological control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Cultural control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Integrated control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(ii) In the case of *Acacia mearnsii*

- Mechanical control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Chemical control methods

SA	A	D	SD
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Biological control methods

SA A D SD

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- Cultural control methods

SA A D SD

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- Integrated control methods

SA A D SD

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(iii) In the case of other Australian acacia species

- Mechanical control methods

SA A D SD

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- Chemical control methods

SA A D SD

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- Biological control methods

SA A D SD

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- Cultural control methods

SA A D SD

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- Integrated control methods

SA A D SD

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19. Which of the above is ideal in the fight against invasive species? For your choice(s) give reasons.

(i) In the case of *Chromolaena Odorata*:

(ii) In the case of *Acacia mearnsii*:

(iii) In the case of other Australian acacia species:

20. Could bio – control be successful in the fight against

(i) *Chromolaena Odorata*?

SA A D SD

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Why?

(ii) *Acacia mearnsii*?

SA A D SD

--	--	--	--

Why?

(ii) Other Australian acacia species?

SA A D SD

--	--	--	--

Why?

QUESTIONNAIRE ON BIODIVERSITY

TOPIC

The impact of alien plant invasions on biodiversity in Cameroon. The case of Chromolaena Odorata.

QUESTIONNAIRE FOR RESEARCHERS, FIELD OFFICERS, SPECIALISED WEED INSPECTORS, AGRICULTURAL / LAND RESOURCE MANAGERS, NATURE CONSERVATION OFFICERS, NATURE CONSERVATION PARK OFFICERS IN CAMEROON.

This questionnaire will go a long way to assess the extent of the existing biodiversity problems of South Africa. It will seek to scheme the views on the impact of alien plant invasions in the country and the continent as a whole. Not only that, but your perceptions of how you weigh the present biodiversity status of Cameroon will bring light to much of the questions raised.

Your sincere contribution will be very much appreciated, as the compounding results will serve to identify weaknesses, bring forth suggestions for strengthening and improving the biodiversity of this part of the world. In this questionnaire, meanings of the following SA, A, D, SD are as follows: (SA; strongly agree, A; agree, D; disagree, and SD; strongly disagree).

Kindly answer the following questions by ticking in the appropriate box, except where other wise stated.

1. Biodiversity is important for Cameroon.

SA A D SD

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2. The loss of biodiversity is important for the growth of Cameroon’s touristic industry.

SA A D SD

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3. There are good reasons for the protection of the earth’s biodiversity.

SA A D SD

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Why?

4. The biodiversity of:

(a) Cameroon's coastal areas are seriously under threat by *Chromolaena odorata*.

SA A D SD

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(b) The grassland areas of Cameroon are hampered by *Chromolaena Odorata*.

SA A D SD

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5. *Chromolaena Odorata* is a major invasive species in the North West and Western Provinces of Cameroon.

SA A D SD

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6. Sensitization about the need to conserve Cameroon's biodiversity has not been sufficient.

SA A D SD

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7. There are more invasive species (problem plants) in Cameroon than native species.

SA A D SD

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8. Chemical methods of controlling invasive species are not adequately used in Cameroon.

SA A D SD

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9. Successful bio – control is not favored in the fight against exotics in Cameroon.

SA A D SD

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10. The use of a combination of control methods to fight invasive species is ideal in Cameroon.

SA A D SD

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11. The spread of *Chromolaena Odorata* is fast gaining grounds across the West African region.

SA A D SD

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12. What is the extent of the impact of alien plants on species diversity in Cameroon? Explain your answer

on a provincial basis per se.

13. How are the environmental policies in Cameroon put in place to deal with this dilemma?

14. Is implementation of these policies effective enough?

If so, why?

15. How best could Cameroon tackle the problem of land infestations by *Chromolaena Odorata* and other alien species?

16. A lot of sensitization has been carried out in Cameroon to educate the public on the risks of the spread of alien plants.

SA A D SD

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17. Is biodiversity conservation a “successful story” in Cameroon?

SA A D SD

--	--	--	--

If so, why?

18. In the fight against alien infestations (invasive species) the following is the best approach:

(i) In the case of *Chromolaena Odorata*

- Mechanical control methods

SA A D SD

--	--	--	--

- Chemical control methods

SA A D SD

--	--	--	--

- Biological control methods

SA A D SD

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- Cultural control methods

SA A D SD

--	--	--	--

- Integrated control methods

SA A D SD

--	--	--	--

(ii) In the case of other alien invasive species.

- Mechanical control methods

SA A D SD

--	--	--	--

- Chemical control methods

SA A D SD

--	--	--	--

- Biological control methods

SA	A	D	SD

- Cultural control methods

SA	A	D	SD

- Integrated control methods

SA	A	D	SD

19. Which of the above is ideal in the fight against invasive species? For your choice(s) give reasons.

(i) In the case of *Chromolaena Odorata*:

(ii) In the case of other alien invasive species, e.g *Acacia*:

20. Could bio – control be successful in the fight against:

(i) *Chromolaena Odorata*?

SA	A	D	SD

Why?

(ii) Other species?

SA	A	D	SD

List those you have in mind:

Why could bio – control be successful in the fight against these plants?

QUESTIONNAIRE ON BIODIVERSITY

TOPIC

The impact of alien plant invasions on biodiversity in Ghana. The case of Chromolaena Odorata.

QUESTIONNAIRE FOR RESEARCHERS, FIELD OFFICERS, SPECIALISED WEED INSPECTORS, AGRICULTURAL / LAND RESOURCE MANAGERS, NATURE CONSERVATION OFFICERS, NATURE CONSERVATION PARK OFFICERS IN GHANA.

This questionnaire will go a long way to assess the extent of the existing biodiversity problems of Ghana. It will seek to scheme the views on the impact of alien plant invasions in the country and the continent as a whole. Not only that, but your perceptions of how you weigh the present biodiversity status of Ghana will bring light to much of the questions raised.

Your sincere contribution will be very much appreciated, as the compounding results will serve to identify weaknesses, bring forth suggestions for strengthening and improving the biodiversity of this part of the world. In this questionnaire, meanings of the following SA, A, D, SD are as follows: (SA; strongly agree, A; agree, D; disagree, and SD; strongly disagree).



Kindly answer the following questions by ticking in the appropriate box, except where other wise stated.

1. Biodiversity is important for Ghana.

SA A D SD

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2. The loss of biodiversity is important for the growth of Ghana's touristic industry.

SA A D SD

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3. There are good reasons for the protection of the earth's biodiversity.

SA A D SD

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Why?

4. The biodiversity of:

(a) Ghana's coastal areas are seriously under threat by Chromolaena odorata.

SA A D SD

--	--	--	--

(b) The grassland areas of Ghana are hampered by Chromolaena Odorata.

SA A D SD

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5. Chromolaena Odorata is a major invasive specie in the North West and Western parts of Ghana.

SA A D SD

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6. Sensitization about the need to conserve Ghana's biodiversity has not been sufficient.

SA A D SD

--	--	--	--

7. There are more invasive species (problem plants) in Ghana than native species.

SA A D SD

--	--	--	--

8. Chemical methods of controlling invasive species are not adequately used in Ghana.

SA A D SD

--	--	--	--

9. Successful bio – control is not favored in the fight against exotics in Ghana.

SA A D SD

--	--	--	--

10. The use of a combination of control methods to fight invasive species is ideal in Ghana.

SA A D SD

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11. The spread of Chromolaena Odorata is fast gaining grounds across the West African region.

SA A D SD

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12. What is the extent of the impact of alien plants on species diversity in Ghana? Explain your answer on a provincial basis per se.

13. How are the environmental policies in Ghana put in place to deal with this dilemma?

14. Is implementation of these policies effective enough?

If so, why?

15. How best could Ghana tackle the problem of land infestations by *Chromolaena odorata* and other alien species?

16. A lot of sensitization has been carried out in Ghana to educate the public on the risks of the spread of alien plants.

SA A D SD

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17. Is biodiversity conservation a “successful story” in Ghana?

SA A D SD

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If so, why?

18. In the fight against alien infestations (invasive species) the following is the best approach:

(iii) In the case of *Chromolaena Odorata*

- Mechanical control methods

SA A D SD

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- Chemical control methods

SA A D SD

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- Biological control methods

SA A D SD

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- Cultural control methods

SA A D SD

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- Integrated control methods

SA A D SD

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(iv) In the case of other alien invasive species.

- Mechanical control methods

SA A D SD

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- Chemical control methods

SA A D SD

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- Biological control methods

SA A D SD

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- Cultural control methods

SA A D SD

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- Integrated control methods

SA A D SD

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19. Which of the above is ideal in the fight against invasive species? For your choice(s) give reasons.

(i) In the case of *Chromolaena Odorata*:

(ii) In the case of other alien invasive species, e.g *Acacia*:

20. Could bio – control be successful in the fight against:

(i) *Chromolaena Odorata*?

SA A D SD

--	--	--	--

Why?

(ii) Other species?

SA A D SD

--	--	--	--

List those you have in mind:

Why could bio – control be successful in the fight against these plants?

APPENDIX D

**A READER'S GUIDE TO EXPLANATIONS OF TERMS USED IN THIS
REPORT**

Alien organisms	Plants, animals and micro-organisms which do not naturally occur in an area, and which are deliberately or accidentally introduced by humans to ecosystems outside of their natural range.
Biological Resources	Any biological components with use or value for humanity.
Biome	Any major ecological community of organisms, usually characterised by a dominant vegetation type.
Biotechnology	Technology that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for use.
Conservation	The management of human use of the biosphere to yield the greatest benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations. Conservation thus includes sustainable use, protection, maintenance, rehabilitation, restoration, and enhancement of the natural environment
Enhancement	Increasing the capacity of an ecosystem or population to fulfil a particular function or yield a specified product.
Fynbos	Fynbos is the main vegetation type of the south-western Cape and of the Cape Floristic Region.
Genebank	A collection point for the ex-situ conservation of seeds, tissues, or reproductive cells of plants or animals.
Habitat	The place or type of site where an organism or population naturally occurs.
Indigenous	Native to a particular area.
Maintenance	Keeping something in good health or repair.
Preservation	Keeping something in its present state.
Protection	See PRESERVATION.
Protected area	A geographically defined area designated and managed to achieve specific conservation objectives. Protected areas are dedicated primarily to the protection and enjoyment of natural or cultural heritage, to the maintenance of biodiversity, and to the maintenance of life-support systems.
Red Data Books	These provide information on the current status and conservation requirements of threatened species and ecosystems. This can be at a global or national level.
Rehabilitation	To return a degraded ecosystem or population to an undegraded condition and to productive use.
Restoration	To return a degraded ecosystem or population to its original condition.
Taxa	The named classification units to which individuals, or sets of species, are assigned.
Sustainable Use of Biological Resources	The use of components of biological diversity in a way and at a rate that does not lead to its long-term decline, thereby maintaining its potential to meet the needs and aspirations of present and future generations.
Wildlife	Any non-domestic animal and plant which occur in the wild.

APPENDIX E

**TABLE ON THE IMPACTS OF SECTORAL ACTIVITIES ON BIOLOGICAL
DIVERSITY IN SOUTH AFRICA**

IMPACT ECONOMIC SECTOR	Habitat Loss and Fragmentation	Over- Exploitation of Species	Air, Water and Soil Pollution	Introduction of Harmful Alien Species	Key State Institutions
Agriculture	✓Primarily through cultivation, requiring the removal of natural vegetation, and through bush encroachment.	✓Overgrazing in parts of the country may result in certain species being overexploited.	✓Largely through the use of agrochemicals, siltation, and from mariculture and aquaculture enterprises.	✓Through the introduction of high-yielding exotic species for cultivation or pastoral purposes, and through the introduction of alien species for mariculture and aquaculture.	Department of Agriculture; Department of Land Affairs; DEAT; related provincial departments; Agricultural Research Council.
Forestry	✓Through afforestation which involves the replacement of natural vegetation.	✓Overexploitation at both commercial and subsistence levels of certain woodland species in parts of the country.	✓Through, <i>inter alia</i> , the pulp and paper industry and the use of agrochemicals.	✓Through the introduction of high-yielding exotic species for commercial forestry and recreational purposes.	Department of Water Affairs and Forestry; DEAT; SAFCOL.
Fisheries	✓Through physical damage to habitat from certain fishing gears.	✓Overexploitation of target and non-target species, with ramifications for other species and supporting ecosystems.	✓From mariculture and aquaculture enterprises, as well as from fishing gear.		Directorate Sea Fisheries (DEAT); Provincial Departments of Nature Conservation.
IMPACT ECONOMIC SECTOR	Habitat Loss and Fragmentation	Over- Exploitation of Species	Air, Water and Soil Pollution	Introduction of Harmful Alien Species	Key State Institutions

Chemical industry			✓Activities related to the chemical industry may result in air, water and soil pollution.		Department of Trade and Industry; DEAT; Department of Water Affairs and Forestry; Department of Health.
Biotechnology Industry				✓Potential risk through the release of genetically modified organisms.	Department of Agriculture; Department of Trade and Industry; DEAT; Department of Health.
Water	✓Through dam construction, and water transfer schemes.			✓Through inter-basin schemes which unintentionally introduce alien species.	Department of Water Affairs and Forestry; Department of Health.
Transport	✓Through road and rail construction and shipping-related activities.		✓Through the dumping of land-generated waste from ships, or from oil spilled or discharged from ships.	✓Through the unintentional introduction of alien species in ship ballast water.	Department of Transport; Directorate Sea Fisheries; Department of Trade and Industry; DEAT.
IMPACT ECONOMIC SECTOR	Habitat Loss and Fragmentation	Over-Exploitation of Species	Air, Water and Soil Pollution	Introduction of Harmful Alien Species	Key State Institutions
Tourism and Recreation	✓Through the construction of tourist-related facilities, particularly along the coast. Through exceeding the tourist carrying capacity in certain areas.	✓Through recreational fishing and the overexploitation of "collectable" species.	✓Through litter, principally plastic waste.	✓Through the introduction of exotic fish species for angling.	DEAT; SATOUR; National Parks Board; provincial departments of environment and tourism and nature conservation agencies.

Housing and Infrastructure	✓Through the clearing of land for development.		✓May occur from construction activities.	✓Through the use of harmful alien species in gardens and parks.	Department of Housing; Provincial Departments of Planning; Other relevant provincial and local government departments.
Trade		✓Overexploitation of species in demand for medicinal or wildlife trade purposes.	✓Through trade in chemicals and other harmful substances.	✓Through the unintentional introduction of harmful alien species.	Department of Trade and Industry; DEAT; Department of Health.
Defence	✓Through the use of the land and sea for weapons testing and training.	✓Overexploitation of species in areas used for purposes of defence.	✓Through the production and use of various weapons.		South African National Defence Force; DEAT; South African Police Services.
Domestic Households	✓Indirectly, through requiring the range of different economic services described above.	✓Through the harvesting of certain plants and animals for food, building, fuel or medicinal purposes.	✓Through the generation of sewage and household waste, as well as pollutants associated with cooking and heating.	✓Through the use of harmful alien species in gardens.	Broad range of national, provincial and local government departments.