

3002/1

IMPACTS OF NATURAL RESOURCE MANAGEMENT PROGRAMME ON SAVANNAH BIODIVERSITY IN THREE GROUP RANCHES IN LAIKIPIA DISTRICT, KENYA. //

BY

LARA SALIDO GRAÑA
BSc [Zoology] Honours
I56/5034/2003

Sign Lara Date 19.10.2006

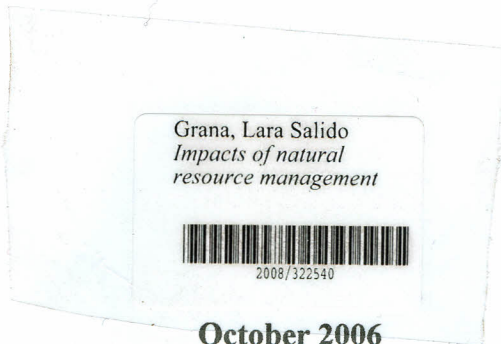
Department of Zoology

A Thesis submitted in partial fulfilment of the requirements for the Degree of Masters of Science (Animal Ecology) in the School of Pure & Applied Sciences of Kenyatta University

SUPERVISOR:

Dr. K. KOTUT

Sign [Signature] Date 02-08-2006



DECLARATION

This thesis is my original work and has not been presented for a degree in any other University or any other award.

Sign Lara

Date 19.10.2006

Supervisor's Approval

I confirm that the work reported in this thesis was carried out by the candidate under my supervision.

Sign [Signature]

Date 02-08-2006

DEDICATION

To the late Professor Okelo

ACKNOWLEDGEMENT

Foremost, I would like to express my gratitude to my supervisor Dr. Kotut for all his advice and help. Next, I would like to thank Dr. N. Oguge for all his technical guidance and support throughout the research. My sincere appreciation goes to staff of the mammal department of National Museums of Kenya (NMK), and especially to Mr. Bernard 'Risky' Agwanda, for all his help, technical advice and encouragement. I would also like to acknowledge the local Maasai communities of Kijabe, Tiamamut, Koija and Kimanjo Group Ranches for their friendliness and cooperation throughout the research period. I am equally grateful and indebted to the local scouts (David Monto, Isaac Sinore, Francis Simat and George Naiputari), without whose local knowledge, support and hard work this study would have been almost impossible. Thanks are also due to AWF for their effort in providing accomodation and transport during the study period and particularly Felix and Mujomba for their incredible driving and helping hands.

I also wish to thank my family for their support and assistance. Finally, to my husband, Booker Ouma, the deepest gratefulness for being beside me all through, for his encouragement, understanding, patience and, most of all, for his unconditional love.

TABLE OF CONTENTS

	Page
Title.....	i
Declaration.....	ii
Dedication.....	iii
Acknowledgement.....	iv
Table of contents.....	v
List of tables.....	vii
List of figures.....	viii
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background.....	1
1.2 Problem statement and justification.....	3
1.3 Research questions.....	3
1.4 Hypotheses.....	4
1.5 Objectives of the study.....	5
1.6 Significance of the study.....	5
CHAPTER TWO: LITERATURE REVIEW.....	7
2.1 Biodiversity and rangelands.....	7
2.2 Natural Resource Management (NRM) programmes.....	11
2.3 Biodiversity assessment and monitoring tools.....	14
2.4 Geographical Information Systems (GIS) and Remote Sensing.....	19
2.5 Traditional/ indigenous knowledge.....	20
CHAPTER THREE: MATERIALS AND METHODS.....	21
3.1 Introduction.....	21
3.2 The study area.....	21
3.2.1 Koiya, Tiamamut and Kijabe Group Ranches location.....	21
3.2.2 Land use distribution within the group ranches.....	23
3.2.3 Sampling sites.....	25
3.3 Methods.....	27
3.3.1 Land cover change.....	27
3.3.2 Vegetation.....	28
3.3.3 Range condition.....	30
3.3.4 Small mammals.....	32
3.3.5 Carnivores and large mammals.....	32
3.3.6 Local community perceptions.....	33
3.4 Data analysis.....	34
3.4.1 Land use cover.....	34
3.4.2 Biodiversity assessment.....	39
3.4.3 Community similarity assessment.....	40
3.4.4 Species richness assessment.....	40

CHAPTER FOUR: RESULTS	41
4.1 GIS analysis	41
4.1.1 Supervised classification	41
4.1.2 NDVI analysis	47
4.2 Vegetation structure	49
4.2.1 Vegetation strata cover	49
4.2.2 Vegetation species richness	51
4.2.3 Vegetation diversity indices	52
4.2.4 Vegetation community similarity	53
4.2.5 Vegetation species dominance	55
4.2.6 Vegetation species occurrence	57
4.3 Range condition assessment	59
4.3.1 Range condition	59
4.3.2 Ecosystem health indicators	61
4.4 Mammal assessment	63
4.4.1 Mammal species richness	63
4.4.2 Mammal diversity indices	63
4.4.3 Mammal community similarity	64
4.4.4 Mammal species occurrence	66
4.5 Community perception assessment	68
4.5.1 Influence of NRM programme	68
4.5.2 Management of conservation areas	70
4.5.3 Human-wildlife conflict	72
CHAPTER FIVE: DISCUSSION	73
5.1 Land cover changes	73
5.2 Vegetation strata cover	75
5.3 Vegetation species richness and diversity	76
5.4 Vegetation community similarity	77
5.5 Vegetation species dominance and occurrence	78
5.6 Range condition	79
5.7 Ecosystem health indicators	80
5.8 Mammal species richness and diversity	81
5.9 Mammal community similarity and species occurrence	82
5.10 Community perception	83
CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS	86
6.1 Conclusion	86
6.2 Recommendations	87
REFERENCES	89
APPENDICES	99
Appendix 1. Mammal species list and distribution	99
Appendix 2. Vegetation species and distribution	101
Appendix 3. Community perceptions questionnaire	105

LIST OF TABLES

	Page
Table 1. Land use area distribution according to the NRM programme	23
Table 2. Vegetation categories for the study according to height.....	28
Table 3. Range condition parameters studied and rating scale	31
Table 4. Land cover types used during the supervised classification	41
Table 5. Error matrix for the 2000 classification map	45
Table 6. Error matrix for the 2004 classification map	45
Table 7. Mean number of vegetation species per quadrat in the three land uses of the group ranches	51
Table 8. Biodiversity indices for vegetation in different land uses of each group ranch.	52
Table 9. Morisita's similarity table for vegetation communities of the three group ranches	54
Table 10. Vegetation dominance regarding percentage cover (>5%) for the three group ranches	55
Table 11. Mean mammal species richness per land use in the three group ranches .	63
Table 12. Biodiversity indices for mammals in the different land uses of each group ranch.	64
Table 13. Morisita's similarity table for mammal communities.....	65
Table 14. Community perception on the impact of the NRM programme on different aspects of their lives in the different group ranches	69
Table 15. Compliance to access restrictions in conservation areas and reasons for maintaining the conservancies in each group ranch.	71
Table 16. Wildlife encounters incidence and responses to wildlife-livestock conflict.	72

LIST OF FIGURES

	Page
Figure 1. Pressure-State-Response framework for biodiversity in rangelands.....	10
Figure 2. The exclusionary approach circle or “fortress” conservation method	11
Figure 3. Theoretical framework for sustainable livelihoods.....	14
Figure 4. Biodiversity assessment setting as a subcomponent of land use and natural resource management planning cycles	15
Figure 5. Steps in assessing biodiversity	16
Figure 6. Methodology framework for Participatory Indicator Development (PID)	18
Figure 7. Map of Kenya showing the location of the Laikipia district and the three group ranches studied	22
Figure 8. Map showing the land use distribution (in hectares) in Koiija, Tiamamut and Kijabe Group Ranches.	24
Figure 9. Map showing the location of the sampling quadrats in the study area.....	26
Figure 10. Quadrat orientation, dimensions and bearings.	27
Figure 11. Vegetation sampling within the 50x50 quadrat	30
Figure 12. Carnivore scent station	33
Figure 13. Supervised classification map for 2000 LANDSAT ETM+ image of the study area	43
Figure 14. Supervised classification map for 2004 LANDSAT ETM+ image of the study area	44
Figure 15. Land cover changes in the study area based on grid analysis of the supervised classification maps.	46
Figure 16. NDVI image differencing between 2004 and 2000 LANDSAT ETM+ images of the study area.....	48
Figure 17. Vegetation cover for (a) canopy layer, (b) mid-layer and (c) herb layer of each land use of the group ranches.	50
Figure 18. Vegetation species occurrence for each land use of the three group ranches	58
Figure 19. Range condition distribution in the land uses of the three group ranches.	60
Figure 20. Ecosystem health indicators abundance in each of the land uses of the three group ranches.....	62
Figure 21. Mammal species abundance distribution for each land use of the three group ranches	67

ABSTRACT

This study looked at the impact of Natural Resource Management (NRM) programmes on the biodiversity of savannah ecosystems and their effectiveness as biodiversity conservation tools. Habitat and attitudinal changes were investigated in three group ranches (Koiya, Tiamamut and Kijabe) in northern Laikipia District (Kenya) following five years of NRM programmes consisting of land division into: conservation, grazing and settlement areas. The study used biodiversity and range condition surveys to determine the current status of vegetation and mammal populations, coupled with GIS technology to assess land cover changes. In addition, a structured questionnaire was used to investigate the perceptions of the local communities on the NRM programme. The GIS and remote sensing analysis revealed an increase in bushland vegetation cover mainly in conservation areas (12.8%) and shrubland decrease in grazing and settlement areas (16.2%). The study showed higher vegetation species diversity and better range conditions in conservation areas as compared to both grazing and settlement areas in all group ranches. Tree species richness was significantly higher in the conservancy than either grazing or settlement areas within each group ranch (Koiya $F=3.547$, $p=0.035$, $n=60$; Tiamamut $F=3.57$, $p=0.036$, $n=49$; Kijabe $F=14.6$, $p<0.001$, $n=59$). A significant difference between land uses in shrub species richness was also noted in Kijabe ($F=7.144$, $p=0.002$, $n=59$). The decreasing values from conservancy to settlement areas were observed for plant diversity indices though no significant difference was recorded in any group ranch except for shrubs diversity in Koiya ($r=-0.998$, $p=0.021$, $n=60$). Vegetation communities and species distribution were different between and within group ranches. Pair-wise comparisons amongst group ranches showed Koiya and Kijabe being the most dissimilar. Comparisons within group ranches showed particularly strong differences among land uses in Kijabe. Furthermore, most rare vegetation species were present mainly in conservancy areas. Variation in mammal abundance and diversity followed a similar pattern to that of vegetation, with higher a species number and diversity in the conservancy areas of the three group ranches (Kijabe $r=-0.996$, $p=0.027$, $n=3$). Leopards and lesser kudu were present only in conservancy areas of Kijabe. Community responses suggested an improvement in livelihood (~100% of respondents) and livestock health (73%) since the introduction of NRM programmes. However, despite such gains, in all group ranches an increase in human-wildlife conflict (~90%), decrease in quality of grazing (56%) and reduction in the number of livestock (80%) were noted. Regarding management of the conservancy areas, the main reasons given by respondents for protecting the conservation areas were preservation for future use and as tourist attractions (53% and 42% respectively). However, in Koiya and Tiamamut the communities still graze in them (100%). On human-wildlife conflict, all group ranches reported encounters with carnivores (64%) with the main responses being moving livestock away (31%) or chasing the wildlife (25%). This study has shown that the NRM programme has had a positive effect in conservation areas, mostly in Koiya and Kijabe, through increase in biodiversity, vegetation cover and better range condition. However, this is not the case at Tiamamut, which does not follow the NRM programme strictly. The NRM programme has also had a detrimental effect on grazing and settlement areas through increase in livestock grazing pressure as a result of reduced pasture areas. Therefore, it may be necessary to implement more inclusive NRM programmes with adequate active rangeland management and long-term biodiversity-monitoring programmes.

CHAPTER ONE: INTRODUCTION

1.1 Background

Concern about the importance of biodiversity and the state of different ecosystems, communities and populations all over the world is not new. In fact, since George Marsh in 1864 pointed out the dangers of overexploitation of nature (Spellerberg, 1996), there has been an increasing concern about species loss and deterioration of the environment. Besides a greater awareness on the importance of conservation of nature, there has been an intensification of the efforts put into investigating different relationships and factors that determine the perpetuity of biodiversity.

One of the most conspicuous responses to the global loss of biodiversity was the establishment of the *Convention on Biological Diversity* (CBD) during the Earth Summit in Rio de Janeiro (Brazil) in 1992, where signatory parties were required to take action in a wide range of areas (Adams, 2001; Blench and Sommer, 1999). Most biodiversity studies in the past concentrated on the assessment of biodiversity in forest and other “hotspots” around the world leaving out less “prominent” ecosystems, such as rangelands (Blench and Sommer, 1999). In fact as early as 1990, Redford and others had observed that the concentration on rainforest had led to the neglecting of other severely threatened ecosystems (Redford *et al.*, 1990). Nevertheless, in the last two decades, some research has been carried out on the biodiversity of grasslands and rangelands of Australia and North America. These studies have concentrated on many different aspects of these ecosystems ranging from population demography of pasture species (Austin and Williams, 1988) through maintenance of biodiversity (James *et al.*, 1996) to vegetation responses to fire (Bock and Bock, 1992) and the effects of grazing by wildlife (Jones, 1981). In contrast,

Africa's and Asia's rangelands, characterised by traditional pastoral or foraging communities, have received little attention despite their great importance to both wildlife conservation and human subsistence. In these regions, pastoralist communities attempt to balance the use of their land between providing pasture for local livestock and the creation of conservation areas for tourism. There is, therefore, an increasing need for more information on the status of those areas regarding biodiversity and the processes that regulate and affect their stability at small, medium and large scale levels. The effects of various grazing patterns, and the status of the range condition and biodiversity have recently been investigated in Arid and Semi-Arid Lands (ASAL) of Africa (Oba *et al.*, 2000; Oba, 2001; Oba and Kotile, 2001; Oba *et al.*, 2003). Considering the mentioned importance of these ecosystems for the sustenance of both human and animal communities, and the ever increasing threats to them (land degradation and habitat fragmentation mainly), there is an increasing need for the development of different tools to conserve and maintain them. Natural Resource Management (NRM) programmes appear to be part of these tools, as their recent boom, especially in Africa's ASAL areas, suggests. NRM programmes have been proposed as theoretically effective tools to integrate and sustainably maintain pastoral and wildlife conservation activities in these areas (Ashley, 2000; Brown, 1998; Nhantumbo *et al.*, 2003; TWNSO *et al.*, 2002). However, there is still a need for studies to shed some light on how effective these programmes are in practice, both in terms of biodiversity conservation and sustainable development of local communities.

1.2 Problem statement and justification

Laikipia District (Rift Valley Province of Kenya) is one of the richest places in the country in terms of wildlife diversity (Lane *et al.*, 2005; Young *et al.* 2005). However, increase in human settlements has led to the fragmentation of the land as a result of the advancement of large scale ranching, pastoralism and small scale farming activities (Jacobs and Coppock, 1999). In the northern part of the district, there are a number of group ranches managed by Maasai pastoral communities. In an effort to promote wildlife conservation while at the same time allowing the pastoral communities to continue with their traditional way of life, NRM programmes have been introduced in the region. However, despite their recent popularity as resource management tools, there is lack of information regarding the impacts of such programmes on both biodiversity and ecosystem health. This study, therefore, is set to investigate the impacts of NRM programmes on the savannah ecosystem of three group ranches in the north of the district (namely, Koiya, Tiamamut and Kijabe Group Ranches). In these group ranches the NRM programme led to land use segregation into conservancy, settlement and grazing areas since the year 2000.

1.3 Research questions

In order to evaluate the impact of land use type on the biodiversity and environmental health following the setting up of a NRM programme in the study area, the following broad questions were addressed:

1. What are the major ecological trends observed since the establishment of the NRM programme?

2. Are there any differences in biodiversity and range conditions amongst the different land use types in each group ranch?

The specific questions addressed were:

1. Have there been any land cover changes in the area since the establishment of the NRM programme?
2. Are there differences in vegetation and mammal diversity amongst the different land uses in each group ranch?
3. Are there differences in range condition amongst the different land uses in each group ranch?
4. How do the local communities perceive the NRM programme?

1.4 Hypotheses

1.4.1 Main hypothesis

Natural Resource Management (NRM) programmes are effective tools in biodiversity conservation in rangelands.

1.4.2 Specific research hypotheses

- i. Land use changes have brought about differences in vegetation cover in each of the group ranches
- ii. Land use changes have brought about differences in vegetation and mammalian diversity amongst the different land use types in each Group Ranch.

- iii. Land use change has brought about differences in range condition in the different land use types in each Group Ranch.
- iv. The NRM programme has impacted positively on the local community.

1.5 Objectives of the study

1.5.1 General objective

To determine the impact of NRM programmes on biodiversity and ecosystem health.

1.5.2 Specific objectives

- i. To determine the land cover changes in the area which have resulted from the establishment of the NRM programme.
- ii. To establish the vegetation and mammalian diversity in each land use type of each group ranch.
- iii. To assess the range condition in each land use type of each group ranch.
- iv. To assess the perceptions of the local community on the NRM programme.



1.6 Significance of the study

NRM programmes are increasingly in use as potential conservation tools in regions where wildlife based tourism is a possible livelihood option for the local communities (Peredo, 2002; USAID, 2005). However, there is need to establish the full scope of impacts of such programmes on biodiversity and ecosystems of such areas before proposing them as a suitable solution for sustainable livelihood development. The information obtained from this study will provide a better understanding of the basic ecological trends expected from this land use

diversification in ASAL areas and the potential use of these programmes as conservation tools in the region. Besides, the results presented here can serve as baseline information for further integrated research looking deeper into the different aspects of socio and ecological effects of NRM programmes.

Journal of Ecology, 1997, 85, 115–124
 © 1997 British Ecological Society

Though it is difficult to quantify the effects of large biologically diverse systems on less diverse systems, we do have a theoretical idea of the kind of effects that may be expected from a decrease in biodiversity (Maron, 1996; Tilman *et al.*, 1996, 1997).

One of the values of biodiversity is the benefit that a wider range of raw materials (e.g. foods, medicines, building materials) and tools (for example, when the trees provide aspects of health care) can be derived from. Biodiversity also supports more effective recycling of nutrients and energy, and thus contributes to the stability of ecosystems (Pimm, 1982).

Indirect values of biodiversity are closely associated with the environmental services that are provided by ecosystems (Maron, 1996). Diverse ecosystems may be able to provide an stable and efficient source of environmental services, such as food, timber and medicines.

Another model of biodiversity is that of productivity of the system as well as the services provided to the system. Diverse systems communities of plants and animals can create value for a wider range of future uses as well as a greater capacity to buffer the system against change.

CHAPTER TWO: LITERATURE REVIEW

2.1 Biodiversity and rangelands

Biodiversity may be defined as “the variability among living organisms from all sources, including, amongst others, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (CBD, 1992).

Though it is difficult to quantify the benefits of more biologically diverse compared to less diverse systems, we do have a broad qualitative idea of the kinds of goods and services that may be enhanced by an increase in biodiversity (Mearns, 2000; Vermeulen and Koziell, 2002):

- a. Direct use values of biodiversity are the benefits from a wider range of raw materials (e.g. foodstuffs, medicine, building materials and fodder for livestock). Often the most valuable aspects of biodiversity as a direct use are associated with supply of resources during critical periods of time when staples are not available (e.g. dry seasons or droughts).
- b. Indirect use values of biodiversity are mostly associated with the environmental services that ecological biodiversity sometimes enhances. More diverse ecosystems may be better providers of stable and effective microclimate regulation, protection from erosion or other services.
- c. Non-use values of biodiversity consist primarily of the option to use biological resources in the future. More diverse communities of plants and animals offer a greater variety of potential future uses as well as a greater capacity to evolve new form and processes.

However, the following should be borne in mind:

- a. Not all facets of biodiversity, or ranges of biodiversity change, are equally valuable (e.g. ant species in a rainforest are more essential than beetle species for ecosystem processes).
- b. Different facets of biodiversity do not increase or decrease in tandem with each other (invader species may increase when there is secondary growth but local species may not react the same).
- c. Biodiversity is a product of both natural evolutionary and human selective processes (some environments considered to be “pristine” have actually been moulded by people living there).

Biodiversity has, for many decades now, been one of the main drivers of conservation biology with regards to both the protection of species and the establishment of natural reserves and national parks. However, most biodiversity studies have concentrated in tropical forests around the globe thought to be “hotspots” of species diversity (Blench and Sommer, 1999; Hambler, 2004). Consequently, despite the importance of other ecosystems, such as grasslands, the amount of database information on forest biodiversity is around eight times greater than for rangelands or savannahs (Blench and Sommer, 1999). Due to this lack of information, the Earth Summit of 1992 devoted specific articles (6a, 6b, 7a, 7b, 7c and 7d) to rangeland and grassland biodiversity, its current threats, pressure and the direct actions to be taken in order to conserve these ecosystems (Blench and Sommer, 1999).

Biodiversity in rangelands has declined due to both (i) the intensification of use, and (ii) fragmentation and loss of habitat. Overall, the total area of rangelands has been declining rapidly over the past few centuries. It is estimated that grasslands once covered up to 40% of the world's land area (Wessman *et al.*, 2004). However, habitat fragmentation has reduced their total area. Some rangeland regions in Africa or South America approach the diversity of tropical rainforest, while others, such as those in Australia seem to be depauperated (Groombridge, 1992; Blench and Sommer, 1999).

Rangelands and grasslands are areas dominated by grass and grass-like species with or without scattered woody plants. Presently they cover an area of about 18-25% of the world area (Sala *et al.*, 1996; Solbrig, 1996). In general, they are considered anthropogenic ecosystems that have come about due to pastoral activities (Blench and Sommer, 1999). Most studies on rangeland biodiversity have been carried out in Australia (Whitehead *et al.*, 2000; Smyth, 2003; Smyth and James, 2004) and North America (Jones, 1981; Bock and Bock, 1992; Jackson and Bartolome, 2002), where the main activity is large-scale ranching. However, little attention has been paid to rangeland ecosystems used by traditional pastoral or foraging communities such as those of Africa or Central Asia. According to Blench and Sommer (1999) this may be because most of the studies in these areas have been done by social anthropologists who are more interested in advocacy rather than the ecological impact of pastoralist activities. However, in areas of tropical rangelands, ecosystem resources are indeed fundamental to the survival of human communities. Here, livelihoods are generally reliant on pastoralism, farms dependent on rain-fed crops, and, in recent times, wildlife, which has become an important factor in providing

income at the national and regional level. Rangelands, therefore, do not only support an important part of the population in developing countries but also significant biodiversity (Blench and Sommer, 1999). Hence, if we are to protect and conserve these ecosystems, there is a need to learn about the factors and processes that determine their composition and stability.

In planning to establish programmes, like NRM, that can help the local communities to use and maintain the available natural resources to develop and sustain their livelihoods, there is need to look at the different levels and relationships that will come into play. The “Pressure-State-Response” framework illustrates the relationships between pressures from human activities, the state of biodiversity and activities initiated by stakeholders to conserve and maintain biodiversity in rangelands (Figure 1).

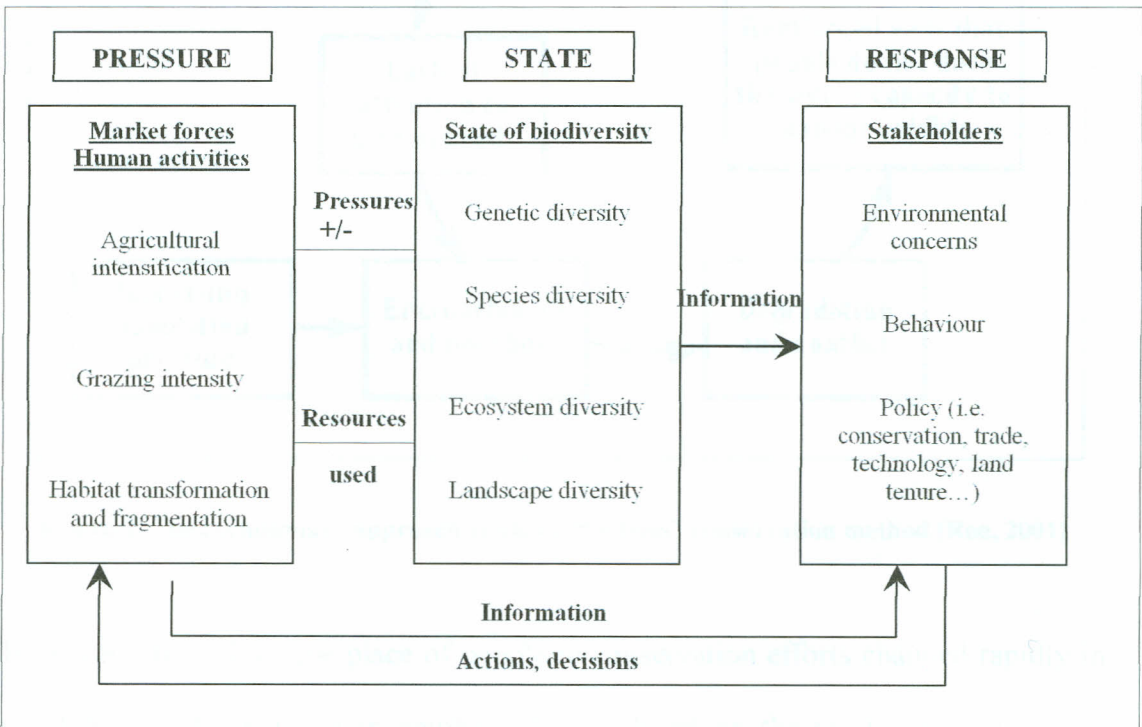


Figure 1. Pressure-State-Response framework for biodiversity in rangelands (De Haan et al, 1997).

2.2 Natural Resource Management (NRM) programmes

The dominant approach to conservation for most of the 20th century was the exclusion of people from ‘natural’ places, the ideology of ‘fortress conservation’ (Adams, 2001; Ribeiro, 2001; Hambler, 2004). According to this principle of conservation, the selected areas were under strict protection and local people were excluded from their land. This meant no access to natural resources and, therefore, compromised sustainability of their livelihoods which led to unsustainable practices (e.g. poaching). This is based on the perception that local communities lack the capacity to properly manage natural resources (exclusionary approach circle, Figure 2).

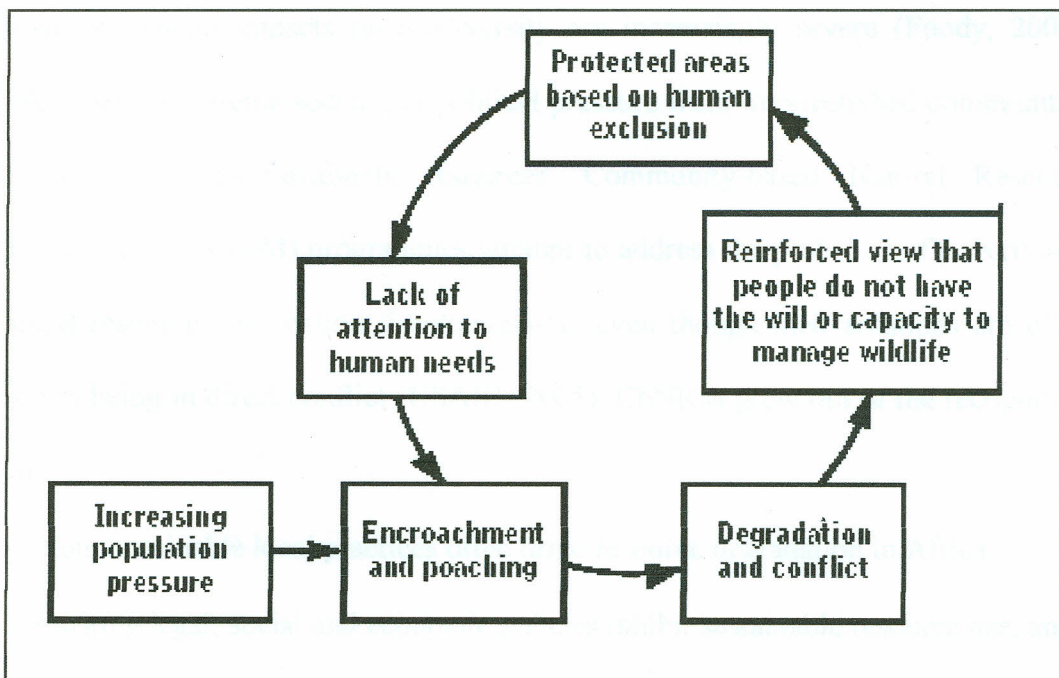


Figure 2. The exclusionary approach circle or “fortress” conservation method (Roe, 2001)

However, ideas about the place of people in conservation efforts changed rapidly in the 1980’s and 1990’s, with emphasis being placed on the needs of local people (Western and Wright, 1994). In recent decades, the involvement of local people in

conservation has become a major component of conservation policy in many countries (TWNSO *et. al*, 2002; USAID, 2005). There is now a strong consensus that local people must be involved in management decisions on protected areas, and that they should benefit from them economically (Mearns, 2000). The support of local people is seen to be essential to their long term survival and integrity. The concept of sustainable development is central to the community approach to conservation and has been put forward as a means of avoiding adverse environmental impacts, negative socio-economic impacts, and the systematic land degradation created by poverty (Adams, 2001). The community based approach appears to be one of the most promising approaches to succeed in the quest for the achievement of Millennium Development Goals (MDG) of ensuring environmental sustainability. However, human impacts on biodiversity are increasingly severe (Foody, 2003). Often there is extreme social and political pressure from impoverished communities to overexploit the available resources. Community-based Natural Resource Management (CbNRM) programmes attempt to address the problems of poverty and natural resource degradation simultaneously- even though their solutions are often seen as being in direct conflict (USAID, 2005). CbNRM grew out of the recognition that:

- Non-sustainable local practices often drive resource degradation in Africa;
- Existing legal, social and economic policies inhibit sustainable resource use, and
- Government in developing countries often lack the financial or institutional resources to adequately manage or regulate natural resource use.

CbNRM has grown significantly in Africa over the last decade, primarily to protect and manage wildlife, but also to foster sustainable management of rangelands,

forested areas, watersheds, fishing and coastal resources. Nationally sponsored programmes have been developed in many countries, including Botswana, Burkina Faso, Chad, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Namibia, Niger, Senegal, South Africa, Tanzania, Uganda, Zambia and Zimbabwe (USAID, 2005).

The CbNRM strategy recognizes the involvement of communities as a means for promoting the sustainable use of resources while allowing communities dependent on these resources to benefit (Nhatumbo, *et al.*, 2003). This will therefore, permit the transformation of natural capital into a realisable economic value and is likely to contribute to a variety of livelihood strategies.

The sustainable livelihoods framework (Figure 3) has been applied in various case studies attempting to establish a link between the policy environment and access to resources. Besides it can be also useful when assessing the impact of such access on the strategies adopted by the rural population (Ashley, 2000; Hobley and Shield, 2000; Nicol, 2000).

The first step when developing a NRM programme is to set up a range of monitoring systems which would map and produce an inventory of plant and animal species present in the area and their status. Once this information is available, appropriate management techniques would put in place so that the local communities can manage the range and monitor it over time so as to ensure that their land is used in a sustainable manner (Dougill and Reed, 2002).

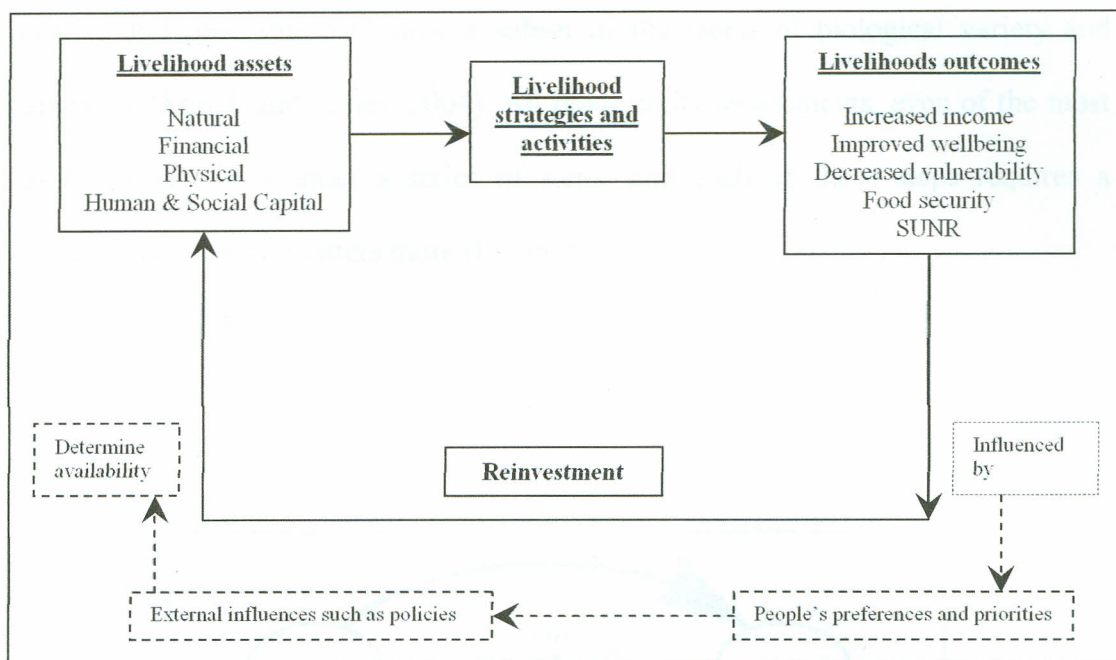


Figure 3. Theoretical framework for sustainable livelihoods (Nhatumbo *et al.*, 2003)

2.3 Biodiversity assessment and monitoring tools

Biodiversity assessments need to provide information that is useful to decision-makers through facilitating more effective management of natural resources. The most direct management decisions are made at local levels, and in this sense the most useful biodiversity assessments are those arrived at locally. At both local and subsequent levels, evaluation of biodiversity is part of a broader cycle of land use and NRM planning, either purposively or not (Figure 4).

If policy decisions are to depend on local as well as national or global biodiversity values, reliable and generalisable methods to contrast or combine different measures are required (Vermeulen and Koziell, 2002).

Biodiversity assessments arise from many different motives and contexts but they all have some basic common features, such as frameworks of time and space, and

reliance and observation of only a subset of the facets of biological variety and variability (Smyth and James, 2004). All biodiversity assessments, even of the most casual variety, also entail a series of steps, and each of these steps requires a prioritisation of what matters more (Figure 5).

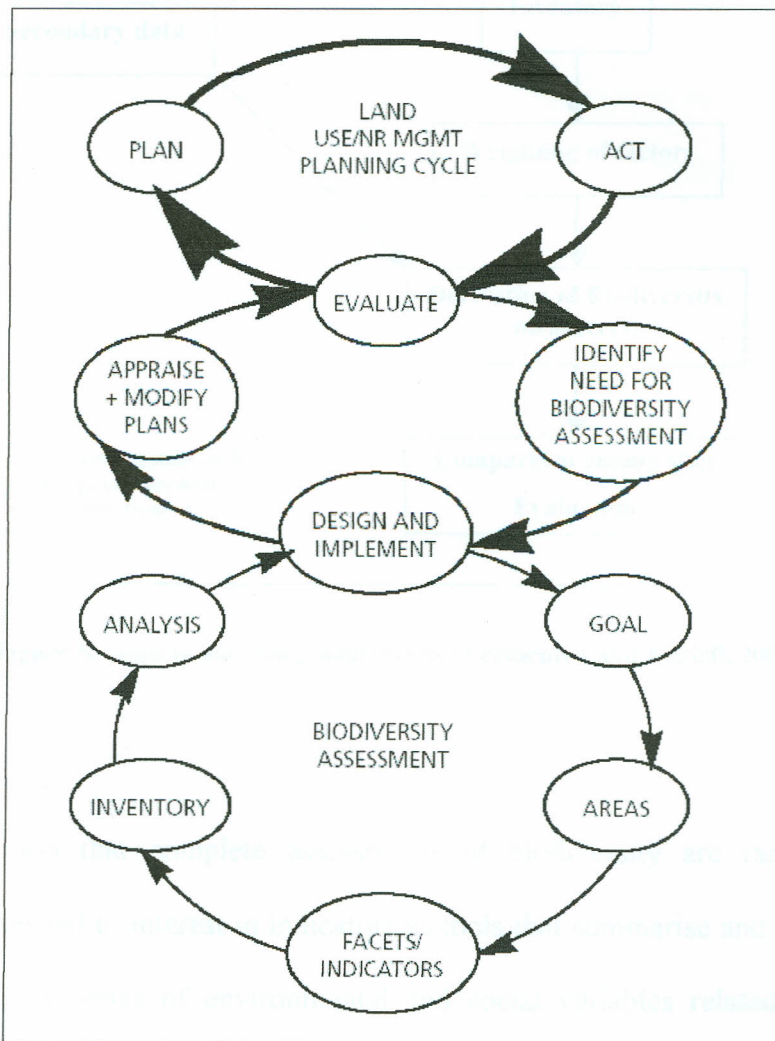


Figure 4. Biodiversity assessment setting as a subcomponent of land use and natural resource management planning cycles (Vermeulen and Koziell, 2002)

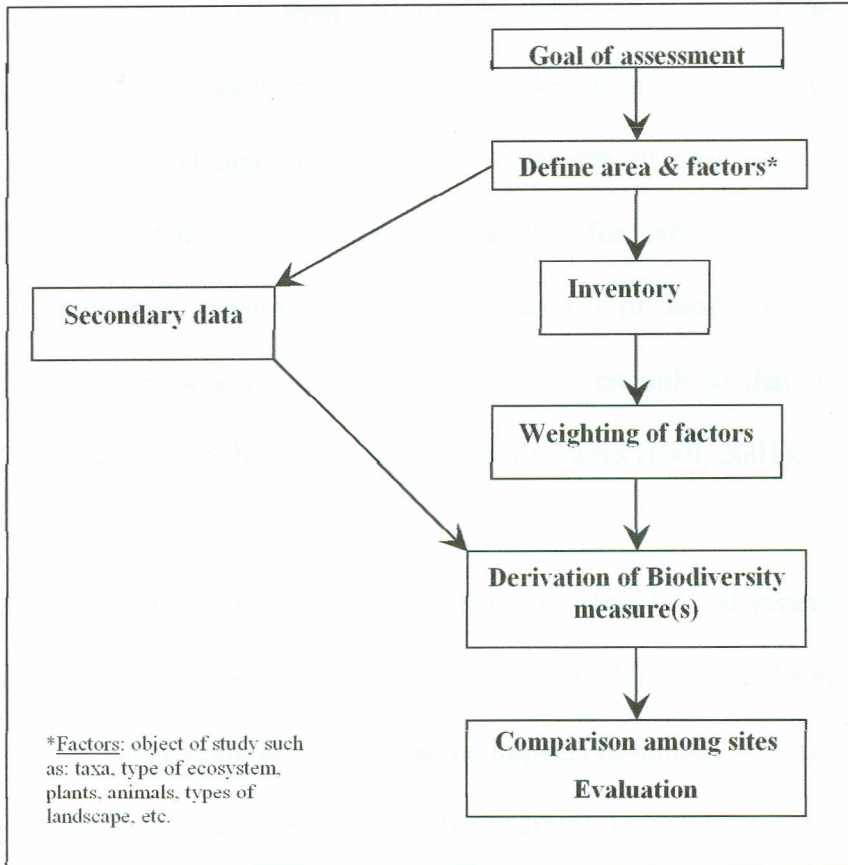


Figure 5. Steps in assessing biodiversity (Vermeulen and Koziell, 2002)

The recognition that complete assessments of biodiversity are rarely, if ever, practicable has led to interest in indicators as tools that summarise and simplify data on the complex series of environmental and social variables related to different ecosystems (Solbrig, 1996). Indicators are measurable surrogates of broader phenomena and in general they should be: relevant to the objectives of assessment, sensitive to change, concise, unambiguous, repeatable and financially and technically feasible. In addition, they must be equally applicable at different locations.

Biodiversity conservation has always been closely associated with particular species. According to Hambler (2004), these species may be key-stone species essential to the ecosystem because (i) of their large numbers and their influence in the ecosystem due to their vast populations, (ii) their activities modify the structure of the environment substantially. If any of such species were to be lost from the ecosystem, this would inevitably produce a change in the ecosystem that may or may not be reversible but would definitely change the conditions available for other species in that area. Hence, if indicators sensitive to land degradation or biodiversity loss can be identified, they can be used to detect change soon enough so that the appropriate measures can be initiated before the ecosystem degrades (Hall, 2001).

The use of indicators through methods such as Rapid Biodiversity Assessment (RBA) or Participatory Indicator Development (PID) (Doughill and Reed, 2002) can therefore, be of great value in monitoring the impacts of human activities on different ecosystems. According to Doughill and Reed (2002), indicators greatly help PID as the decision making process is facilitated and appropriate actions can be implemented and modified over time in order to maintain the livelihoods and stability of the ecosystem (Figure 6).

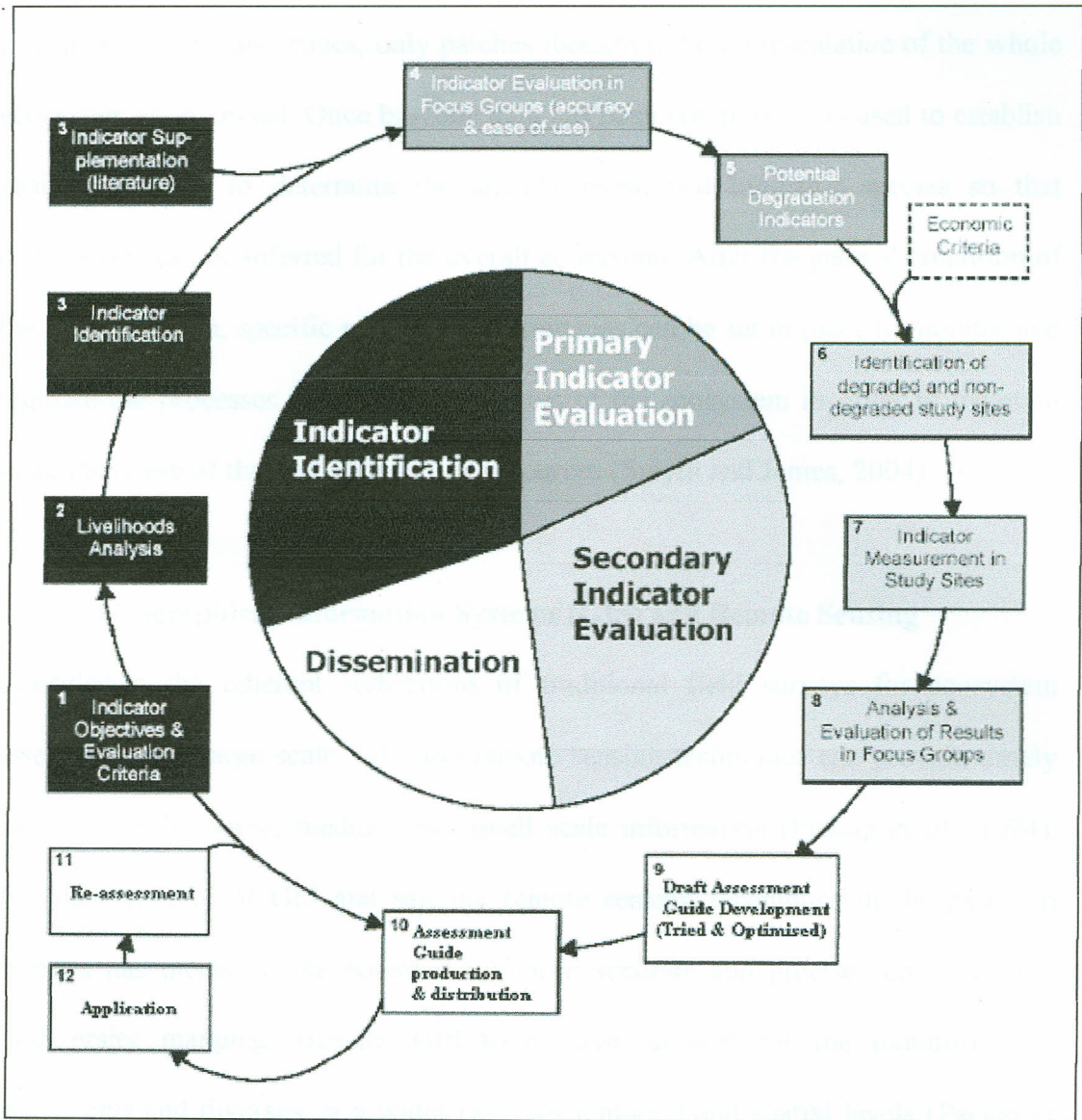


Figure 6. Methodology framework for Participatory Indicator Development (PID) (Doughill and Reed, 2002)

In general, most biodiversity assessment studies are based on field surveys of plants, animals or both. However, due to constrain of time and resources associated with measuring whole landscapes, only patches thought to be representative of the whole ecosystem are assessed. Once baseline data has been compiled, it is used to establish basic guidelines to determine the already mentioned indicator species so that conclusions can be inferred for the overall ecosystem. After the general condition of the area is known, specific management strategies can be set in place to monitor and regulate the processes influencing the status of the ecosystem in order to maintain sustainable use of the available natural resources (Smyth and James, 2004).

2.4 Geographical Information Systems (GIS) and Remote Sensing

Considering the inherent restrictions of traditional field surveys for ecosystem assessment at a large scale, GIS and remote sensing techniques can provide timely and inexpensive large, medium and small scale information (Pickup *et al.*, 1994). The development of GIS and satellite remote sensing techniques in the past two decades has increased the potential for more accurate and precise ecological and biodiversity mapping. Besides GIS tools have allowed for the monitoring of ecosystems and diversity at a wider range of temporal and spatial levels (Packer *et al.*, 1999). Due to the high resolution of satellite images and the power of different GIS tools, spatial problems such as those related to natural resource management are being resolved with increasing accuracy and especially those which involve land cover changes on the vast savannah ecosystems. Several studies (Byrne *et al.*, 1980; Malila, 1980; Ludwig *et al.*, 2003; Serra *et al.*, 2003) have used remote sensing and geographical information systems (GIS) to analyse land cover changes with considerable amounts of success.

In remote sensing, change detection has been defined as the identification and location of changes in radiance values between sets of multi-temporal images (Wang, 1993). From a conceptual point of view, land cover change detection permits the identification of long-term trends in time and space and the formulation of policy in anticipation of problems that accompany changes in land use. Besides, timely and accurate detection of change on the Earth's surface features is extremely important for understanding the relationships and interactions between human and natural phenomena in order to promote better decision making (Ogutu, 2004).

2.5 Traditional/ indigenous knowledge

Most ecological research done in the past has ignored the knowledge that indigenous people have regarding the management and maintenance of the ecosystems they inhabit. In general, most of the studies carried out in relation to indigenous people, and especially pastoralist communities, have concentrated mostly on the advocacy side of social research, neglecting their traditional ecological knowledge. However, in the past decade, authors such as Oba *et al.* (2000), Oba (2001) and Mapinduzi *et al.* (2003) have attempted to blend both scientific and traditional knowledge in an effort to discover the processes behind biodiversity persistence and to come up with sustainable management practices for pastoralist communities in ASAL regions.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

Vegetation and mammal biodiversity survey work, range condition assessment, land cover change evaluation and local perceptions appraisal work took place in Koija, Tiamamut and Kijabe Group Ranches (the three group ranches where the NRM programme is been established), located in the northern part of Laikipia District. Sampling was carried out once every month for a week between October 2004 and June 2005.

3.2 The study area

3.2.1 Koija, Tiamamut and Kijabe Group Ranches location

Koija, Tiamamut and Kijabe Group Ranches are situated within the Mukugodo division of the Laikipia District, and form a geographical border between Laikipia and Isiolo districts of Kenya (Figure 7).

The three group ranches fall under the agro-ecological zones V and VI (GOK, 1982), which correspond to semi-arid and arid areas respectively, and often considered to have a low agricultural potential. However, they have most of the country's rangelands, game reserves and national parks. Laikipia District is one of the most diverse areas of the country with respect to wildlife, holding approximately 8% of the large wildlife herbivores found outside protected areas (Legilisho-Kiyiapi, 2003). In the three Group Ranches the main land use activities are related to livestock keeping and wildlife conservation.

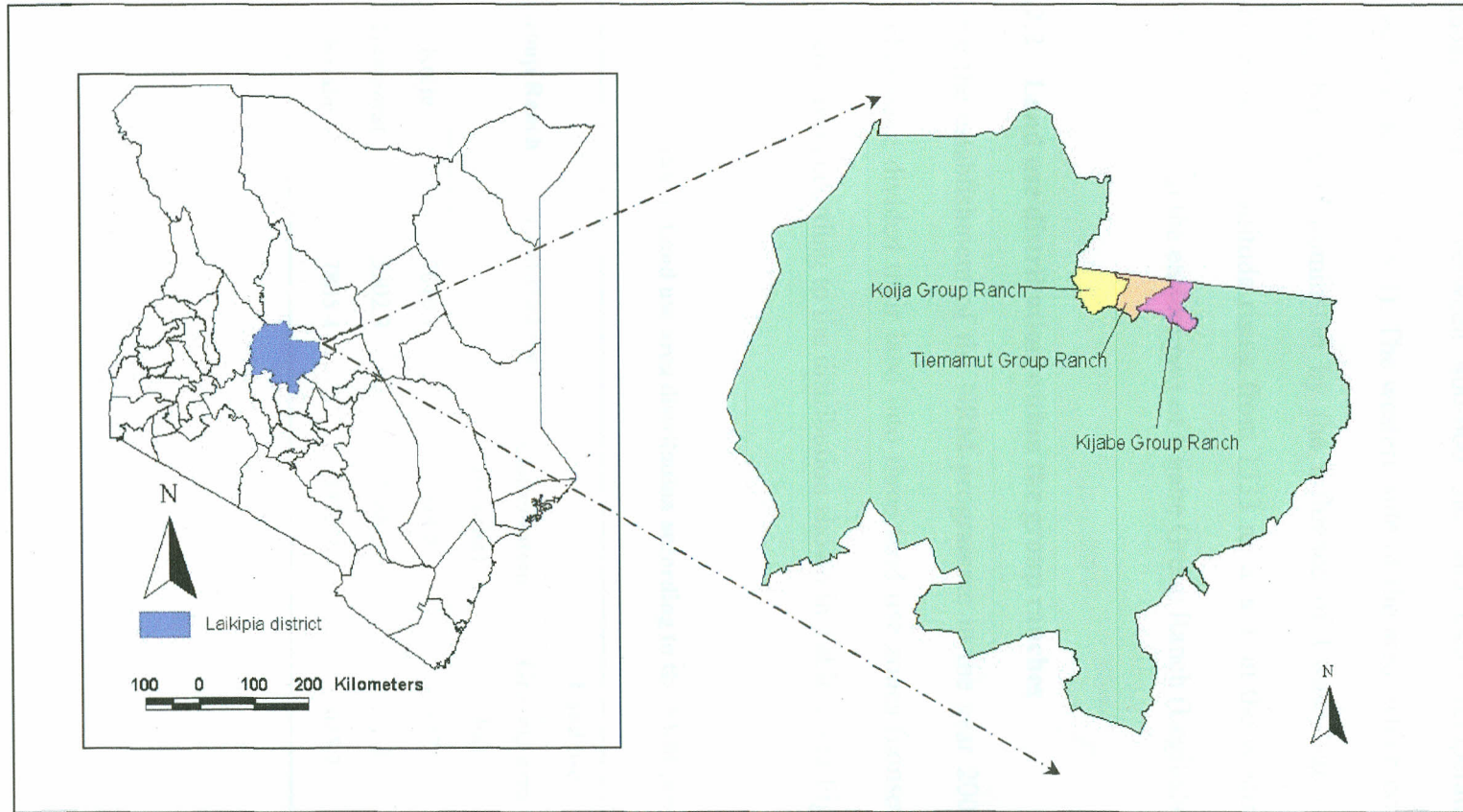


Figure 7. Map of Kenya showing the location of the Laikipia district and the three group ranches studied

The rainfall pattern in this area is bimodal with the long rainy season between March and May and a short rainy season between October and December, with a mean annual rainfall of between 400-600 mm and mean temperatures of 18-21 °C (Legilisho-Kiyiapi, 2003). The western side of the area, which corresponds to Koiya Group Ranch, is dominated by the influence of Ewaso-Ngiro River. The study ranches have an altitude rising from 1333 m. a. s. l. in the western part of Koiya to 1800 m. a. s. l. at the eastern part of Kijabe Group Ranch (Legilisho-Kiyiapi, 2003).

3.2.2 Land use distribution within the group ranches

Since the establishment of the NRM programme in the year 2000, the three group ranches have divided their land into three land use zones (conservation, settlement and grazing) according to the distribution shown in Table 1 and Figure 8.

Table 1. Land use area distribution according to the NRM programme

Group Ranch	Total land (ha)	Land use		
		Conservation area (ha)	Grazing area (ha)	Settlement area (ha)
Koiya	7610.7	1514.8	3447.7	2648.2
Tiamamut	5202.3	2388.3	796.1	2017.9
Kijabe	7805.4	2572.2	3025.7	2207.5

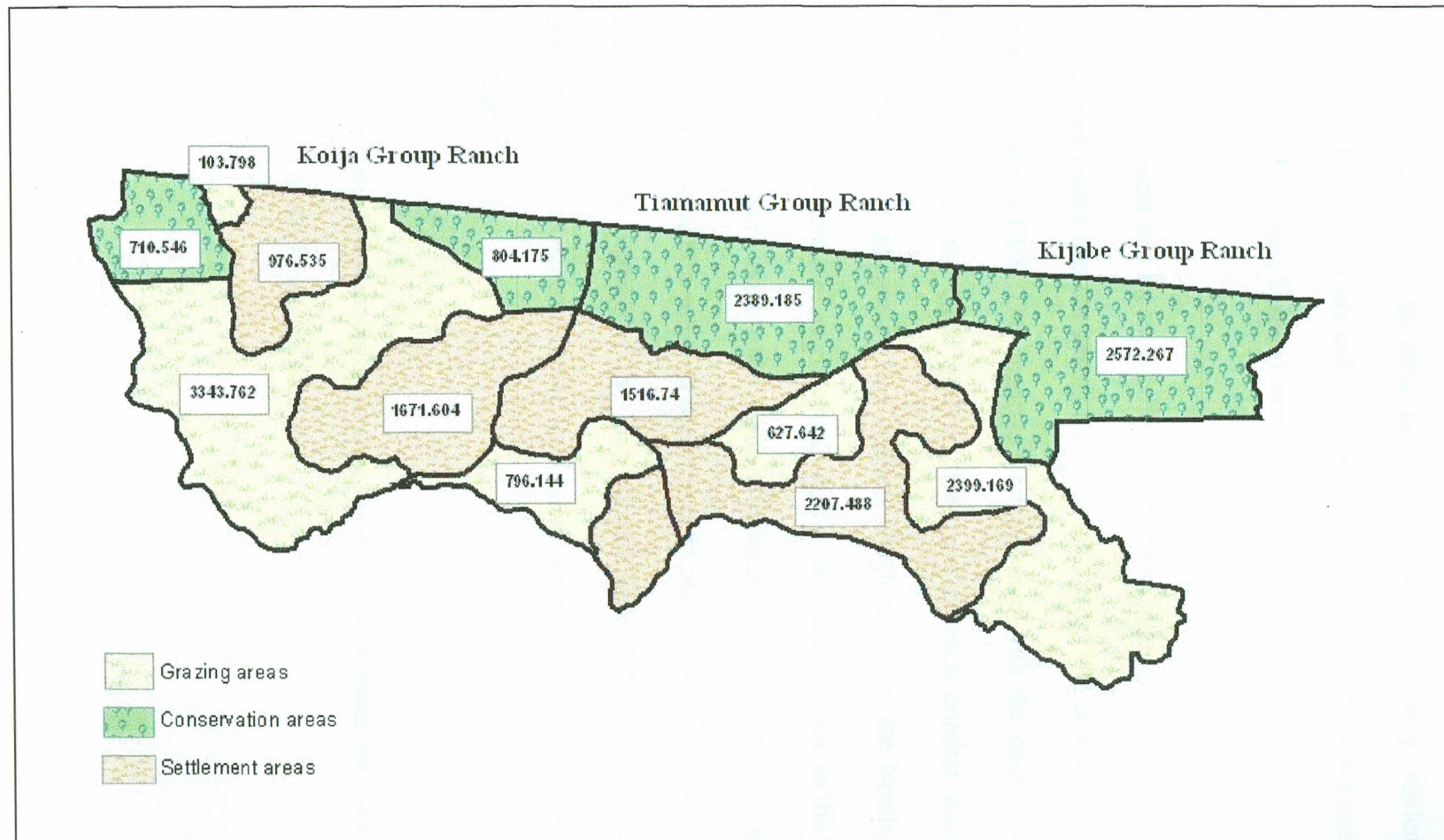


Figure 8. Map showing the land use distribution (in hectares) in Koiya, Tiamamut and Kijabe Group Ranches.

3.2.3 Sampling sites

Data collection in each Group Ranch involved laying quadrats located along roads and trails that run across the three land-use types (conservancy, settlement and grazing areas) (Figure 9). Data collection quadrats were geo-referenced using a GPS (Geographical Positioning System) receiver.

Due to the roughness and inaccessibility of the terrain, quadrats were laid 50-100 m from roads and tracks that cut across the three land uses. The centre of the quadrat was marked using a GPS. The quadrats were oriented with the help of an inbuilt compass provided by the GPS receiver. The base of each quadrat was oriented perpendicularly to an imaginary line transect which ran from the North to South passing through the centre of each quadrat. Using the quadrat centre as the reference point, the corners were established using a separate GPS set. In this regard, the distance between the centre and each corner was 34.5m (derived from the Pythagoras Theorem), while the bearing of the four corners were 45° , 135° , 225° and 315° (Figure 10). The plot corners (visible tree/ bush) were marked using highly visible masking tape.

Studies on vegetation, mammals and range condition took place on each land use type as described in the following section.

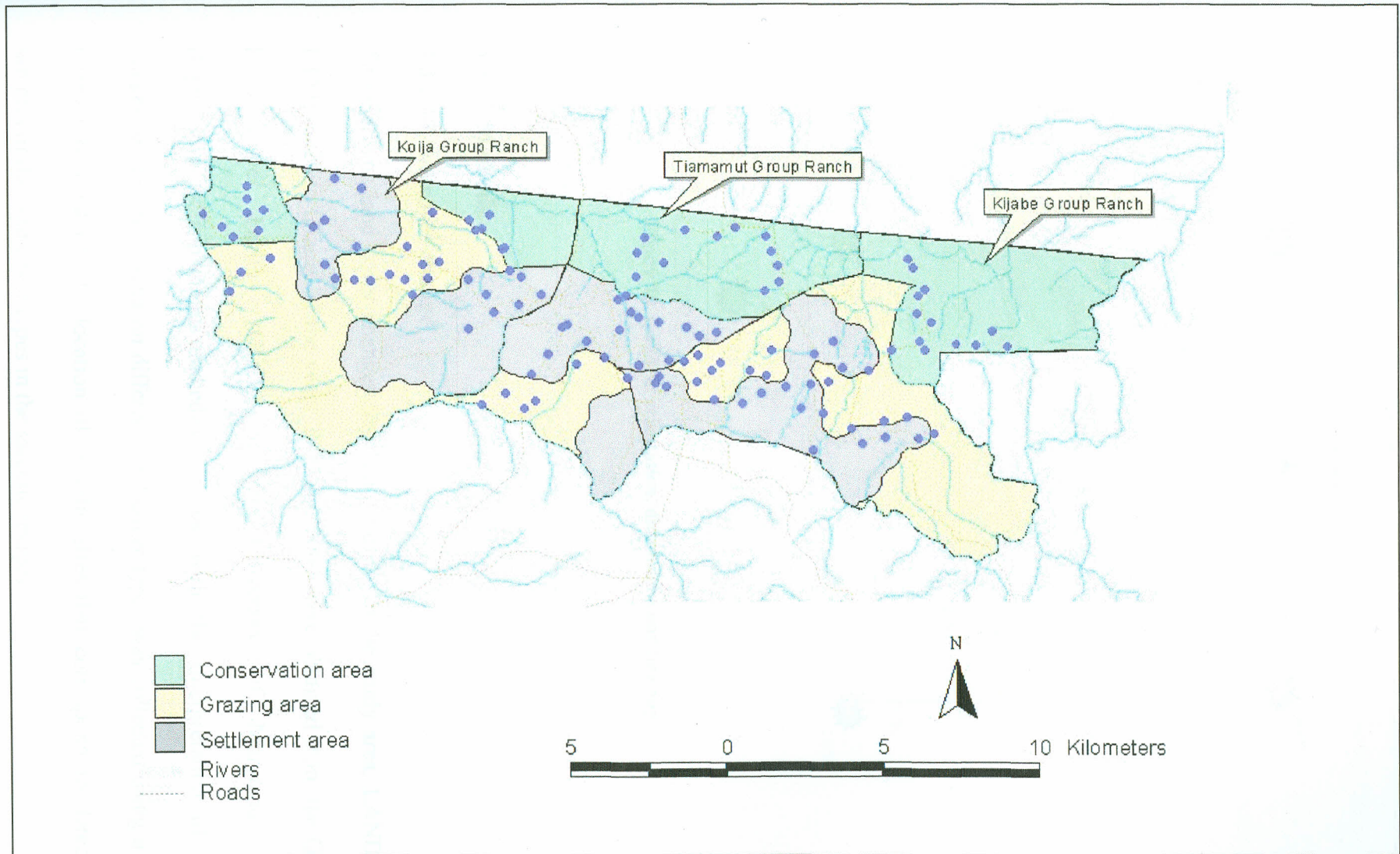


Figure 9. Map showing the location of the sampling quadrats in the study area

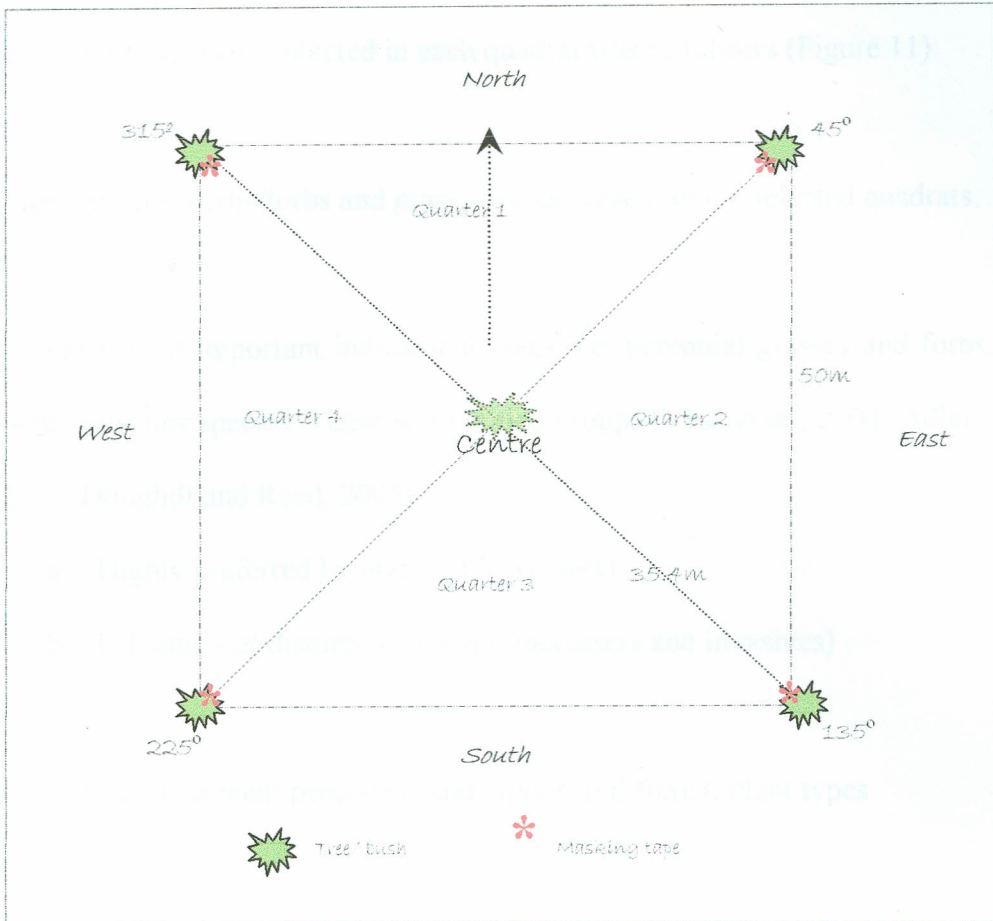


Figure 10. Quadrat orientation, dimensions and bearings.

3.3 Methods

3.3.1 Land cover change

To determine land cover changes that had occurred in the study area, LANDSAT ETM+ satellite images of the years 2000 and 2004 were obtained from the Global Land Cover Facility (GLCF) at the University of Maryland, USA (<http://www.glcapp.umiacs.umd.edu>). To aid with the interpretation of these images, ground-truth data on different land cover types was collected using a GPS receiver to establish the location of specific sites that correspond to detectable samples of the land cover types in the satellite images.

3.3.2 Vegetation

Vegetation information collected in each quadrat was as follows (Figure 11):

1. Trees, shrubs, herbs/forbs and grass species present in the selected quadrats.
2. Abundance of important indicator forages, i.e. perennial grasses and forbs, and other indicator species. These were in two groups (Vesk *et al.*, 2004; Adler *et al.*, 2005; Doughill and Reed, 2005):
 - a. Highly preferred by grazers (decreasers)
 - b. Indicators of disturbed habitats (increasers and invasives)
3. Growth form (annual/ perennial) and vigour of different plant types

The vegetation in the study area was categorized as follows (Ben-Shahar and Macdonald, 2002):

Table 2. Vegetation categories for the study according to height

Growth form	Height
Trees	> 3 m
Tall shrubs	1.5-3 m
Dwarf shrubs	0.5-1.5 m
Herb layer (grasses and herbs/forbs)	< 0.5 m

a. Trees and tall shrubs

All trees and tall shrubs with more than 50% of their canopy falling within a randomly chosen quarter of each 50x50 m quadrat were counted and recorded based on species. Percentage cover of each tree and tall shrub species in each plot was estimated visually.

b. Dwarf shrubs

These were sampled within one 10x10 m quadrat randomly located in one quarter of the 50x50 m quadrat. Dwarf shrub species with more than 50% of their canopy falling within each 10x10 m plot were identified and recorded. The percent cover by each dwarf shrub species was estimated visually.

c. Herb layer cover

Herb layer vegetation was sampled using a combination of one 1x1 m quadrat and a 10-pin frame randomly located in one quarter of the 50x50 m plot. The 1x1 m quadrat was used to select the area of in which samples will be collected and the 10-pin frame was used to avoid any biasness on herb/ grass cover estimation (if individual species are too small they might be neglected).

Herbaceous species found within each quadrat were identified and recorded. As mentioned in the previous paragraph, percent cover of different herbaceous species, litter and bare-ground was estimated using a 10-pin frame. This was placed 4 times within the 1x1m quadrat, maintaining a parallel position to one of the sides of the quadrat. Then, the number of pin hits by foliage for each species, bare ground and litter were recorded.

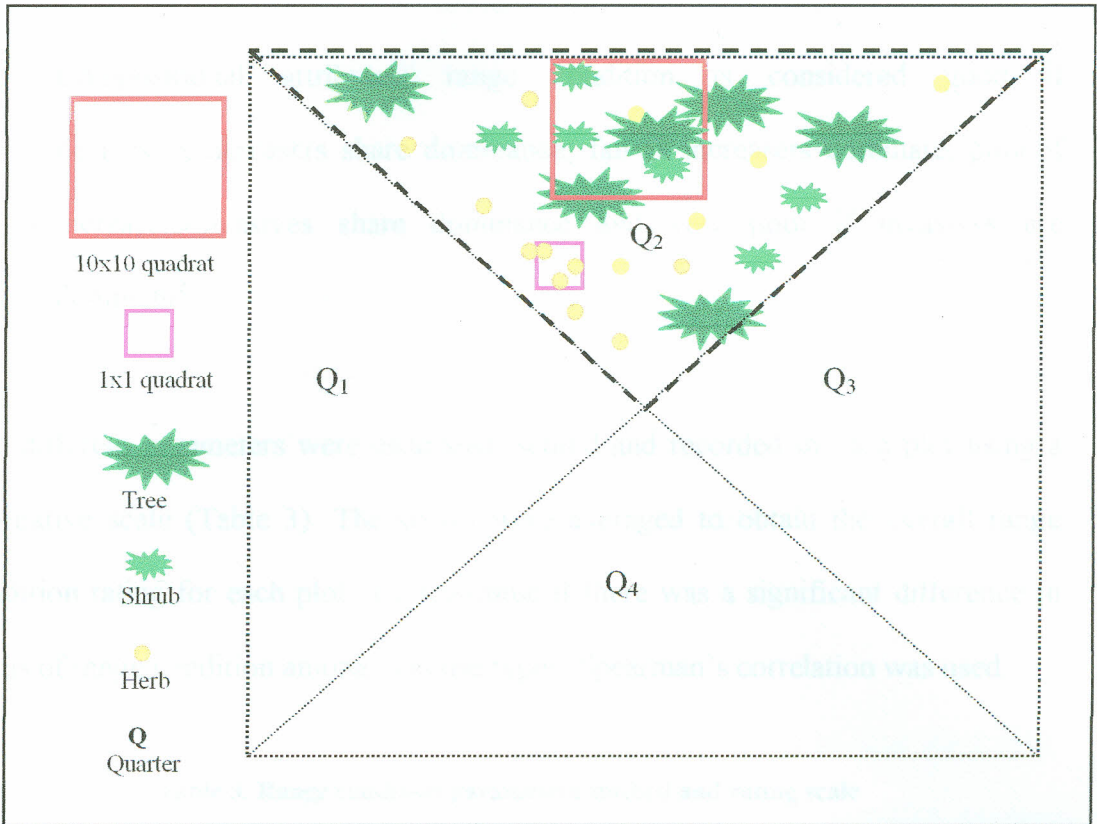


Figure 11. Vegetation sampling within the 50x50 quadrat

Where parametric statistical data analyses were required, the percentage cover results were normalized using the arsine transformation.

3.3.3 Range condition

Using the methods developed by Herlocker (1995), Shabaani *et al.* (1992) and Thurow and Herlocker (1993), the following parameters were assessed:

- a. Soil erosion (trampling, degree of litter cover, surface crusting, sheet erosion and bare ground cover).
- b. Shrub hedging (cumulative impact of grazing/browsing on trees and shrubs).

- c. Compositional attributes: range condition is considered good if decrease/increaser share dominance; fair if increaser dominate; poor if increaser/invasives share dominance and very poor if invasives are dominant.

The different parameters were estimated, scored and recorded in each plot using a qualitative scale (Table 3). The scores were averaged to obtain the overall range condition rating for each plot. To determine if there was a significant difference in status of range condition among land use types, Spearman's correlation was used.

Table 3. Range condition parameters studied and rating scale

Parameter	Rating scale				
	3 (Good)	2 (Moderate)	1 (Poor)	0 (Very poor)	
Soil Erosion	Surface crusting	No visible crusts	Some small crusts near vegetation	Widespread crusts	Deep widespread crusts
	Sheet erosion/gullies	No gullies or sheets	Some sheet erosion due to water flush	Deep sheet erosion and developing gullies	Deep gullies and abundant sheet erosion
	Bare ground cover	< 25 % bare ground	25% < bare ground < 50%	50% < bare ground < 75%	> 75% bare ground
	Litter cover	> 75% litter cover	75% < litter < 50%	50% < litter < 25%	< 25% litter
	Trampling	No visible livestock trails	Few livestock trails (< 25%)	Wide-spread livestock trails	Abundant human and livestock trails
Shrub hedging	No visible shrub/ tree hedging	Some shrub hedging	Some debarking and shrub hedging	Abundant tree debarking and dwarf shrubs	
Compositional attributes	Decreaser-increaser species share dominance	Increaser species dominant	Increaser-invasive species share dominance	Invasive species dominant	
Plant vigour	Green and healthy vegetation	Green tree canopy, shrub and most of herb layer vegetation green	Some signs of withering vegetation	Dry, wilt vegetation	

3.3.4 Small mammals

Two groups of non-volant small mammals were targeted: rodents and shrews. Sherman's live traps were used to trap these small mammals. Each trapping site consisted of 50 traps distributed on several line transects within each 50x50 m quadrat. The traps were located at 5 m intervals in microhabitats suspected to be used by the animals and were baited with a mixture of fried coconut cubes, peanut butter and corn oil (Barnett and Dutton, 1995; Oguge *et. al*, 2004) that also served as food for the animals. Traps were checked every morning and removed from the field at the end of each collecting session (every two days).

The captured specimens were weighed, sexed and identified to species level. Also the reproductive condition was recorded with females being classified as non-reproductive or reproductively active (dependent on non-perforate or perforated vagina), pregnant or lactating; and males as non-reproductive (abdominal testes) or reproductively active (scrotal testes).

3.3.5 Carnivores and large mammals

a. Carnivore presence

Carnivore scent stations were used to determine the presence of small and large predators. These were set at one of the plots in each of the three land use areas in every visit to the field. These stations consisted of a 1 x 1m wooden platform covered with finally grinded sand with a 1m tall pole where rotten meat was spread to attract the animals (Figure 12). The stations were inspected every morning for animal tracks.

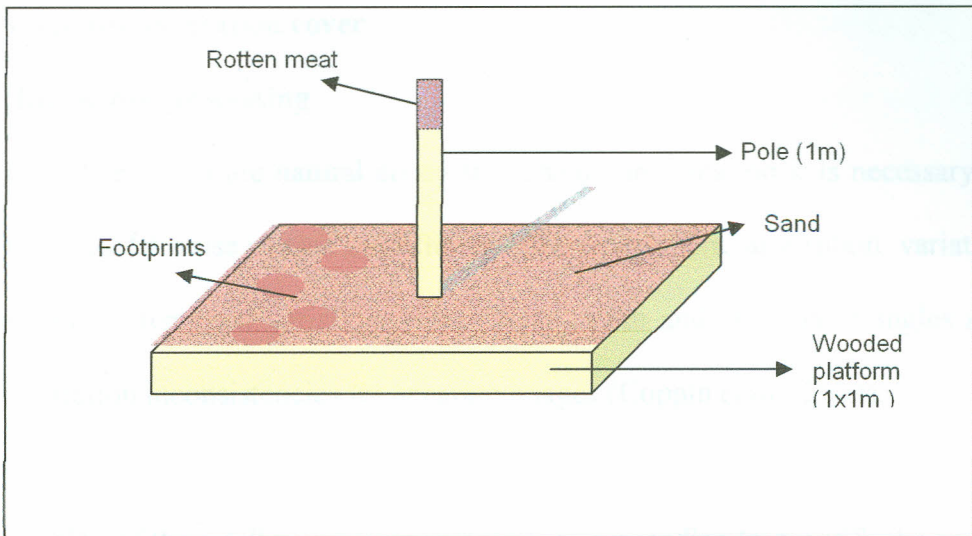


Figure 12. Carnivore scent station

b. Large mammals presence and abundance

Large mammal presence and abundance was recorded through direct observations along roads that crossed all land use types of the three group ranches. The observed animals were identified to species level and their numbers recorded. The observations were made between 6 am and 8am when these animals are more easily spotted.

3.3.6 Local community perceptions

The perceptions and knowledge of the local communities on the NRM programme were assessed through a one to one interviews carried out by local scouts where a structured questionnaire (Appendix 3) was filled in by 50 individuals from each group ranch. To analyse the responses of the local people to the questionnaire, percentages for each section of the questionnaire were calculated.

3.4 Data analysis

3.4.1 Land use vegetation cover

3.4.1.1 Image pre-processing

In order to obtain accurate natural ecosystem change information it is necessary to reduce the inherent noise caused by differences in atmospheric absorption, variation in water vapour, temporal variations in the solar zenith and/or azimuth angles and sensor calibration inconsistencies for separate images (Coppin *et al.*, 2004).

Pre-processing of the satellite sensor images before proceeding to quantify the actual change detection is therefore essential as it will help establish a more direct linkage between the data and the biophysical phenomena on the ground.

a. Atmospheric correction

The presence of an atmosphere between the ground and the satellite means that a pixel value in a remotely sensed image is unlikely to truly represent the radiance originating from the ground. Radiation from the earth's surface interacts with the atmosphere through absorption and scattering before reaching the sensor. The amount of atmospheric interaction/distortion is wavelength dependent, with shorter wavelengths experiencing more scattering than longer wavelengths (Sabins, 1997). Subsequently, atmospheric correction is considered a necessary step before extracting quantitative information from a set of images.

In this study, the dark pixel subtraction (DOS) was used as a simple, direct and effective method for correcting atmospheric effects. The principle behind this approach is that some dark objects (e.g. deep water or dark dense vegetation) in the

image will have zero or near zero reflectances in certain wavelengths. However, due to atmospheric scattering, the minimum values of these dark pixels are usually not zero, but some larger value (Campbell, 2002). These minimum values for each band are then assumed to represent the contribution of atmospheric scattering. Hence, if the minimum is subtracted for each band, the lowest value of each band is set to zero, assuming the correct signature for dark objects is zero in the absence of atmospheric scattering.

In this study, water features were selected and an area of interest (AOI) identified and the mean values of each band in the AOI calculated. These mean values were then used in the dark object subtraction procedure. Only water bodies in which the spectral values of the blue band equal zero were used for the atmospheric correction.

The atmospheric correction procedure was executed using the ERDAS Imagine Modeller function as described in the ERDAS Image Tour Guide (Erdas, 1999).

b. Geometric correction

Geometric correction addresses the errors in the relative positions of pixels. The images used in this study were acquired already systematically corrected for sensor geometry and terrain variations to level 1G (maximum level) by the Global Land Cover Facility (GLCF) at the University of Maryland, USA (<http://www.glcapp.umd.edu>).

3.4.1.2 Image processing

Once the images had been pre-processed (corrected for atmospheric distortion and geometric variation) and made “ready” for the essential image analysis, the following image analysis procedures were employed to detect the land cover changes in the study area.

a. Normalized Difference Vegetation Index (NDVI) computation

Vegetation indices (VIs) based upon digital brightness, have been extensively used to study vegetation biomass or vigour (Tucker, 1979; Tucker, 1986). The indices are based on the premise that chlorophyll in actively growing vegetation is a strong absorber of red radiation, and the cell-wall structure of healthy leaves strongly reflects Near Infrared (NIR) radiation. Greater photosynthetic activity will therefore result in lower reflectance in the red band and higher reflectance in the NIR. It is for this reason that the red and NIR regions of the electromagnetic spectrum are primary bands utilized in remote sensing of vegetation. By combining these two spectral regions in a ratio, the sensitivity of the sensor to photosynthetic activity is enhanced. While a variety of VIs have been used over the past decades, the NDVI is the most commonly applied index:

$$NDVI = \frac{NIR - RED}{NIR + RED} \dots\dots\dots \text{Equation 1}$$

By normalizing the difference between the channel values, NDVI values are scaled to lie in the range between -1 and +1. High positive values of NDVI correspond to dense vegetation cover whereas negative values are usually associated with bare soils, snow, clouds or non-vegetation areas (Oindo and Skidmore, 2000).

In this study, the NDVI values were calculated using the ERDAS Image Modeller function using the following equation:

$$NDVI = \frac{Band4 - Band3}{Band4 + Band3} \dots\dots\dots \text{Equation 2}$$

b. Classification

The classification process consists of two stages (Mather, 1999). The first is the recognition of categories of real-world objects. In the context of remote sensing of land surface examples of these categories include: woodlands, water bodies, grasslands, and other land cover types depending on the geographical scale and nature of the study. The second stage in the classification process is the labelling of entities (normally pixels) to be classified. Therefore, the process of classification often requires the user to: 1) determine in advance the number and nature of the categories in terms of which the land cover is to be described and, 2) assign numerical levels to the pixels on the basis of their properties using a decision making procedure, usually termed a decision rule or classification rule. There are three distinct classification approaches used in the field of remote sensing: unsupervised, supervised and hybrid classification. In this study, the supervised classification method was used to determine the land cover types in each of the satellite images because of the high accuracy and flexibility it offers the user in terms of using data collected in the field during the classification process.

Supervised classification

Supervised classification has been defined as the process of using samples of known identity (i.e. pixels already assigned to informal classes: bushland, water bodies, etc) to classify pixels of unknown identity (Campbell, 2002). Knowledge of the data, the classes desired and the algorithm to be used is required before training is done. By identifying patterns in the imagery, the computer is trained to identify pixels with similar characteristics. There are a several algorithms for performing supervised classification, but the most commonly used method is the maximum likelihood classifier. It is also considered to be the most accurate of the classifiers compared to other algorithms (Erdas, 1999).

Accuracy assessment

Accuracy assessment allows a researcher to compare certain pixel values in the thematic raster layer (original image) to the reference pixels, for which the class is known. This is an organized way of comparing the classification with ground-truth data, a previously tested map, aerial photos, or other data of the study area. Accuracy assessment is therefore important for understanding the developed results and employing these results for decision-making.

The most common accuracy assessment method is the preparation of a classification error matrix (or confusion matrix). Error matrix compares, on a category-by-category basis, the relationship between known pixel reference data and corresponding results of an automated classification. The most common elements of the error matrix accuracy assessment include overall accuracy, producer's accuracy, user's accuracy and kappa coefficient (Lillesand and Kiefer, 2000).

3.4.2 Biodiversity assessment

Biodiversity indices and evenness measures were used to assess the biodiversity of both vegetation and mammal species within the different land uses. Simpson's index (1-D) and Shannon-Weiner index (H') were used to calculate the mammal and vegetation biodiversity of every land use in each group ranch, to have indices which put emphasis both on dominant species (Simpson's) and rare species (Shannon-Weiner's). Smith-Wilson index was selected to quantify the evenness of the data samples as it is independent of species richness and is sensitive to both rare and common species in the community (Krebs, 1999):

$$(1 - D) = 1 - \sum p_i^2 \dots\dots\dots \text{Equation 3}$$

$$H' = \sum_{i=1}^s (p_i)(\log_2 p_i) \dots\dots\dots \text{Equation 4}$$

$$E_{var} = 1 - \left[\frac{2}{\pi \arctan \left\{ \frac{\sum_{i=1}^s \left(\log_e(n_i) - \sum_{j=1}^s \log_e(n_j / s) \right)^2}{S} \right\}} \right] \dots\dots\dots \text{Equation 5}$$

Where,

Equation 3: Simpson's Index

Equation 4: Shannon-Weiner's Index

Equation 5: Smith-Wilson's Index of evenness

(1 - D): Simpson's Index

p_i : proportion of individuals of species 'i' in the community

H' : Shannon-Wiener's Index

s : number of species in the entire sample

p_i : proportion of total sample belonging to the i^{th} species

E_{var} : Smith-Wilson's Index of evenness

n_i : number of individuals in species ' i ' in sample ($i = 1, 2, \dots, s$)

n_j : number of individuals in species ' j ' in sample ($j = 1, 2, \dots, s$)

The differences in biodiversity indices among land uses within each group ranch were investigated using Pearson's correlation.

3.4.3 Community similarity assessment

During this study, Morisita's index of similarity was used to compare the difference in flora and fauna composition of the three land uses within and between group ranches. This index varies from 0 (no similarity) to 1 (complete similarity) and is nearly independent of sample size, except for very small sample sizes. Morisita's index is considered to be the best overall measure of similarity for ecological use (Krebs, 1999).

3.4.4 Species richness assessment

To capture the species richness of the different land uses in each group ranch, the mean number of species per quadrat per land use type was calculated and compared using one way ANOVA at .05 significance level. Tukey HSD test was used to determine the direction of the differences.

CHAPTER FOUR: RESULTS

4.1 GIS analysis

4.1.1 Land cover type changes

Based on the signatures from supervised classification, the visual inspection of the original image and the available secondary data (GPS ground-truthing points), the satellite images (LANDSAT ETM+) were classified into seven land cover categories (Table 4).

Table 4. Land cover types used during the supervised classification

Land cover type	Description
Mixed bushland/ riverine vegetation	Included areas with $\geq 50\%$ mixed cover of <i>Acacia etbaica</i> , <i>A. mellifera</i> , <i>A. nilotica</i> , <i>A. tortilis</i> , <i>Olea europaea</i> and <i>Maytenus</i> spp. and areas of riverine vegetation
<i>Acacia mellifera</i> bushland	Included areas with $\geq 50\%$ cover of <i>Acacia mellifera</i>
Mixed shrubland	Included areas with $\leq 40\%$ tree cover and $\geq 50\%$ cover of different shrub species such as <i>Croton dichogamus</i> , <i>Acacia brevispica</i> , <i>A. etbaica</i> , <i>Commiphora</i> spp, <i>Maerua</i> spp, <i>Balanites</i> spp
Mixed grassland	Included areas with $\leq 20\%$ tree cover and $\geq 40\%$ herb layer composed of different grasses and forbs such as <i>Themeda</i> spp, <i>Digitaria milanjana</i> , <i>Aristida</i> spp and <i>Cynodon</i> spp
<i>Pennisetum</i> spp grassland	Included areas $\geq 50\%$ cover of <i>Pennisetum</i> spp and <i>Acacia drepanolobium</i> generally located on black cotton soil
Bare ground/ rock outcrop/ sandy areas	Included sandy and rocky areas as well as bare ground soils
Shadows	Included areas where shadows were present at the time

Analysis of the year 2000 satellite image (Figure 13) revealed that areas of bushland are found mainly in the conservation areas and some patches in grazing areas of the three group ranches. Shrubland appeared widely distributed in grazing and conservation areas, while grasslands are mainly located in settlement (particularly in Koiya and Tiamamut) and grazing areas of the three group ranches. In the 2004 image (Figure 14), bushland areas were found in conservation areas and grazing areas near them. Shrublands were restricted to grazing areas and a few patches in conservancies while grasslands were widely distributed through settlement and grazing areas. Accuracy assessment of the 2000 and 2004 images (Tables 5 and 6 respectively), indicated an overall accuracy of 71.8% and 72.9% respectively.

In order to determine the relative area covered by each vegetation type, a grid analysis of the supervised maps was run (Figure 15). A comparison of the changes in the percentage cover of the five general vegetation categories between the 2000 and 2004 images, revealed that bushland and grassland cover have undergone a general increase (12.8% and 1.1% respectively) while shrubland cover declined noticeably over that period (16.2 %). Some increase (3.3%) in bare ground and sandy areas was also observed in the three group ranches.

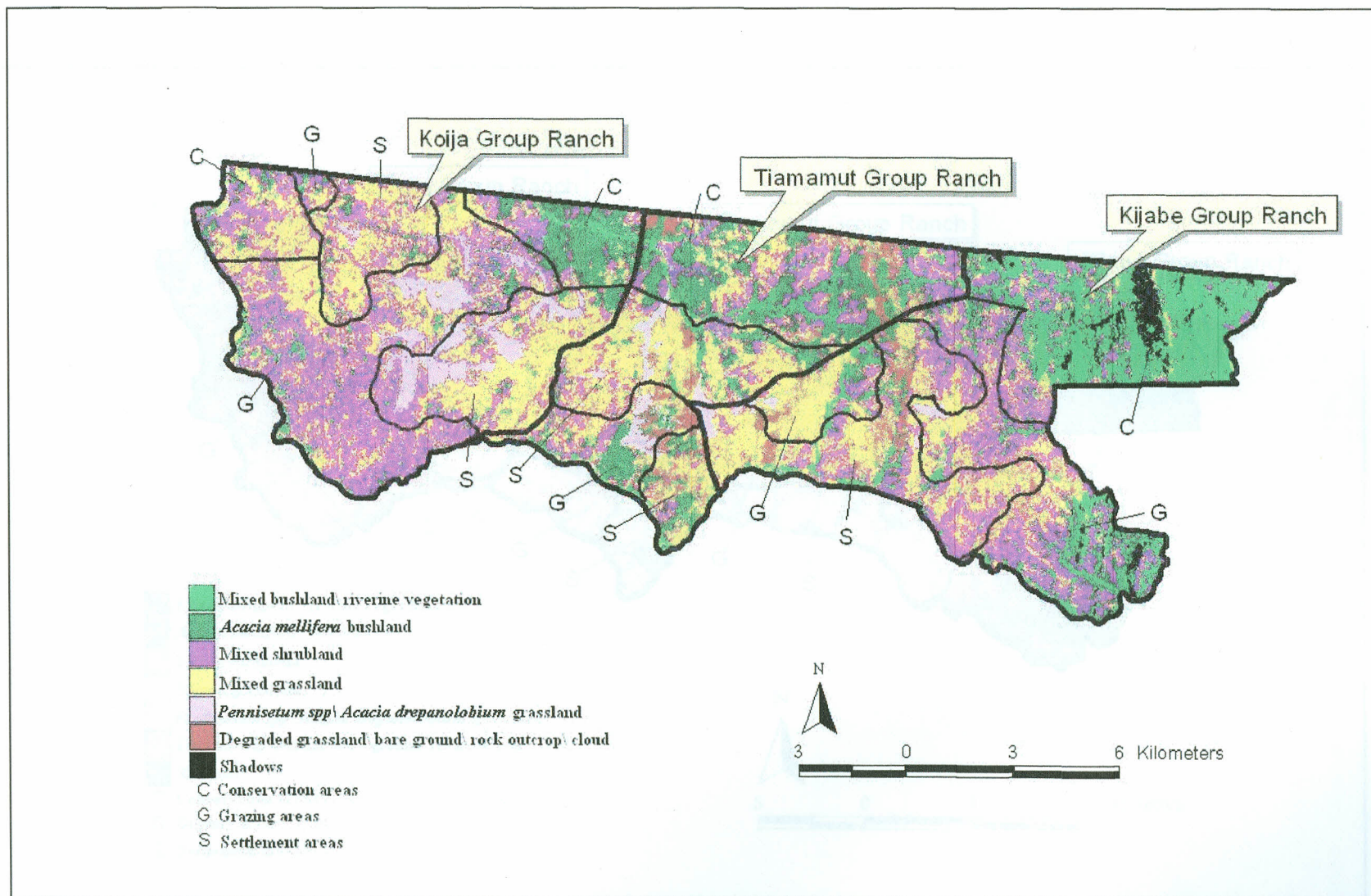


Figure 13. Supervised classification map for 2000 LANDSAT ETM+ image of the study area

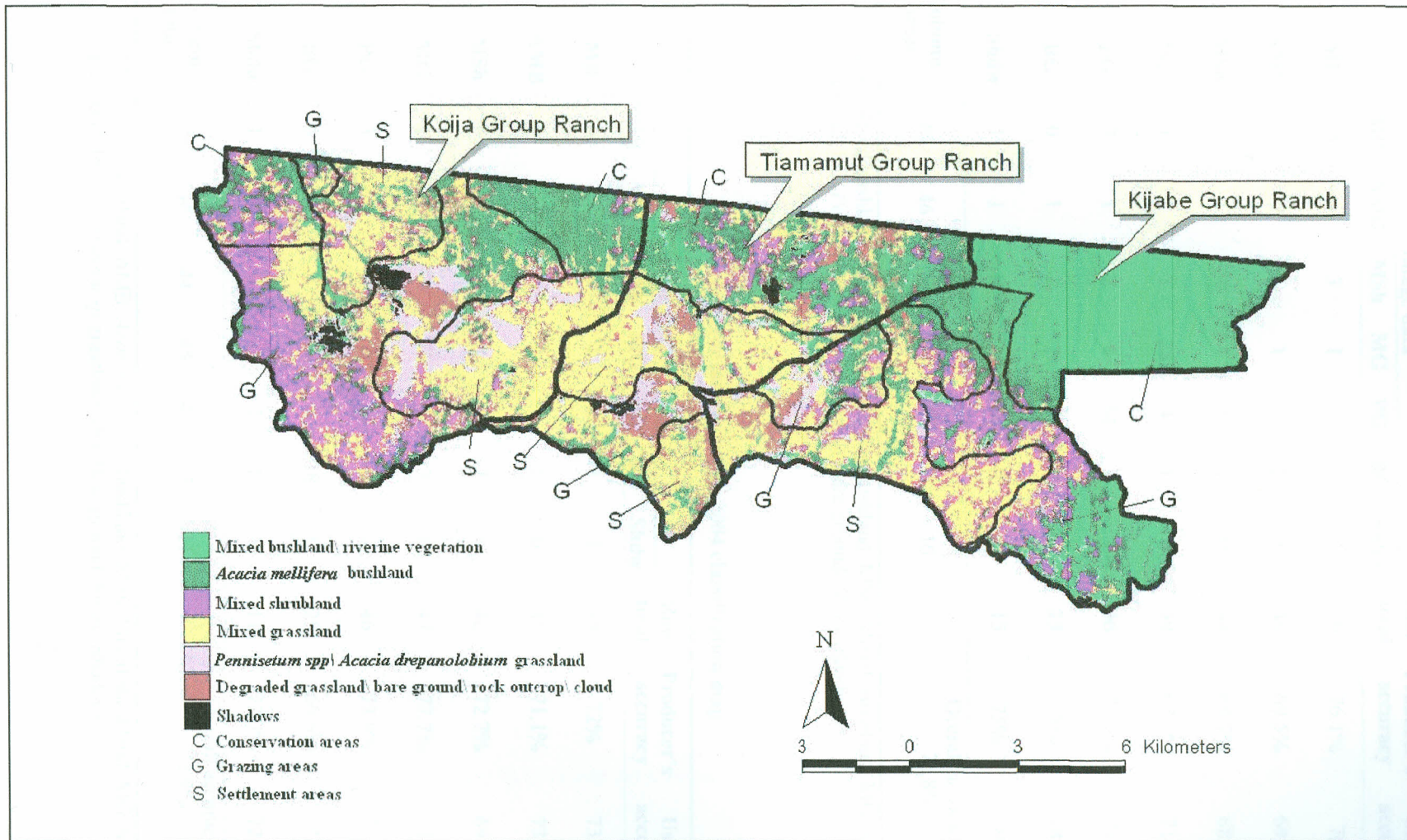


Figure 14. Supervised classification map for 2004 LANDSAT ETM+ image of the study area

Table 5. Error matrix for the 2000 classification map

	Image data							Row total	Producer's accuracy	User's accuracy	
	MB	AMB	MSh	MG	PG	BG	Shdw				
Reference data	MB	35	6	3	1	2	1	2	50	76.1%	70%
	AMB	4	32	4	1	3	1	1	46	69.5%	69.5%
	MSh	3	3	30	4	3	1	0	44	69.7%	68.2%
	MG	1	2	3	28	4	1	0	39	68.3%	71.8%
	PG	2	1	2	4	34	2	1	46	72.3%	73.9%
	BG	0	1	1	2	1	18	0	23	75%	78.3%
	Shdw	1	1	0	1	0	0	12	15	75%	80%
Column total	46	46	43	41	47	24	16	Overall accuracy : 71.8%			

MB: Mixed bushland; AMB: *Acacia mellifera* bushland; MSh: Mixed shrubland; MG: Mixed grassland; PG: *Pennisetum sp* grassland; BG: Bare ground; Shdw: Shadows.

Table 6. Error matrix for the 2004 classification map

	Image data							Row total	Producer's accuracy	User's accuracy	
	MB	AMB	MSh	MG	PG	BG	Shdw				
Reference data	MB	36	5	3	1	2	1	1	49	72%	73.4%
	AMB	6	33	2	2	1	1	0	45	71.1%	73.3%
	MSh	3	4	32	3	2	2	0	46	72.7%	69.5%
	MG	1	2	3	35	3	3	0	47	77.7%	74.4%
	PG	3	1	3	2	34	1	2	46	73.9%	73.9%
	BG	0	1	1	2	3	18	0	25	66.6%	72%
	Shdw	1	0	0	0	1	1	8	11	72.7%	72.7%
Column total	50	46	44	45	46	27	11	Overall accuracy : 72.9%			

MB: Mixed bushland; AMB: *Acacia mellifera* bushland; MSh: Mixed shrubland; MG: Mixed grassland; PG: *Pennisetum sp* grassland; BG: Bare ground; Shdw: Shadows.

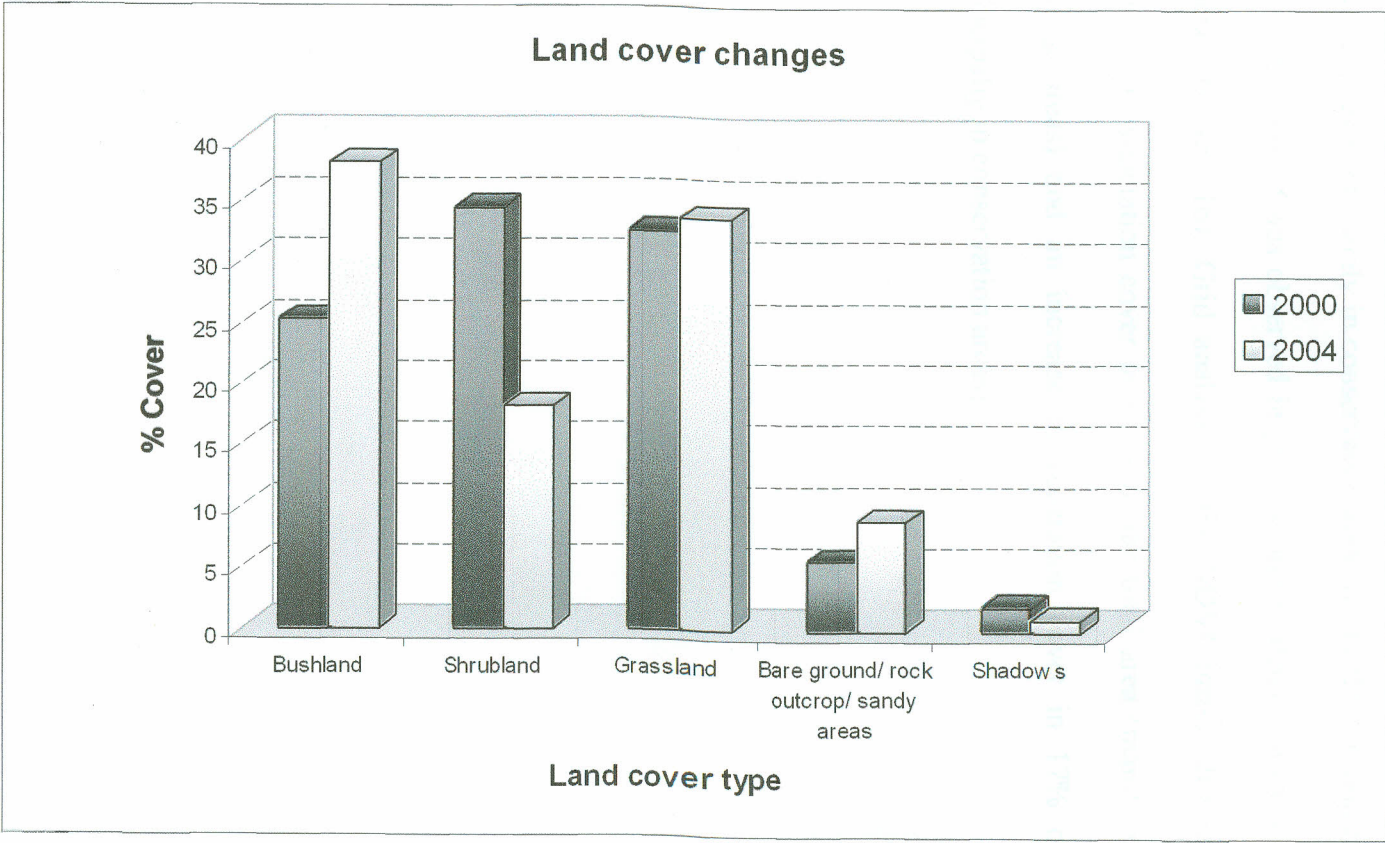


Figure 15. Land cover changes in the study area based on grid analysis of the supervised classification maps.

4.1.2 Land cover variation

Analysis of the images through NDVI image differencing located the significant land cover changes since the establishment of the NRM programme. Increase in land cover was evident mainly in conservancy areas of the three group ranches whereas a decrease in cover was observed in grazing and settlement areas of the three group ranches (Figure 16). Grid analysis of the NDVI image differencing showed a decrease in vegetation cover in 6.3% of the total area (mainly in settlement and grazing areas) and an increase in vegetation cover in 17% of the total area (principally in conservation areas).

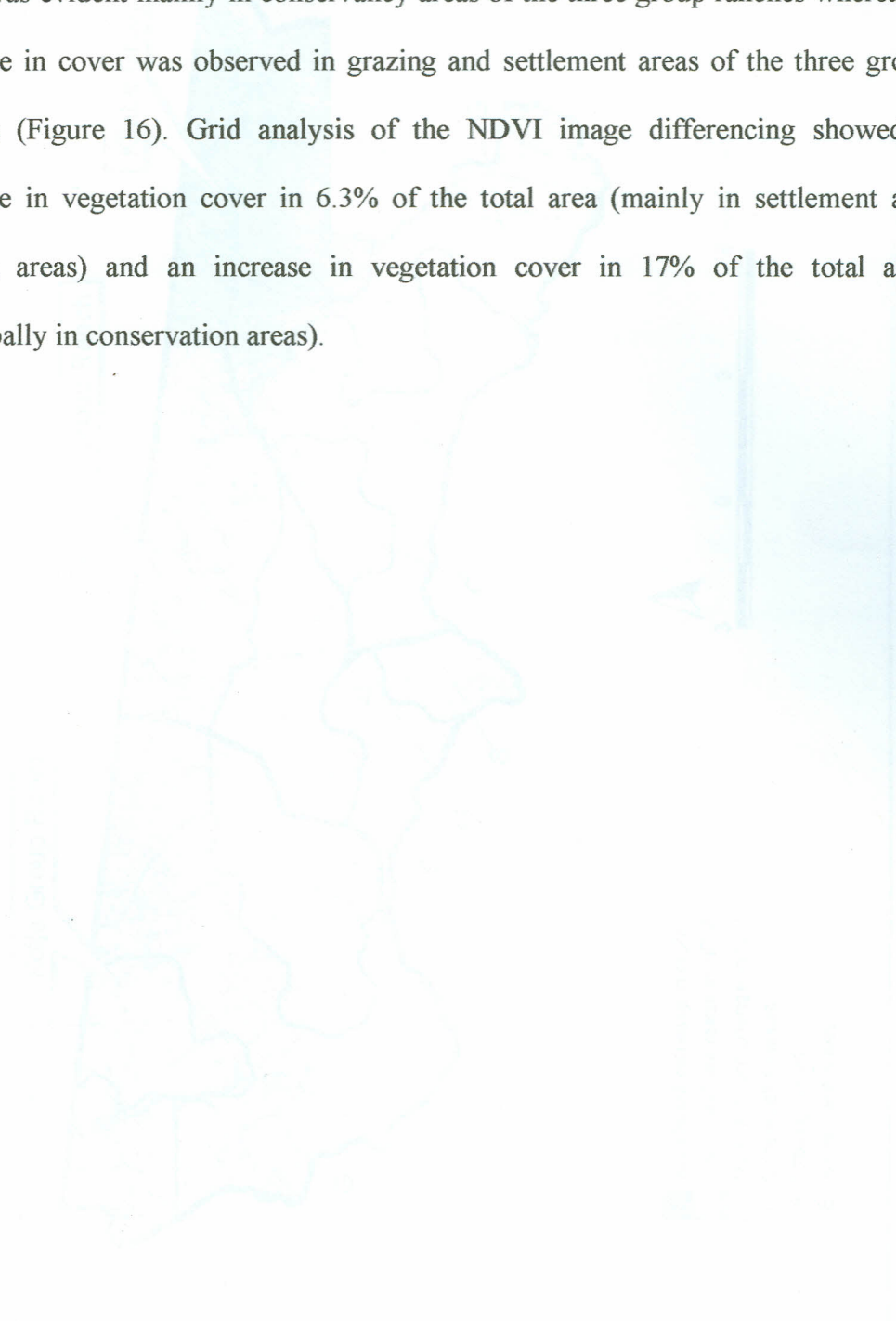


Figure 16: NDVI image differencing between 2004 and 2009. The map shows three group ranches with various land cover types. A legend on the right indicates 'Increase in NDVI' (green) and 'Decrease in NDVI' (red). The map shows a significant increase in vegetation cover in the conservancy areas and a decrease in cover in the grazing and settlement areas.

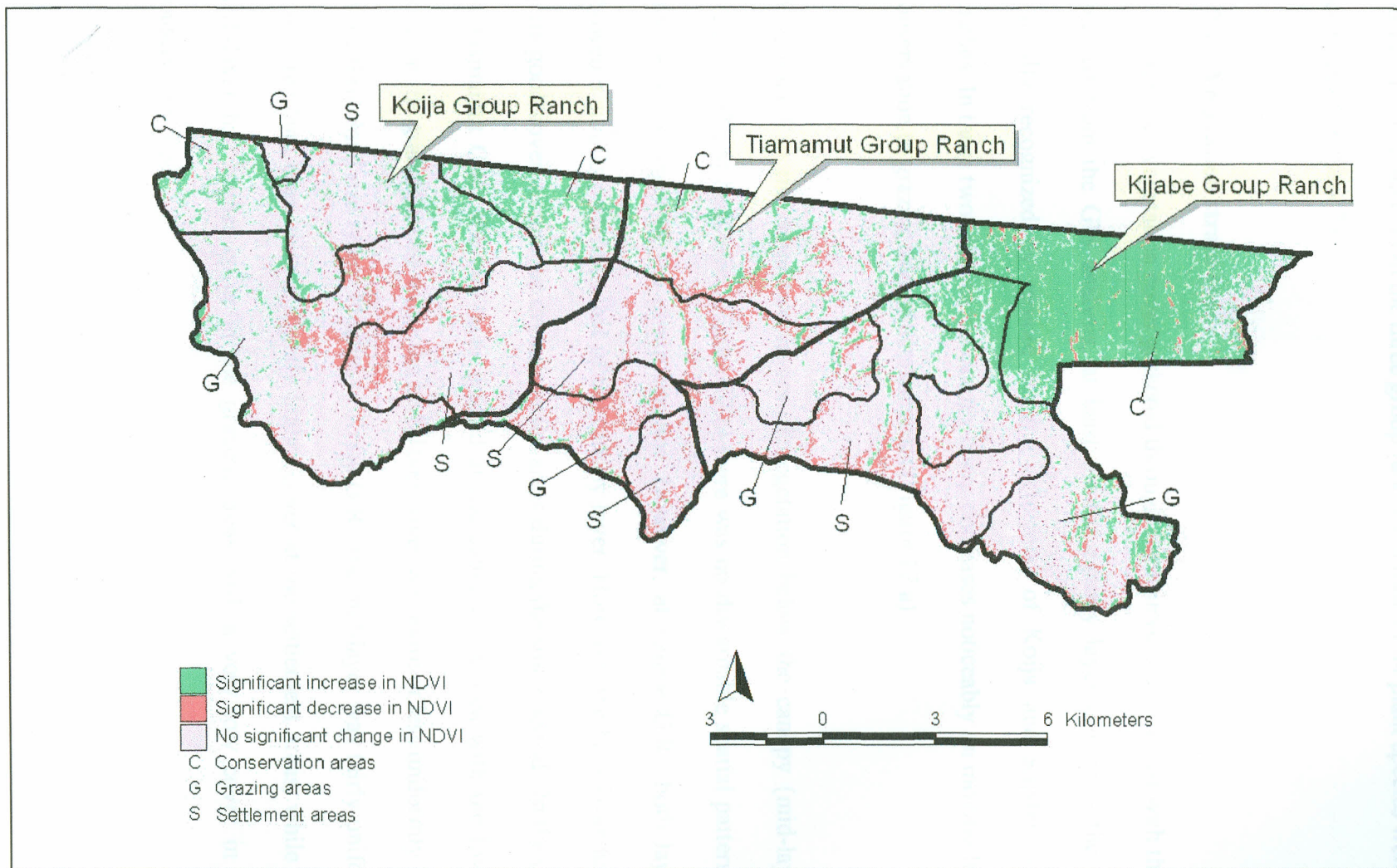


Figure 16. NDVI image differencing between 2004 and 2000 LANDSAT ETM+ images of the study area

4.2 Vegetation structure

During the field surveys in the three group ranches, a total of 84 plant species were recorded (Appendix 2).

4.2.1 Vegetation strata cover

The results for vegetation cover gathered through field surveys, concurred with those obtained from the GIS analysis, at least for the canopy layer (which is the one generally recognized by remote sensing detectors) of Koiija and Kijabe group ranches. In these two ranches the canopy cover decreases noticeably on moving from conservation to grazing and settlement areas (Figure 17 a).

With regard to the other two layers of vegetation below the canopy (mid-layer, Figure 17 b; and herb-layer, Figure 17 c) there was no discernable spatial pattern of change across each of the group ranches. However, at Kijabe G.R., both layers showed a similar pattern to that of the canopy layer. However, the herb-layer had a quite good cover despite the dryness of the areas during the study period. In the case of Tiamamut G.R., the mid-layer peaked at the conservancy area with the lowest cover at the grazing areas, while the herb-layer cover was more or less uniformly low at the three land use types. Finally, in Koiija G.R., the mid-layer was fairly uniform across the land uses, with a slightly higher cover at the settlement areas, while the herb-layer had higher cover at the grazing areas with a very low cover in the conservancy area.

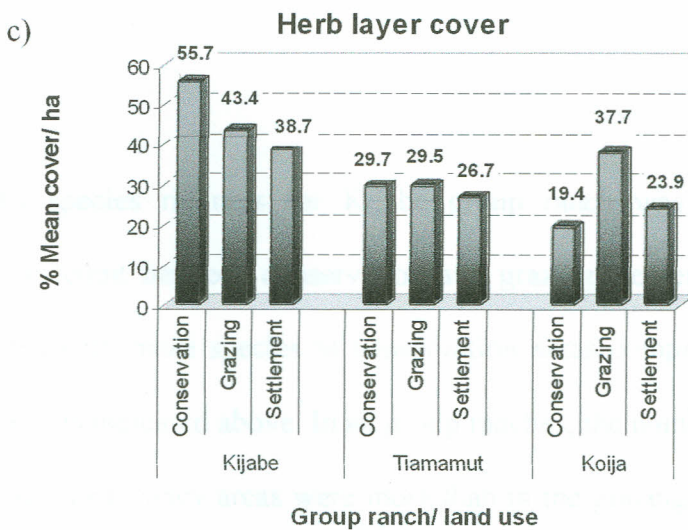
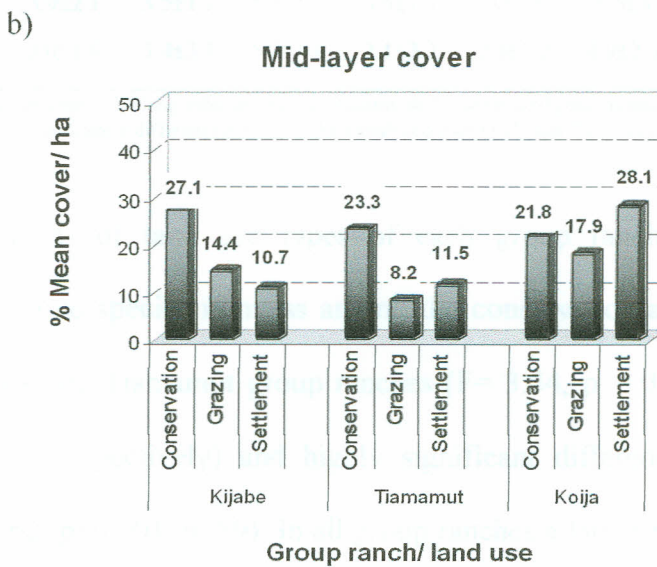
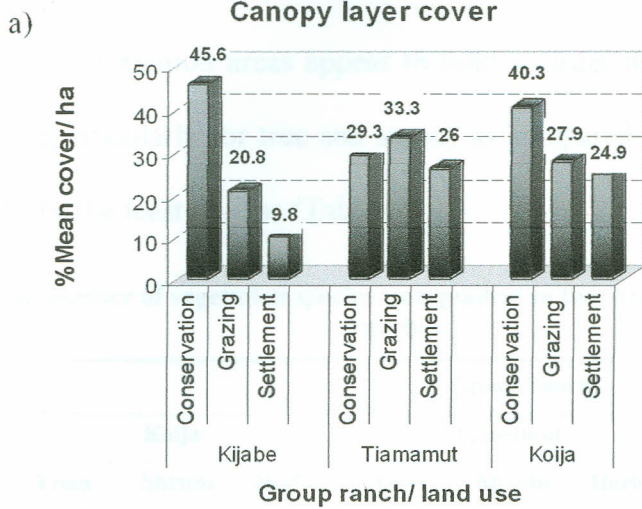


Figure 17. Vegetation cover for (a) canopy layer, (b) mid-layer and (c) herb layer of each land use of the group ranches.

4.2.2 Vegetation species richness

In general, the conservation areas appear to hold a larger number of species in all group ranches (particularly for tree and shrub) as compared to the settlement areas, which seem to be the least diverse (Table 7).

Table 7. Mean number of vegetation species per quadrat in the three land uses of the group ranches

Land use type	Group Ranch								
	Koiya			Tiamamut			Kijabe		
	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs	Trees	Shrubs	Herbs
Conservation	4.5*±1.5	4.2±2.7	5.5±3.1	3.5*±1.3	3.7±2.2	4.4±2.9	5.3**±3.5	4.8*±2.3	5.8±2.2
Grazing	3.9±2.1	3.5±1.7	5.2±3.5	3.4±1.5	3±1.8	6.5±3	2.3±0.97	3.2±1.7	5.1±1.8
Settlement	3.0±1.6	3.4±3.1	5.7±2.4	2.1±2.2	2.8±2.2	4.9±2.5	1.8±1.2	2.2±2.3	5.7±2.1

Means with superscripts (*) along columns are significantly different ($p < 0.05$) and means with superscripts (**) are highly significantly different ($p < 0.001$) when analysed with UAV and Tukey HSD.

The comparisons of land use types of each group ranch revealed significant differences in tree species richness among the conservation and grazing/settlement areas of Koiya and Tiamamut group ranches ($F = 3.54$, $p = 0.035$, $n = 60$ and $F = 3.57$, $p = 0.036$, $n = 49$ respectively) and highly significant differences for Kijabe group ranch ($F = 14.62$, $p < 0.001$, $n = 59$). In all group ranches a larger number of tree species were recorded at the conservancy areas than the grazing and settlement areas (Table 7).

Dwarf shrubs species richness for Kijabe group ranch was also found to be significantly different between conservation and grazing/ settlement areas ($F = 7.14$, $p = 0.002$, $n = 59$) with more species in conservation areas compared to grazing and settlement areas as indicated above. In all group ranches, the number of shrub species recorded at the conservancy areas were more than in the grazing or settlement areas (Table 7).

The number of herb species, were not significantly different among land use types of each group ranch. For all group ranches, the numbers of herb species were more or less similar among land uses (Table 7).

4.2.3 Vegetation diversity indices

In general, biodiversity results, (Table 8), suggest that vegetation in conservancies tends to be more diverse (higher values for Simpson's and Shannon-Weiner's indices) than grazing and settlement areas. These results were consistent with the results of species richness. Evenness values in all group ranches were of high to intermediate values (0.82 - 0.48).

Table 8. Biodiversity indices for vegetation in different land uses of each group ranch.

Group Ranch	Land use	Tree/ tall shrubs			Dwarf shrub			Herb			Total vegetation		
		(1-D)	H'	E _{var}	(1-D)	H'	E _{var}	(1-D)	H'	E _{var}	(1-D)	H'	E _{var}
Koiya	Conservation	0.897	3.573	0.691	0.929	4.059	0.669	0.945	4.406	0.717	0.958	4.956	0.540
	Grazing	0.910	3.816	0.669	0.913	3.940	0.745	0.935	4.364	0.694	0.959	4.985	0.625
	Settlement	0.872	3.197	0.563	0.897	3.791	0.592	0.950	4.666	0.694	0.953	4.824	0.480
Tiamamut	Conservation	0.869	3.278	0.516	0.929	4.037	0.706	0.943	4.384	0.782	0.954	4.843	0.533
	Grazing	0.828	2.918	0.597	0.920	3.808	0.823	0.933	4.263	0.621	0.931	4.540	0.600
	Settlement	0.842	2.983	0.602	0.921	3.755	0.806	0.935	4.337	0.703	0.947	4.655	0.571
Kijabe	Conservation	0.943	4.472	0.654	0.936	4.251	0.708	0.953	4.731	0.651	0.971	5.429	0.569
	Grazing	0.803	2.715	0.515	0.925	4.095	0.729	0.942	4.424	0.630	0.958	4.928	0.528
	Settlement	0.777	2.432	0.677	0.881	3.575	0.764	0.943	4.465	0.685	0.959	4.934	0.632

(1-D): Simpson's index; H': Shannon-Weiner index; E_{var}: Smith and Wilson's index of evenness

Correlation analysis of the vegetation diversity in all land use types of the three group ranches, showed a significant negative correlation ($r=-0.998$, $p=0.021$, $n= 3$) between intensity of land use and shrub diversity in Koiya. As intensity of land use

increases (from conservancy to grazing to finally settlement areas), dwarf shrub diversity decreases.

4.2.4 Vegetation community similarity

Morisita's similarity indices for the different land use types within each of the three group ranches were in most cases greater than 0.60 (Table 9). However, at Kijabe, a comparison of conservancies with grazing and settlement areas, yielded indices lower than 0.60 (Table 9). In general, the plant communities within the land uses of the three group ranches were quite similar with the exception of Kijabe, where the conservancy plant community was noticeably different when compared with either grazing or settlement areas.

Considering the similarities among same land uses in different group ranches, the Morisita's values were noted to be comparatively lower (Table 9), particularly between Kijabe and Koiija group ranches. Similarity values for tree and dwarf shrub communities of the two group ranches were less than 0.5. Similarities based on the three layers of vegetation (total vegetation), revealed that the vegetation of Koiija and Kijabe were dissimilar for all land use types (values around 0.5). Similarity values for Tiamamut fell in between those of the other two ranches (values over 0.65). However, the grazing areas of this group ranch showed greater resemblance with Kijabe than Koiija (0.66 and 0.48 respectively).

Table 9. Morisita's similarity table for vegetation communities of the three group ranches

Vegetation type	Group Ranch	Land use	Group Ranch/ Land use								
			Tiamamut			Kijabe			Koiya		
			Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
Tree /tall shrubs	Tiamamut	Con	1.00	0.88	0.92	0.55	0.78	0.82	0.63	0.70	0.87
		Gra	0.88	1.00	0.96	0.41	0.77	0.79	0.72	0.66	0.86
		Set	0.92	0.96	1.00	0.40	0.71	0.74	0.77	0.74	0.92
	Kijabe	Con	0.55	0.41	0.40	1.00	0.58	0.56	0.37	0.37	0.46
		Gra	0.78	0.77	0.71	0.58	1.00	0.97	0.33	0.32	0.64
		Set	0.82	0.79	0.74	0.56	0.97	1.00	0.36	0.36	0.68
	Koiya	Con	0.63	0.72	0.77	0.37	0.33	0.36	1.00	0.82	0.78
		Gra	0.70	0.66	0.74	0.32	0.36	0.82	0.82	1.00	0.77
		Set	0.87	0.86	0.92	0.46	0.64	0.68	0.78	0.77	1.00
Dwarf shrubs	Tiamamut	Con	1.00	0.77	0.65	0.58	0.66	0.68	0.61	0.58	0.59
		Gra	0.77	1.00	0.77	0.66	0.61	0.66	0.59	0.57	0.68
		Set	0.65	0.77	1.00	0.54	0.49	0.45	0.68	0.71	0.64
	Kijabe	Con	0.58	0.66	0.54	1.00	0.53	0.53	0.46	0.37	0.42
		Gra	0.66	0.61	0.49	0.53	1.00	0.75	0.46	0.39	0.41
		Set	0.68	0.66	0.45	0.53	0.75	1.00	0.33	0.33	0.36
	Koiya	Con	0.61	0.59	0.68	0.46	0.46	0.33	1.00	0.79	0.82
		Gra	0.58	0.57	0.71	0.37	0.39	0.33	0.79	1.00	0.80
		Set	0.59	0.68	0.64	0.42	0.41	0.36	0.82	0.80	1.00
Herbs/ forbs	Tiamamut	Con	1.00	0.82	0.86	0.65	0.87	0.80	0.76	0.89	0.78
		Gra	0.82	1.00	0.85	0.54	0.85	0.82	0.65	0.76	0.78
		Set	0.86	0.85	1.00	0.60	0.84	0.81	0.67	0.88	0.76
	Kijabe	Con	0.65	0.54	0.60	1.00	0.72	0.71	0.76	0.67	0.62
		Gra	0.87	0.85	0.84	0.72	1.00	0.87	0.73	0.84	0.78
		Set	0.80	0.82	0.81	0.71	0.87	1.00	0.71	0.80	0.73
	Koiya	Con	0.76	0.65	0.67	0.76	0.73	0.71	1.00	0.78	0.81
		Gra	0.89	0.76	0.88	0.67	0.84	0.80	0.78	1.00	0.75
		Set	0.78	0.78	0.76	0.62	0.78	0.73	0.81	0.75	1.00
Total vegetation	Tiamamut	Con	1.00	0.60	0.82	0.66	0.84	0.74	0.65	0.65	0.67
		Gra	0.60	1.00	0.67	0.34	0.66	0.56	0.50	0.48	0.54
		Set	0.82	0.67	1.00	0.50	0.68	0.66	0.76	0.79	0.79
	Kijabe	Con	0.66	0.34	0.50	1.00	0.73	0.68	0.50	0.49	0.45
		Gra	0.84	0.66	0.68	0.73	1.00	0.85	0.50	0.53	0.56
		Set	0.74	0.56	0.66	0.68	0.85	1.00	0.45	0.56	0.54
	Koiya	Con	0.65	0.50	0.76	0.50	0.50	0.45	1.00	0.85	0.85
		Gra	0.65	0.48	0.79	0.49	0.53	0.56	0.85	1.00	0.82
		Set	0.67	0.54	0.79	0.45	0.56	0.54	0.85	0.82	1.00

Con: Conservancy; Gra: Grazing; Set: Settlement

4.2.5 Vegetation species dominance

Considering the species dominance in the three group ranches, most land use areas were dominated by *Acacia* species (Table 10).

Table 10. Vegetation dominance regarding percentage cover (>5%) for the three group ranches

Plant species	Group Ranch/ Land Use								
	Koiya			Tiamamut			Kijabe		
	Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
<i>Acacia etbaica</i>	-	7	-	5	-	6	-	-	-
<i>A. mellifera</i>	22	11	11	8	13	13	-	-	-
¹ <i>A. nilotica</i>	-	-	-	7	-	-	13	7	-
¹ <i>A. reficiens</i>	-	5	-	-	-	-	-	-	-
<i>A. tortilis</i>	5	-	10	13	17	10	9	12	5
<i>Cenchrus</i> sp	-	-	-	-	-	-	5	-	-
¹ <i>Croton dichogamus</i>	-	-	-	-	-	-	5	-	-
<i>Digitaria milanjiana</i>	-	14	5	7	-	7	14	11	7
<i>Eragrostis</i> sp	-	-	-	5	-	-	6	5	-
¹ <i>Ipomoea</i> sp	-	-	-	-	-	-	6	-	-
<i>Maytenus</i> sp	-	-	-	-	-	-	9	-	-
<i>Pennisetum mezianum</i>	-	-	-	-	8	7	-	7	9
¹ <i>Sansivieria</i> sp	9	11	17	-	-	-	-	-	-
¹ <i>Solanum</i> sp	-	-	-	8	-	-	9	10	8
<i>Tribulus</i> sp	-	-	6	-	-	-	-	-	-

Con: Conservation; Gra: Grazing; Set: Settlement; -: less than 5% cover; ¹: invasive species

In the conservation area of Koiya (Table 10), apart from the mentioned *Acacia* species (particularly *A. mellifera* and *A. tortilis*), the other abundant species fell under the category of invasive species, *Sansevieria* sp. In grazing areas the most abundant species was the grass *Digitaria milanjiana* closely followed by *A. mellifera* and the invasive *Sansevieria* sp.. Other *Acacia* spp. notable for their abundances are *A. etbaica* and *A. reficiens* (considered as an invasive)(Table 10). In the settlement areas *Sansevieria* sp. was the most abundant species followed by *A. mellifera* and *A.*

tortilis. Herb species like *Digitaria milanjiana*, *Tribulus* sp. were also present (Table 10).

In Tiamamut, the most abundant species in conservation areas besides *Acacia* spp. (i.e. *A. tortilis*, *A. mellifera*, *A. nilotica* and *A. etbaica*) were the invasive species *Solanum* sp. and herbs like *Digitaria milanjiana* and *Eragrostis* spp. (Table 10). In the case of grazing *A. tortilis* and *A. mellifera* were the most dominant followed by *Pennisetum mezianum* (Table 10). In settlement areas, *A. mellifera*, *A. tortilis* and *A. etbaica* were the prevailing species, followed by *Pennisetum mezianum* and *Digitaria milanjiana* (Table 10).

In the conservation area of Kijabe, the community was more homogenous with several contributors to vegetation cover such as: the herb *Digitaria milanjiana*, *Acacia* spp. (i.e. *A. nilotica* and *A. tortilis*) and tall shrubs like *Maytenus* sp., *Croton dichogamus*. Other herbs such as *Cenchrus* sp. and *Eragrostis* sp. had considerable contributions to vegetation cover as well as invasive species such as *Solanum* sp. and *Ipomoea* sp. (Table 10). In grazing areas *A. tortilis* and *A. nilotica* together with *Digitaria milanjiana*, *Pennisetum mezianum* and *Solanum* sp, were the most dominant species (Table 10). Settlement areas of this group ranch were characterized by herb species such as *Digitaria milanjiana* and *Pennisetum mezianum*, invasives like *Solanum* sp. and trees of *A. tortilis* (Table 10).

4.2.6 Vegetation species occurrence

Most vegetation species, over 65% of the total species in each land use, fell under the category of abundant (present in more than 7 land uses) and common species (present in more than 4 land uses) (Figure 18). However, occasional (present in 2-3 land uses) and unique species (present only in 1 land use) were more frequent in conservancy areas of the three group ranches (overall values of 15% in Koiija, 16% in Tiamamut and 23% in Kijabe).



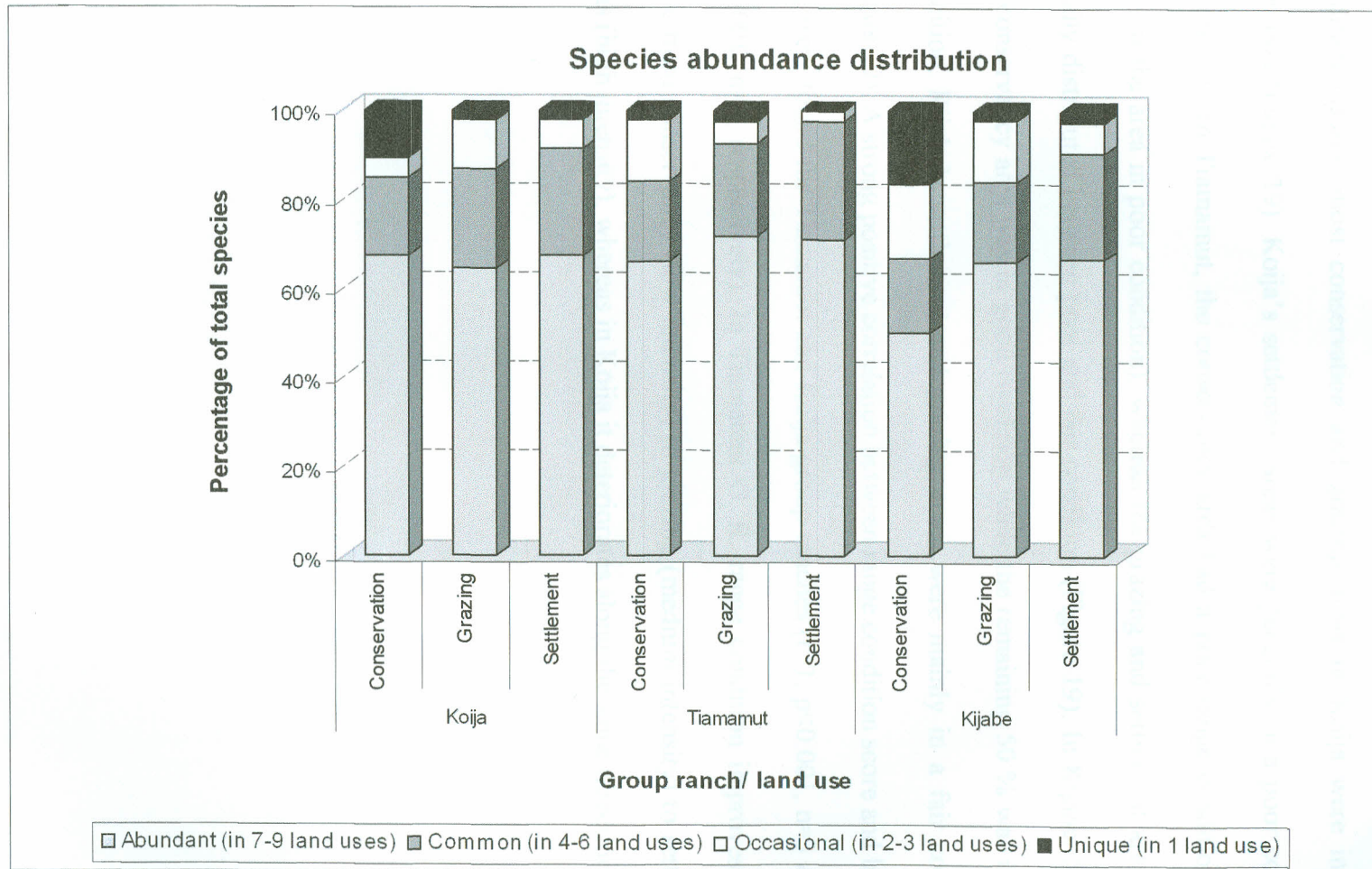


Figure 18. Vegetation species occurrence for each land use of the three group ranches

4.3 Range condition assessment

4.3.1 Range condition

In terms of the proportion of the land use types falling under the different range condition classes, most conservation and grazing areas in Koiya were in a fair condition (Figure 19). Koiya's settlement areas were generally in a poor condition (Figure 19). In Tiamamut, the conservancy area had a poor range condition (over 80% of the area in poor condition), whereas the grazing and settlement areas were equally distributed between poor and fair condition (Figure 19). In Kijabe, 50 % of the conservancy area was in good condition while the remaining 50 % was in a fair condition. Kijabe's settlement and grazing areas were mainly in a fair condition (Figure 19). A strong positive correlation between range condition score and land use type were found for Tiamamut and Koiya group ranches ($r=1$, $p<0.001$, $n=3$ & $r=-1$, $p<0.001$, $n=3$, respectively). In Tiamamut G. R. range condition improves as we move from conservancy (low intensity) to grazing (medium intensity) to settlement areas (high intensity), whereas in Koiya it deteriorates along the same direction.

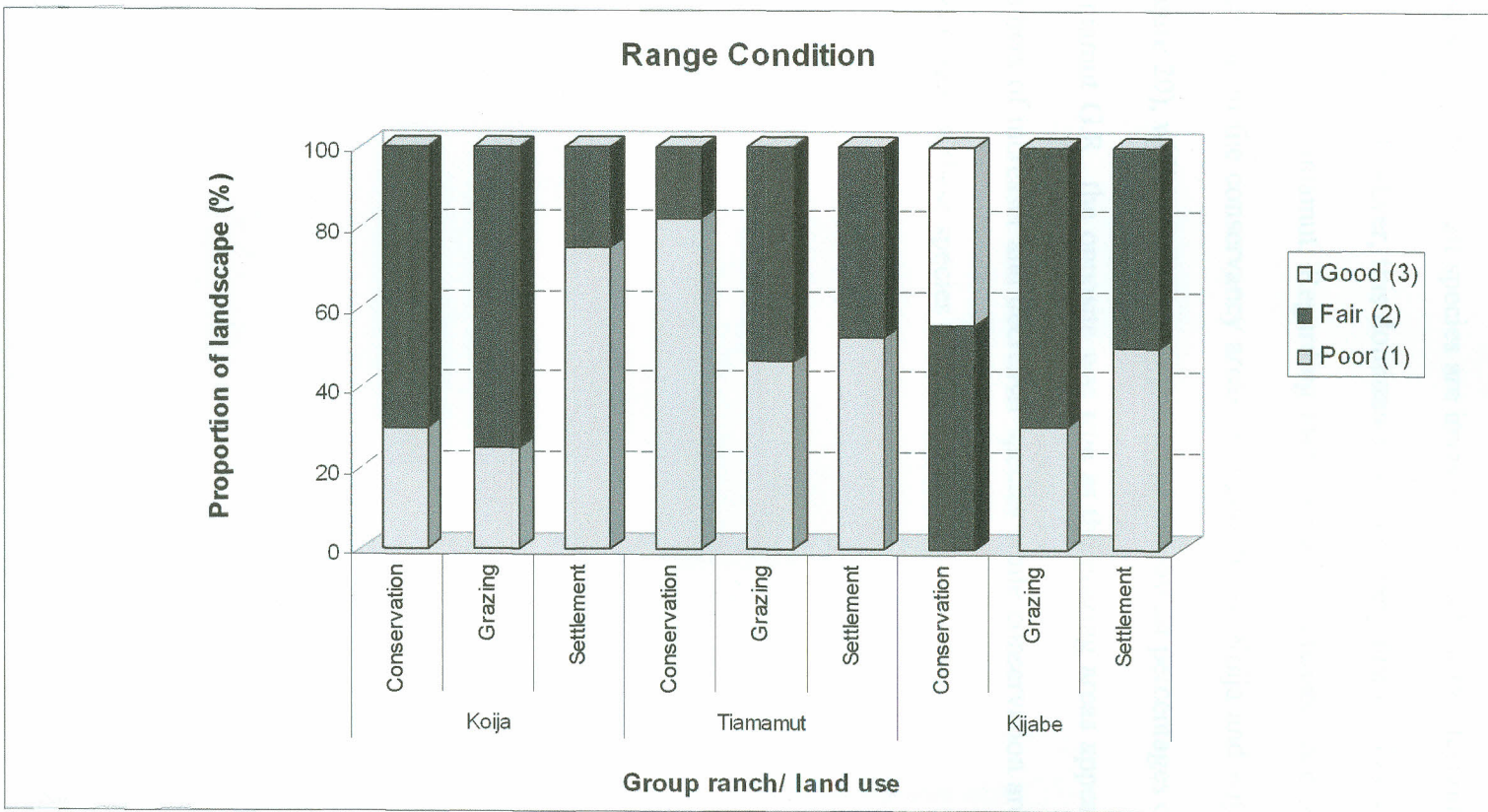


Figure 19. Range condition distribution in the land uses of the three group ranches

4.3.2 Ecosystem health indicators

All group ranches were characterized by dominance of invasive species (generally between 10-15% of all species are invasive) in each of the designated land use types (Figure 20). However, this dominance was not very distinct in conservancy areas of Kijabe and Tiamamut. Regarding increaser and decreaser species, they were more abundant in the conservancy areas, particularly for Koiija and Kijabe group ranches (Figure 20), while grazing areas presented the lowest percentages of these species. In Tiamamut G.R., the opposite was true as the grazing areas appeared to hold larger numbers of increaser and decreaser species while conservation areas had the lowest percentages of these species (Figure 20).

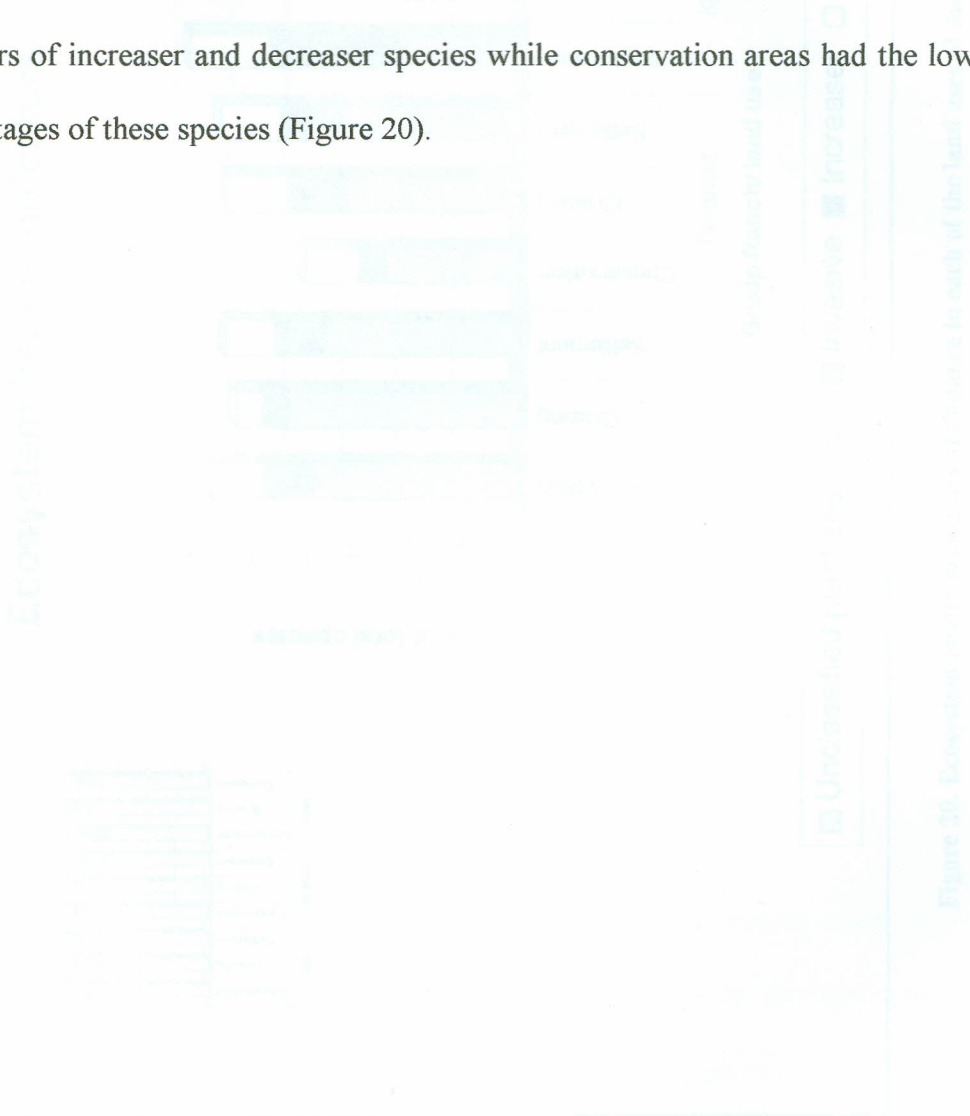


Figure 20. Ecosystem health indicators of species in each of the land use types.

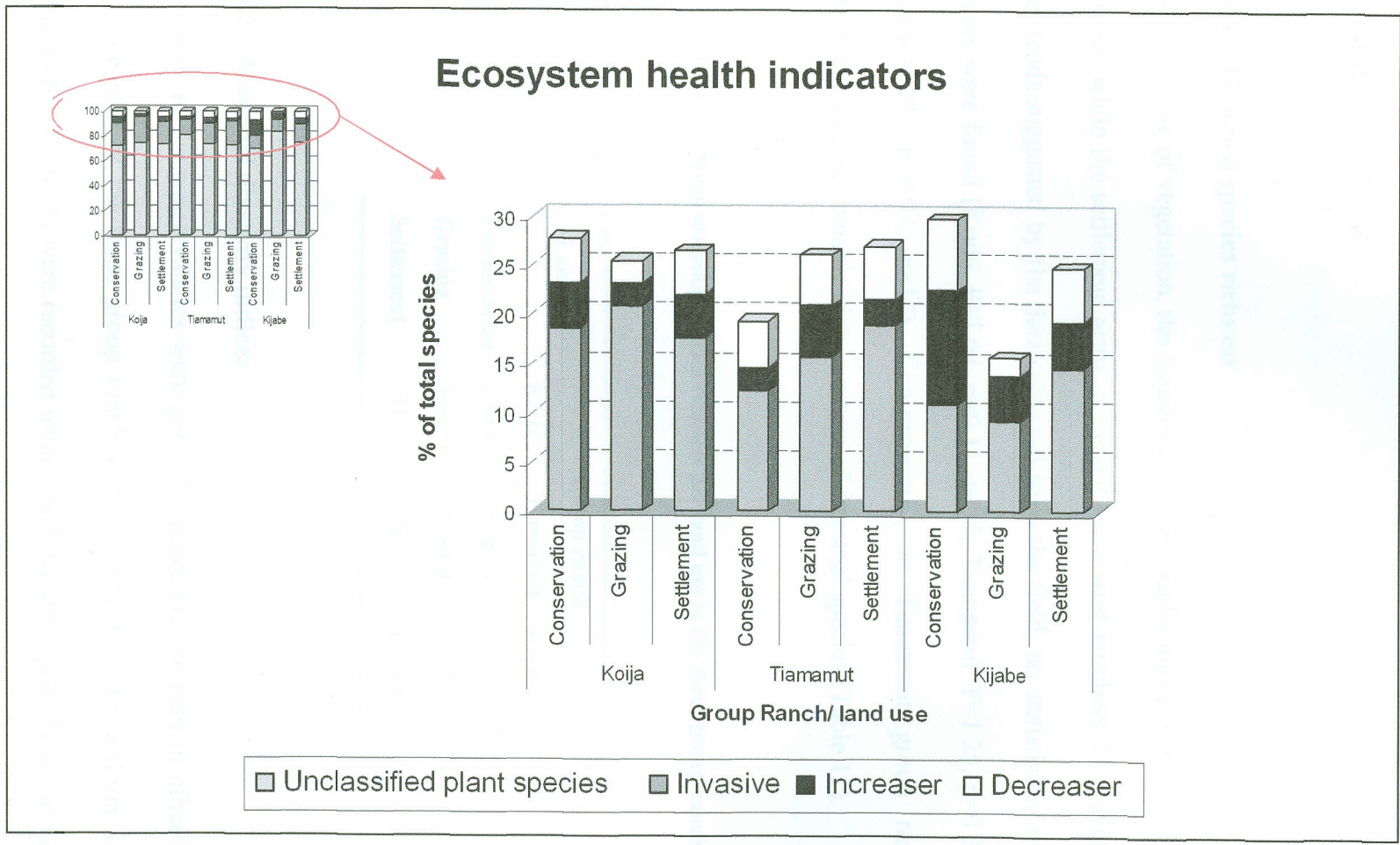


Figure 20. Ecosystem health indicators abundance in each of the land uses of the three group ranches.

4.4 Mammal assessment

During field observations and rodent surveys, a total of 26 mammal species were recorded (Appendix 1).

4.4.1 Mammal species richness

As in the case of vegetation, the conservation areas had a higher number of mammal species, while the settlement areas presented the lowest numbers. However, despite the trends suggested by the data collected from the field, no statistically significant results were found (Koiya: $F=2.64$, $p=0.11$, $n=15$; Tiamamut: $F=1.25$, $p=0.32$, $n=15$; Kijabe= 3.21 , $p=0.07$, $n=15$). Conspicuously, in Tiamamut group ranch, the settlement area had notably high numbers of mammal species (Table 11).

Table 11. Mean mammal species richness per land use in the three group ranches

Land use	Group ranch		
	Koiya	Tiamamut	Kijabe
Conservation	6.6±1.8	5.6±1.3	5±2.7
Grazing	5.6±2.6	3.6±1.8	3±1
Settlement	3±3.1	5±2.7	1.8±1.9

4.4.2 Mammal diversity indices

Mammals in the conservancies were generally more diverse than in other land use areas in each of the three group ranches (Table 12). Low to medium values of evenness (0.33 – 0.56) were recorded within the land use types of each group ranch. Correlation analysis showed a significant negative correlation between land use types

and mammal diversity in Kijabe ($r=-0.996$, $p=0.027$, $n=3$). With increasing intensity of land use (from conservation to settlement areas) the mammal diversity decreases.

Table 12. Biodiversity indices for mammals in the different land uses of each group ranch.

Group Ranch	Land use	(1-D)	H'	E _{var}
Koiya	Conservation	0.813	2.899	0.337
	Grazing	0.768	2.721	0.495
	Settlement	0.839	2.827	0.489
Tiamamut	Conservation	0.767	2.511	0.345
	Grazing	0.757	2.590	0.569
	Settlement	0.617	2.096	0.414
Kijabe	Conservation	0.718	2.493	0.400
	Grazing	0.751	2.240	0.400
	Settlement	0.727	1.998	0.363

(1-D): Simpson's index; H': Shannon-Weiner index; E_{var}: Smith and Wilson's index of evenness

4.4.3 Mammal community similarity

Morisita's similarity indices for the different land use types within Koiya and Tiamamut group ranches were in most cases greater than 0.70 (Table 13). However, for Kijabe, when comparing conservancies with grazing and settlement areas, the values were lower than 0.10 (Table 13). The mammal community within the different land use types of Koiya and Tiamamut were generally uniform, whereas the mammal community at Kijabe conservancy was noticeably different from that of the grazing and settlement areas.

Looking at the mammal similarity of the same land uses in different group ranches, the Morisita's values were generally lower than those obtained from within group ranch comparisons (Table 13). This was the case, particularly between Koiya and

Tiamamut group ranches where Morisita's values were less than 0.3 for any land use comparison. In the case of Kijabe and Koiya, the Morisita's values were low when the grazing and settlement areas of the two ranches were compared (values below 0.2). The same applied to comparisons between conservation areas of Tiamamut and Kijabe (Table 13). Hence, in the conservancy areas, the mammal communities of Koiya and Kijabe were similar, while Tiamamut conservancy was noticeably different from that of Koiya and Tiamamut. However, the grazing and settlement areas of Kijabe and Tiamamut were closely similar, while the Koiya mammal communities were markedly distinct from that of the other two group ranches.

Table 13. Morisita's similarity table for mammal communities

Group Ranch	Land use	Group ranch/ land uses								
		Koiya			Tiamamut			Kijabe		
		Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
Koiya	Con	1.00	0.88	0.89	0.25	0.17	0.05	0.73	0.16	0.12
	Gra	0.88	1.00	0.78	0.25	0.17	0.08	0.86	0.20	0.26
	Set	0.89	0.78	1.00	0.22	0.21	0.11	0.59	0.16	0.10
Tiamamut	Con	0.25	0.25	0.22	1.00	0.74	0.78	0.12	0.66	0.77
	Gra	0.17	0.17	0.21	0.74	1.00	0.95	0.09	0.81	0.73
	Set	0.05	0.08	0.11	0.78	0.95	1.00	0.02	0.77	0.70
Kijabe	Con	0.73	0.86	0.59	0.12	0.09	0.02	1.00	0.00	0.01
	Gra	0.16	0.20	0.16	0.66	0.81	0.77	0.00	1.00	0.93
	Set	0.12	0.26	0.10	0.77	0.73	0.70	0.01	0.93	1.00

Con: Conservancy; Gra: Grazing; Set: Settlement

4.4.4 Mammal species occurrence

Most mammal species (over 50% of the total species in each land use) fell under the category of abundant and common species (present in more than 4 land uses, Figure 21). However, occasional (present in 2-3 land uses) and unique species (present only in 1 land use) were more frequent in conservancy areas of the three group ranches (overall values of 35.7% in Koija, 27.3% in Tiamamut and 53.8% in Kijabe). Of the unique and occasional species one of them, Grevy's zebra (*Equus grevyi*), has been classified as an endangered species (EN A1a+2c) under the CITES red books (IUCN, 2004).



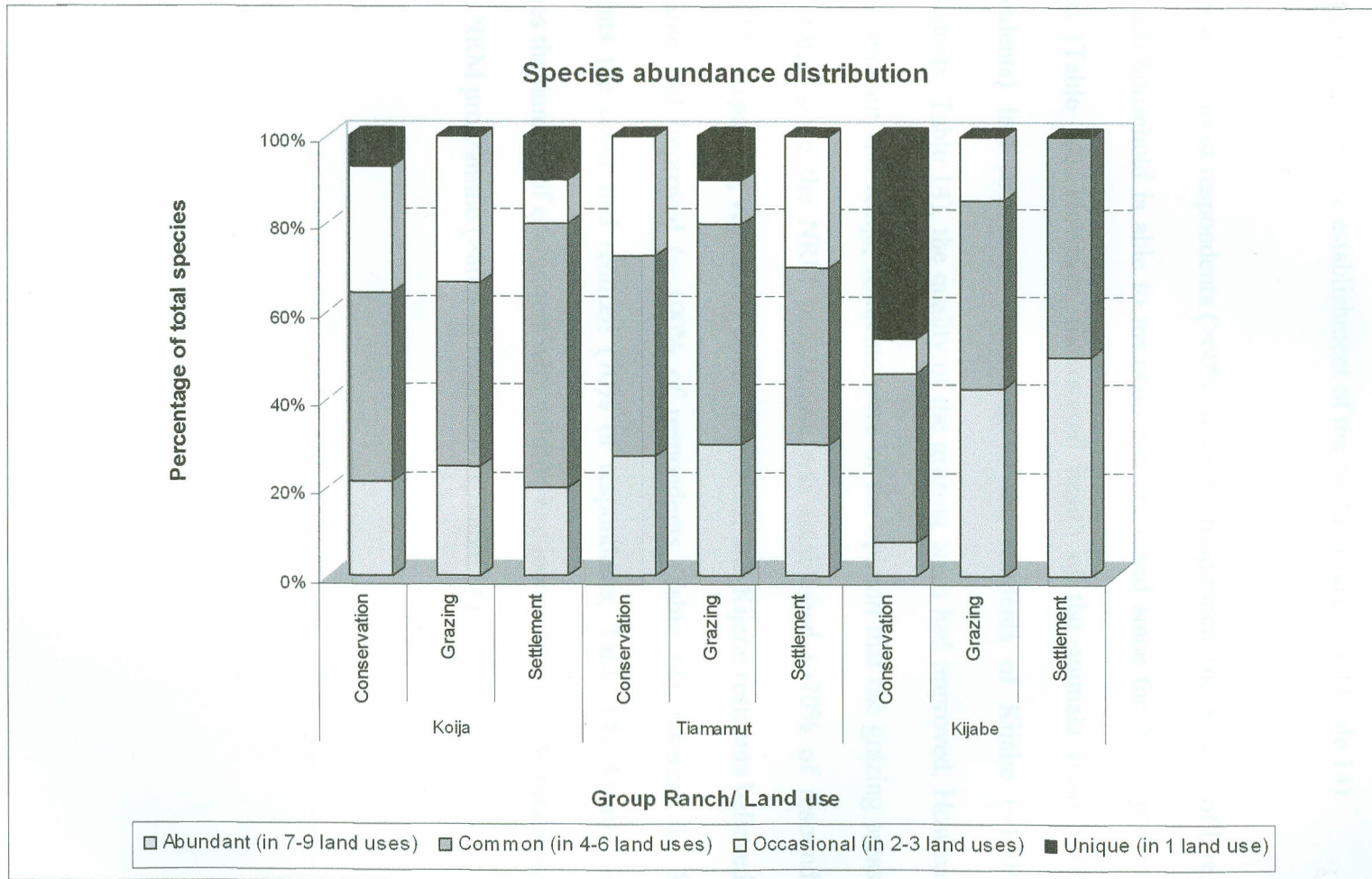


Figure 21. Mammal species abundance distribution for each land use of the three group ranches

4.5 Community perception assessment

4.5.1 Influence of NRM programme

In all group ranches most respondents (about 100%) thought that their livelihoods had improved since the establishment of the NRM programme (Table 14).

According to most respondents (>60%) in each group ranch, the number of livestock that each household is able to maintain has decreased since the NRM programme started (Table 14). However, the overall health of the animals (also >60% of respondents) had improved. According to the residents of Kijabe (~100% of respondents, Table 14), the quality of the grazing areas had improved. However, in both Tiamamut and Koiya, residents were of the opinion that the grazing areas had deteriorated since the NRM programme was established (>70% of respondents, Table 14). Regarding vegetation cover, Tiamamut and Kijabe residents believed that the same had improved (~ 100% of respondents, Table 14), whereas for Koiya residents the cover had reduced (70% of respondents, Table 14). Finally, in all ranches the number of encounters with wildlife had increased since the establishment of the NRM programme (>80% of respondents, Table 14).

Table 14. Community perception on the impact of the NRM programme on different aspects of their lives in the different group ranches

	Koiya (n=50)	Tiamamut (n=50)	Kijabe (n=50)	Total (n=150)
<u>Livelihood:</u>				
Better	50 (100%)	47 (94%)	50 (100%)	147 (98%)
Same	-	3 (6%)	-	3 (2%)
Worse	-	-	-	-
<u>Number of livestock:</u>				
Better	15 (30%)	3 (6%)	-	18 (12%)
Same	2 (4%)	6 (12%)	-	8 (5.3%)
Worse	33 (66%)	41 (82%)	50 (100%)	124 (82.7%)
<u>Livestock health:</u>				
Better	22 (44%)	38 (76%)	50 (100%)	110 (73.3%)
Same	-	6 (12%)	-	6 (4%)
Worse	28 (56%)	6 (12%)	-	34 (22.7%)
<u>Quality of grazing:</u>				
Better	15 (30%)	3 (6%)	48 (96%)	66 (44%)
Same	-	-	-	-
Worse	35 (70%)	47 (94%)	2 (4%)	84 (56%)
<u>Vegetation cover:</u>				
Better	15 (30%)	47 (94%)	46 (92%)	108 (72%)
Same	-	3 (6%)	-	3 (2%)
Worse	35 (70%)	-	4 (8%)	39 (26%)
<u>Wildlife encounters:</u>				
More	41 (82%)	47 (94%)	43 (86%)	131 (87.3%)
Same	-	3 (6%)	-	3 (2%)
Less	9 (18%)	-	7 (14%)	16 (10.7%)

4.5.2 Management of conservation areas

The only group ranch in which restrictions on grazing accessibility to conservation areas were followed was Kijabe Group Ranch, with 80% of respondents reporting limitation in grazing access (Table 15), whereas both Tiamamut and Koiya respondents admitted grazing within the conservation areas (almost 100% of respondents, Table 15).

In Koiya, preservation for future and tourist attraction appeared the most common reasons (both ~40% respondents) followed by poor quality land and conflict with cattle from Samburu communities that move south into Laikipia district (Table 15). In Tiamamut G.R. besides preserving conservancies for future use (>90% respondents), avoidance of conflicts with Samburu cattle seemed to be the most important reason for avoiding grazing in these areas (>60% respondents, Table 15). Finally in Kijabe G.R., conservation for tourist attraction and future use were the dominant reasons given by residents to protect conservancy areas (Table 15).

Table 15. Compliance to access restrictions in conservation areas and reasons for maintaining the conservancies in each group ranch.

	Koija (n=50)	Tiamamut (n=50)	Kijabe (n=50)	Total (n=150)
<u>Grazing in conservancies:</u>				
Yes	50 (100%)	50 (100%)	9 (18%)	109 (72.6%)
No	-	-	41 (82%)	41 (27.4%)
<u>Reason for keeping conservancies: (multiple choice question)</u>				
Conflict with wildlife	4 (8%)	9 (18%)	-	13 (8.7%)
Distance to water point	2 (4%)	6 (12%)	-	8 (5.3%)
Poor quality pastureland	9 (18%)	12 (24%)	-	21 (14%)
Preserve for future use	22 (44%)	47 (94%)	10 (20%)	79 (52.7%)
Conflict with Samburu cattle	5 (10%)	31 (62%)	-	36 (24%)
Conserve for tourist attraction	21 (42%)	-	42 (82%)	63 (42%)

4.5.3 Human-wildlife conflict

Regarding conflict with wildlife on grazing areas (Table 16) most Koiya and Tiamamut residents report encountering wildlife within the grazing areas (>80% of respondents, Table 16), while in Kijabe G.R. no major problems with wildlife were mentioned (>80% of respondents agree on the lack of conflict, Table 16).

In Koiya G.R., the two main reactions were to move the livestock away or/and chase the wild animal away (Table 16). In Tiamamut G.R., besides the above mentioned responses, there were also reports of wildlife killings (Table 16), whereas in Kijabe G.R. incidents were occasionally reported to the appropriate authorities or wildlife groups (Table 16).

Table 16. Wildlife encounters incidence and responses to wildlife-livestock conflict

	Koiya (n=50)	Tiamamut (n=50)	Kijabe (n=50)	Total (n=150)
<u>Conflict with wildlife over grazing areas:</u>				
Yes	41 (82%)	44 (88%)	11 (22%)	96 (64%)
No	9 (18%)	6 (12%)	39 (78%)	54 (36%)
<u>Conflict resolution:</u>				
Chase wildlife away	4 (8%)	34 (68%)	-	38 (25.3%)
Move livestock away	39 (78%)	3 (6%)	5 (10%)	47 (31.3%)
Kill wildlife	-	3 (6%)	-	3 (2%)
Report incident	-	-	3 (6%)	3 (2%)
No response	7 (14%)	10 (20%)	42 (84%)	59 (39.4%)

CHAPTER FIVE: DISCUSSION

5.1 Land cover changes

5.1.1 Main vegetation cover changes

The main vegetation cover changes observed since the establishment of the NRM programme in 2000, have involved bushland and shrubland vegetation (Figures 15). The increase in bushland cover in conservancy areas (12.8%, mostly in Koiija and Kijabe group ranches, Figures 13 and 14) fits perfectly well with the traditional theories of savannah evolution. In this ecosystem, an increase in natural vegetation cover (bush) is expected when the numbers of browsers decline (Young and Price, 2000; Roques *et al.*, 2001; Augustine and McNaughton, 2004). This could have occurred in these conservancy areas following the removal of livestock browser species such as goats and camels (particularly in Kijabe group ranch). On the other hand, the 16.2% decrease in shrubland cover observed, can be attributed to two different processes: 1) a general opening of this vegetation in areas of settlement and grazing in the three groups ranches and replacement with grasslands (which increased by a 1.1%) and, 2) gradual regression to bushland vegetation in some grazing areas near to conservation areas (such as the northern conservancy of Koiija G.R., Figures 13 and 14). These shrubland changes can generally be linked to the NRM programme because the area available for livestock grazing after the NRM programme establishment was reduced; hence, despite the reduction in livestock numbers over the years, there has been a maintained considerable grazing pressure on the remaining land. As a result of this continuous grazing pressure, the scattered shrubland switched to grassland. However, grazing and settlement areas located near to conservancy areas which are not very accessible to livestock, have undergone a conversion from shrubland to bushland areas due to reduced access to them by

livestock browser species (particularly in northern areas of Koiya and Kijabe, Figures 13 and 14). Similar bush encroachment in other areas of Laikipia district has been reported, particularly in Laikipia Ranch, Mugie Ranch, Solio Ranch and the lower sections of Ol Pajeta Ranch, which were also associated with restriction of livestock grazing and limitation in the use of fire (Ogutu, 2004).

The increase in areas of bare ground/ rock outcrop/ sand by 3.3% can be attributed to the degradation of traditional areas of pastureland as a result of the continuous grazing pressure on the already overused pastureland (particularly in Koiya and Tiamamut grazing and settlement areas).

5.1.2 Land cover changes

Increase in vegetation cover in conservation areas (17%, Figure 16) can be explained by the 12.8% increase in bushland cover and the 1.1% increase in grassland cover (Figure 15). Conversely, an overall 6.3% decline in vegetation cover can be associated with the 16.2% decrease of shrubland (out of which 12.8% would have gone towards the increase in bushland cover) and the 3.3% increase in bare ground/ rock outcrop/ sandy areas. Increasing bush cover has also been reported in abandoned encampments in the central Borana region of Ethiopia (Oba *et al.*, 2000).

On a regional scale, the results therefore, suggest that conservation areas have become “greener” as a consequence of an increase in the bushland cover, while the grazing and settlement areas have opened up due to a decrease in the shrubland cover and an increase in the grassland and bare ground areas. The processes driving these changes are the same as those explained in section 5.1.1 for changes in vegetation

cover. Similar vegetation changes have been reported for private ranches in Laikipia district (Ogutu, 2004).

5.2 Vegetation strata cover

High values of vegetation cover reported for the canopy layer (or bush cover) observed in the conservation areas of the three group ranches (Figure 17 a), can be attributed to the absence of significant livestock browsing and grazing in these areas. Increase in canopy layer cover following reduced browsing and grazing pressure has been reported in similar ecosystems e.g.: Queen Elizabeth National Park, Uganda (Lenzi-grillini *et al.*, 1996); southern Kalahari, South Africa (Jeltsch *et al.*, 1997); North America (Scholes and Archer, 1997 and Soulé and Knapp, 1999); southern Ethiopia (Oba *et al.*, 2000) and Laikipia, Kenya (Young *et al.*, 2005).

A similar pattern of change in mid and herb layers to that described for the canopy layer at Kijabe is consistent (Figures 17 b and c) with the expected increase in grazing pressure from grazing to settlement areas. However, it should be noted that despite the dry conditions of the area during the period of the survey, the herb layer cover was quite high, suggesting an overall moderate grazing pressure in the group ranch. In the case of Koiya, the low cover of herb layer in the conservancy area can be attributed to the rocky nature of the terrain and the observed soil degradation on some areas. Edaphic, topographic and geo-morphological factors have been known to significantly influence vegetation cover in savannah regions (Archer, 1994; Jeltsch *et al.*, 2000). Finally in Tiamamut, the low mid-layer cover in grazing areas and uniform herb layer across the land uses may suggest a high browser pressure in pastureland and high grazing pressure on the whole group ranch.

5.3 Vegetation species richness and diversity

The significantly higher number of tree and shrub species observed in conservation areas than in either grazing or settlement areas (Table 7) can be explained by the “intermediate disturbance theory” (Krebs, 1972). This theory states that once a major/frequent disturbance is removed from a system, the system can revert to a previous intermediate disturbed and more stable state that is more diverse. The more recent model of “state-transition” (ST Model) suggests that changes from one to another state of the savannah community is dependent of factors such as competition amongst plant species, fire regimes and herbivory (Archer, 1996; Sankaran *et al.*, 2004). Hence, considering livestock grazing the main force driving transitions in this area, if access is restricted to the conservation areas, this would lead to the reestablishment of vegetation species that could not tolerate the high level of disturbance. These species would now be able to establish themselves and settle in a system subjected to moderate disturbance by wildlife browsers that promote ecosystem diversity (Mearns, 2000; Palmer and Fortescue, 2003).

Similarity in the number of herb species amongst land uses, may suggest that either the herb species present have developed enough defences against grazing in the study area or that other factors (i.e. soil structure, water/nutrient availability, etc), not determined in this study, influence their presence or absence in these areas. As previously mentioned (section 5.3), there are other biotic and abiotic factors that greatly influence the establishment and maintenance of vegetation species in savannah ecosystems. These factors include: climatic, topographic, edaphic and herbivory from underground invertebrates (Archer, 1994; Archer, 1995; Archer, 1996; Jeltsch *et al.*, 2000).

Higher species diversity in conservancies, as compared to grazing or settlement areas, closely agrees with a pattern of larger diversity in less disturbed areas. This pattern has been reported for the central lowveld of South Africa. Lower species diversity was reported in communal grazing lands, with high utilization; as compared with private game reserves and commercial cattle farm sites where grazing pressure was significantly lower (Higgins *et al.*, 1999). Hence, conservancies do not only hold a larger number of some species but have also a high number of species.

The high to intermediate evenness values (ranging from 0.82 to 0.48) indicate a mid situation with a few species having high abundances while the majority are present in low numbers.

5.4 Vegetation community similarity

The low similarity between conservation areas of Koiija and Kijabe group ranches (Table 9), and the grazing areas of the two group ranches, can be explained by the difference in topography and access to water. As earlier mentioned (section 3.2.1), the western side of the study area, where Koiija is located at an elevation of 1333 m. a. s. l. and is greatly influenced by the Ewaso-Ngiro river, which provides the area with permanent water supply. On the other hand, Kijabe, on the eastern side of the study area, stands at an elevation of about 1800 m. a. s. l., with a more hilly landscape and without any significant source of permanent water. Tiamamut, lies in between Koiija and Kijabe, hence it represents an intermediate situation. As indicated by Coughenour (1991), topography greatly influences plant growth and distribution. Factors such as soil mineral content or water availability (Coughenour, 1991; Archer 1996), can greatly affect the establishment of plant species. Hence the landscape

differences between the three ranches may be the main cause of the low similarity between Kijabe and Koiya group ranches.

5.5 Vegetation species dominance and occurrence

Dominance of most areas of the group ranches by *Acacia* sp is a characteristic feature of the savannah ecosystem (Table 10). This dominance by a small number of species concurred with the indices of evenness observed (Table 8) reinforcing the idea of plant communities characterized by a few dominant species and a large number of less abundance “weak” species.

A heterogeneous vegetation community at Kijabe conservancy (Table 10) suggests a regression towards a community with dominance of vegetation by several species. In the case of Koiya and Tiamamut conservancies (Table 10), dominance by *A. mellifera* and *A. tortilis*, can be attributed to the special adaptation of both species to demanding environments (Herlocker, 1995; Kiringe and Okello, 2005). This hardy species indicate the presence of high grazing pressure in these areas.

In settlement and grazing areas of all group ranches (Table 10), a common presence of *A. tortilis* indicates a significant land use intensity in these land use types throughout the study area. In Tiamamut the presence of *A. drepanolobium* is associated with grazing areas located in black cotton soils and with grass species such as *Pennisetum*. Abundant invasive species (such as *Sansevieria* sp.) in grazing and settlement areas are indicative of the highly degraded areas and this may explain the high values of biodiversity in grazing and settlement areas of Koiya group ranch.

Presence of more bushy species (such as *Acacia* spp. and other shrubs) in conservancy areas corroborates the theory of vegetation regression from shrubland to bushland areas. A heterogeneous composition at Kijabe conservancy as compared to dominance by *A. mellifera* in Tiamamut and Koiya in these communities suggests that these latter conservancies are in a worse condition than that of Kijabe (*A. mellifera* may be the only species able to survive in the conservancy areas of Koiya and Tiamamut and exclude other emerging species). Presence of several invasive species in conservancy areas of the three group ranches suggests a possible history of high grazing pressure before the areas were set aside for conservation. Similarly, a high abundance of invasive species in settlement areas of Koiya indicates a highly degraded environment that may need urgent intervention.

When vegetation occurrence was analysed, most species fell within the abundant or common categories in all land use types. However, most unique species were found in the conservancy areas (particularly in Kijabe and Koiya G.R., Figure 18). This suggests that these conservancy areas act as refuges for those species, which are particularly sensitive to grazing pressure (e.g. *Harpachne* sp or *Themeda triandra* in Kijabe). For other species, the conservancy areas provide suitable environmental conditions (i.e. suitable altitude, moisture, soil composition, etc) for them to grow (i.e. *Olea europaea* Kijabe or *Grewia* sp. in Koiya).

5.6 Range condition

A generally poor range condition in most areas of the group ranches studied seems to suggest an overexploitation of the resources available, particularly in grazing and settlement areas (Figure 19). This supports the trends observed in the GIS analysis of

these areas that suggested an opening of the shrubland and subsequent degradation of the grazing areas. Denudation and degradation of grazing areas has been reported to be associated with the overuse of resources by livestock (Doughill and Cox, 1999; Homewood and Brockington, 1999). Furthermore, high impacts zones (sacrifice zones) characterized by loss of woody vegetation and increase in base soil erosion (human-induced desertification) have been described around settlements in studies carried out in the same region (Jacobs and Coppock, 1999).

5.7 Ecosystem health indicators

Abundance of invasive species in most land uses of the three group ranches (Figure 20) indicates that the area in general is under significant grazing pressure levels and that there is a danger of invasion of the rangeland by unpalatable (invasive and exotic) species. In Australian rangelands, regional studies have confirmed that increasing grazing intensity can ultimately lead to the replacement of local palatable perennials by exotic unpalatable annuals (Clarke, 2003; Lunt, 2005).

At ranch level, Kijabe G.R. appears to hold the largest numbers of decreaser and increaser species, especially in the conservancy areas (Figure 20). This suggests that these areas still serve as refuges for species vulnerable to high grazing pressures. This pattern of grazing sensitive plants being confined to areas where they escape regular herbivory has been described also for native Australian species (McIntyre *et al.*, 2003; Lunt, 2005). At Koiya and Tiamamut group ranches, low levels of both decreaser and increaser species (Figure 20), suggests an overexploitation of all land uses and a significant danger of losing valuable livestock grazing areas to invasive species.

5.8 Mammal species richness and diversity

The presence of a greater variety of animals in conservancy areas of the group ranches as compared to grazing and settlement areas (Table 11) can be explained by the “habitat heterogeneity hypothesis” (Simpson, 1949; MacArthur and Wilson, 1967). This hypothesis states that structurally complex habitats may provide more niches and diverse ways of exploiting the environmental resources and therefore increases species diversity. Because of the more complex vegetation structure reported for conservancy areas, they are expected to have more microhabitats and hence, a greater number of animal species in these areas (Lawton, 1983; McCoy and Bell, 1991; Davidowitz and Rosenzweig, 1998).

The low to medium values of evenness (ranging from 0.33 to 0.56) (Table 12) indicates that most land uses are dominated by one or a few mammal species with a high abundance while the other species were restricted to low numbers.

A greater number of animal species explains the high animal diversity of the conservation areas (Table 12). However, it is noteworthy to mention that the biodiversity values seem to decrease on moving from Koija G.R. (highest biodiversity values) to Kijabe G.R. (lowest biodiversity values). This decline can be attributed to a decrease in water availability, on moving further away from the Ewaso-Ngiro river in Koija to the rocky water-scarce areas of Kijabe. The importance of water resource as a limiting factor to animal distribution has been reported by Western (1975), Williamson *et al.* (1988) and Coughenour (1991).

5.9 Mammal community similarity and species occurrence

Similarity of mammalian species in the three land use types of Koiya and Tiamamut group ranches and a difference between the mammal species of the conservation area of Kijabe from that of settlement and grazing areas (Table 13) concurs with the vegetation species results suggesting a linkage between vegetation and mammal species. Most mammal species encountered in the settlement and grazing areas were with alcelaphines (i.e. Impala, *Aepyceros melampus*), gazelles (i.e. Thomson's and Grant's gazelles, *Gazelle rufifrons* and *Gazelle granti* respectively) and dwarf antelopes (i.e. Steinbuck *Raphicerus campestris*-) associated with open grasslands where they share pastureland with livestock species (Kingdon, 2001). In conservancy areas the community is more varied with carnivore (i.e. leopard, *Panthera pardus*-), primate (i.e. Olive baboon, *Papio anubis*-) and bovine (e.g. Lesser kudu, *Tragelaphus imberbis*-) species, which are generally associated with closer canopy and mixed woodland-grassland (Kingdon, 2001).

5.10 Local community perceptions

Similarity of mammal communities of conservation areas of Koiya and Kijabe, and a significant difference with Tiamamut can be explained by the more complex vegetation communities the conservation areas of both Koiya and Kijabe group ranches than that of Tiamamut. This has resulted in the appearance of many different micro-habitats (habitat heterogeneity hypothesis) in the two ranches. A variety of available micro-habitats favours the establishment of a larger and more diverse community of mammal species.

In the case of settlement and grazing areas, similarity of mammal community types at Kijabe and Tiamamut and a significant difference from similar areas of Koiya can

be the result of a lack of permanent water sources, which in more open environments, is an important limiting factor for the occurrence of mammal species (Williamson *et al.*, 1988; Coughenour, 1991).

As in the case of vegetation species, most mammal species fell within the abundant and common categories. However, most unique species were found in the conservancy areas (particularly in Kijabe and Koiya G.R., Figure 21). These results, once again, corroborate the fact that these conservancy areas act as refuges for those species which may be especially sensitive to grazing and human disturbance (Augustine and McNaughton, 2004; Young *et al.*, 2005). One of the occasional species encountered during the field work, the Grevy's zebra (*Equus grevyi*), has been classified as endangered according to CITES red books (IUCN, 2004). This further indicates the importance of these conservancy areas as refuges for wildlife.

5.10 Local community perceptions

Overall, the general acknowledgement by communities that their livelihoods have improved (Table 14) is essential for the long-term viability of the NRM programme (Roe, 2001). This view of improved overall livelihood of local communities in the group ranches can be due to the fact that, despite the reduction in livestock numbers, the communities (particularly from Koiya G.R. where the "Starbed" lodge is located) are taking into consideration the income generated by the wildlife based tourism experienced in the area since the establishment of the NRM programme. A deterioration of the grazing areas, despite the reduction in livestock numbers, can be linked to the grazing patterns used in each of the group ranches. Kijabe G.R. (which reported an improvement in the grazing areas) still practices a "traditional" range

management method of pasture rotation (Tobler *et al.*, 2003). Koiya and Tiamamut have no clear pattern of rangeland use (probably because most areas are already quite degraded and the available pasture land is significantly reduced). Traditional pasture systems, particularly in semi-arid ecosystems, have been reported to be important for the maintenance of a good range condition at all levels (Lusigi and Buursink, 1994; Niamir, 1999). According to Coughenour (1991), Niamir (1999) and Tobler *et al.* (2003), the rotation of grazing areas on a seasonal basis allows saving of forage for critical periods, maintains a uniform grazing pressure and sustains a good range condition over the whole area. The residents of Kijabe gave similar reasons for the use of rotational grazing areas.

Regarding the maintenance of the conservancy areas (Table 15), the only group ranch that seems to enforce the limited access of livestock to this area is Kijabe G.R., which may also help explain the better range condition in this area and the dramatic increase in its bushland cover since the establishment of NRM the programme. Looking at the reasons given by the community members for protecting the conservancy areas (Table 15), the main motivation appears to be the gains expected from improved tourism.

Finally, conflict with wildlife appears to be related to community access to conservancy areas. While Kijabe (with more restricted access) reports hardly any conflicts with wildlife, Tiamamut and Koiya group ranches (with more relaxed controls) report significant encounters (Table 16). Taking into consideration that most wild animals naturally take refuge where contact with livestock and human is limited (conservancy areas) grazing in conservancy areas increases chances of

encounter with wildlife, which may lead to conflict between livestock and wildlife. Considering the importance of savannah mammals in promoting tourism (especially carnivores) and as agents of vegetation change (both browsers and grazers), the attitude of the local communities towards them is paramount for the success of the programme. As pointed out by Augustine and McNaughton (2004), browsers do not only reduce the rates of shrub encroachment on managed rangelands but are also important tools for rangeland shrub control where fire is not a suitable option (e.g. in Laikipia District). Hence wildlife does not only generate income through promoting tourism but also help maintain the grazing areas by biologically controlling bush encroachment.

10. *grassland in grazing and settlement areas*. Similarly with the shrub encroachment observed in pastures of grazing and settlement areas, the vegetation in the three group ranches, the different land uses present considerable differences in species richness, biodiversity and composition of both vegetation and mammals, indicating a general higher diversity in the conservation areas.

11. *Range condition in general is quite poor in all land uses of the group ranches*. However, the conservancy areas (especially in Kijabe G.R.) appear to be a better management of grazing areas.

12. *Attitudes of local communities towards the park programme is generally positive in Kijabe G.R.* but there is lack of serious involvement of areas that are not conservancy areas (especially Kajiado G.R.). Therefore, and lack of involvement of local people in actively managing the range areas.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the results from this study, we can say the null hypothesis is rejected as the NRM programme has had a major impact not only on the livelihood of the local communities and their perceptions about the environment, but also on the ecosystem.

The major conclusions can be summarized as follows:

1. The land cover of the area has changed since the NRM programme establishment with significant increases in bushland cover in the conservation areas and opening of shrubland to grassland in grazing and settlement areas. Similarly some degradation has occurred in pastures of grazing and settlement areas.
2. In each of the three group ranches, the different land uses present considerable differences in species richness, biodiversity and communities of both vegetation and mammals, indicating a general higher diversity in the conservancy areas.
3. Range condition in general is quite poor in all land uses of the group ranches; however, the conservancy areas (especially in Kijabe G.R.) appear less degraded than settlement or grazing areas.
4. In general, the attitudes of local communities towards the NRM programme is positive (especially in Kijabe G.R.) but there is lack of active enforcement of access restrictions to conservancy areas (particularly Koiya and Tiamamut) and lack of understanding of how to actively manage the grazing areas.

5. Traditional rotational grazing patterns appear to be better management tool than unregulated access to all grazing areas throughout the year.

6.2 Recommendations

As indicated by Sullivan and Rohde (2002), pastoral system dynamics, especially those in arid and semi-arid regions, can effectively be explained by the non-equilibrium theory. Pastoral societies (as the Maasai in Laikipia District), operate continually in a “non-equilibrium” mode where flexibility and mobility remain vital for optimal and efficient use of the scattered and unpredictable resources. However, nowadays these free movements and their spatial scale are changing and the challenge now is to refine and expand the knowledge of specific traditional rangeland management and integrate it with modern adaptive management methods to provide, not only environmental sustainability but also social equality.

As Roe (2001) pointed out, most benefits-cost analyses exclude the opportunity cost of land. Considering that these pastoral communities rely on the rangeland for the survival of their livestock in which they depend on for their survival, NRM programmes should make sure that the development of conservancies and their potential as tourist attractions will compensate for the loss of grazing land and degradation currently seen in these areas. Hence, sometimes NRM programmes should not be merely judged by their income generating ability but by benefits such as increase biomass, employment, etc. This implies that there is need for continuous participatory monitoring of the programme and consideration of the community perception and basic needs so that they can fit those offered by the NRM programme.

There is therefore need for the establishment of integrated long term monitoring programmes on the impacts of NRM programmes. Such a study should include the following:

- a. An in depth study of different aspects of savannah biodiversity (different animal groups, keystone species, vegetation communities, ecosystem structure, etc)
- b. Socio-economic assessment of cost-benefit implications of NRM programmes in arid and semi-arid areas.
- c. Gathering of traditional rangeland management methods for possible integration with modern range management.

Moreover, if these NRM programmes are to be established and implemented in semi-arid areas of sub-Saharan Africa, where livestock keeping is a major income generation for the local populations, there is need for the inclusion of active rangeland management programmes to halt the degradation of the pastureland areas (as seen in this study). The first phase of the NRM programme should be the restoration of degraded areas (i.e. removal of invasive species and re-seedling with native grass species), followed by establishment of traditional and modern methods of range management for the purpose of achieving the maximum potential of the available rangeland. Finally, if income generation activities are to be put place and be successful, conservancies should undergo a thorough scientific and socio-economic analysis to establish their potential as both refuges for wildlife and vegetation and possible tourist attraction for income generation.

REFERENCES

- Adams, W. M. (2001)** Green Development. Environment and Sustainability in the Third World. 2nd Edition. Routledge, London.
- Adler, P. B., Milchunas, D. G., Sala, O. E., Burke, I. C., Lauenroth, W. K. (2005)** Plant traits and ecosystem grazing effects: comparison of U.S. sagebrush steppe and Patagonian steppe. *Ecological Applications* 15(2): 774-792.
- Archer, S. (1994)** Woody plant encroachment into south-western grasslands and savannahs: rates, patterns and proximate causes. In: Ecological Implications of Livestock Herbivore in the West. Eds., Vavra, M., Laycock, W.A. and Pieper, R.D.. Society for Range Management, Denver.
- Archer, S. (1995)** Herbivore mediation of grass-woody plant interactions. *Tropical Grasslands* 29: 218- 235.
- Archer, S. (1996)** Assessing and interpreting grass-woody plant dynamics. In: The Ecology and Management of Grazing Systems. Eds., Hodgson, J. and Illius, A.W. CAB International, New York.
- Ashley, C. (2000)** The Impacts of Tourism on Rural Livelihoods: Namibia's Experience. Working paper 128, Overseas Development Institute (ODI), London.
- Augustine, D. J. and McNaughton, S. J. (2004)** Regulation of shrub dynamics by native browsing ungulates on East Africa rangelands. *Journal of Applied Ecology* 41: 45- 58.
- Austin, M. P. and Williams, O. (1988)** Influence of climate and community composition on the population demography of pasture species in semi-arid Australia. *Vegetation* 77: 43- 49.
- Barnett, A. and Dutton, J. (1995)** Expedition field techniques. Small mammals (excluding bats). Expedition advisory centre, Royal Geography Society, London.
- Ben-Shahar, R. and Macdonald, D. W. (2002)** The role of soil factors and leaf protein in the utilization of mopane plants by elephants in northern Botswana. BMC Ecology 2002, 2:3. BioMed Central.
- Blench, P. and Sommer, F. (1999)** Understanding Rangeland Biodiversity. Working paper 121. Overseas Development Institute (ODI), London.
- Blundell, M. (1992)** Collins Photo Guide to the Wild Flowers of East Africa. Harper Collins Publishers, London.

- Bock, J. H. and Bock, C.E. (1992)** Vegetation responses to wildlife in native versus exotic Arizona grassland. *Journal of Vegetation Science* 3: 431- 446.
- Brown, D. (1998)** Participatory Biodiversity Conservation- Rethinking the Strategy in the Low Tourist Potential Areas of Tropical Africa. Natural Resource Perspectives 33. Overseas Development Institute (ODI), London.
- Byrne, G. F., Crapper, P. F. and Mayo, K. K. (1980)** Monitoring of land cover change by principal components analysis of multi-temporal Landsat Data. *Remote Sensing of Environment*, 10: 175-184.
- Campbell, J. B. (2002)** Introduction to Remote Sensing. Taylor and Francis Ltd., London.
- CBD (1992)** Text on the Convention on Biological Diversity. <http://www.biodiv.org/convention/articles.asp> (viewed on January 2006).
- Clarke, P. J. (2003)** Composition of grazed and cleared temperate grassy woodlands in eastern Australia: patterns in space and inferences in time. *Journal of Vegetation Science* 14: 5- 14.
- Coppin, R. D., Jonckheere, J., Nackaetts, K., Muys, B. and Lambin, E. (2004)** Digital change detection methods in ecosystem monitoring: a review. *International Journal of Remote Sensing* 25: 918- 927.
- Coughenour, M. B. (1991)** Spatial components of plant herbivore interactions in pastoral, ranching and native ungulate ecosystems. *Journal of Range Management* 44(6): 530- 542.
- Davidowitz, G. and Rosenzweig, M. L. (1998)** The latitudinal gradient of species diversity among North America grasshoppers within a single habitat: a test of the spatial heterogeneity hypothesis. *Journal of Biogeography* 25: 553-560.
- De Haan, C., Steinfeld, H. and Blackburn, H. (1997)** Livestock and the Environment. Finding a Balance. A Study Sponsored by the European Commission, FAO, World Bank and others, Suffolk.
- Doughill, A. and Cox, J. (1999)** Land Degradation and Grazing in the Kalahari New Analysis and Alternative Perspectives. Overseas Development Institute (ODI), London.
- Doughill, A. and Reed, M. (2002)** Participatory Indicator Development for sustainable Natural Resource Management. Overseas Development Institute (ODI), London.
- Doughill, A. and Reed, M. (2005)** Frameworks for Community-based Rangeland Sustainability Assessment in the Kalahari. Overseas Development Institute (ODI), London.
- Erdas Inc. (1999)** Erdas Tour Guide version 8.4. Atlanta, Georgia.

- Foody, G. M. (2003)** Remote sensing of tropical forest environments: towards the monitoring of environmental resources for sustainable development. *International Journal of Remote Sensing* vol.24(20): 4035- 4046.
- Government of Kenya (1982)** Farm Management Handbook of Kenya. Volumes I to IV. Ministry for Agriculture, Republic of Kenya, Nairobi.
- Groombridge, B. (1992)** Global Biodiversity. Status of the Earth's Living Resources. Chapman & Hall, London.
- Hall, J. P. (2001)** Criteria and indicators of sustainable forest management. *Environmental Monitoring and Assessment*, 67: 109- 119.
- Hamblen, C. (2004)** Conservation. Cambridge University Press, Cambridge.
- Herlocker, D. J. (1995)** Range Resource Monitoring: Field and Office Guidelines. Range Management Handbook of Kenya, Volume III, 10. Ministry of Agriculture, Livestock Development and Marketing, Nairobi.
- Higgins, S. I., Shackleton, C. M., Robinson, E. R. (1999)** Changes in woody community structure and composition under contrasting land-use systems in a semi-arid savanna, South Africa. *Journal of Biogeography* 26: 619- 627.
- Hobley, M. and Shields, D. (2000)** The Reality of Trying to Transform Structures and Processes: Forestry in Rural Livelihoods. Working paper 132, Overseas Development Institute (ODI), London.
- Homewood, K. and Brockington, D. (1999)** Biodiversity, conservation and development in Mkomazi Game Reserve, Tanzania. *Global Ecology and Biogeography* 8:301-313.
- IUCN (2004)** 2004 IUCN Redlist of Threatened Species. www.iucnredlist.org. (viewed on February 2006)
- Jackson, R. D. and Bartolome, J. W. (2002)** A state transition approach to understanding non-equilibrium plant community dynamics in Californian grasslands. *Plant Ecology* 162: 49- 65
- Jacobs, M. and Coppock, D. L. (1999)** A Review of Changes in Rangeland Vegetation and Livestock Populations for Northern Kenya. GL-CRSP Pastoral Risk Management Project Draft Technical Report No. 06/99, Utah State University, Logan.
- James, C. D., Landsberg, J. and Morton, S. R. (1996)** Maintaining biodiversity in Australian rangelands. 9th Biennial Australian Rangeland Conference, September 24-27, 1996, Port Augusta, Australian Rangeland Society.

- Jeltsch, F., Milton, S. J., Dean, W. R. J. and van Rooyen, N. (1997)** Analysing shrub encroachment in the southern Kalahari: a grid based modelling approach. *Journal of Applied Ecology* 34: 1497- 1508.
- Jeltsch, F., Weber, G.E. and Grimm, V. (2000)** Ecological buffering mechanisms in savannas: A unifying theory of long-term tree-grass coexistence. *Plant ecology* 161: 161- 171.
- Jones, K. B. (1981)** Effects of grazing on lizard abundance and diversity in western Arizona. *South-western Naturalist* 26: 107- 115.
- Kingdon, J. (2001)** The Kingdon Field Guide to African Mammals. AP Natural World Academic Press, London.
- Kiringe, J. N. and Okello, M. M. (2005)** Use and availability of tree and shrub resources on Maasai communal rangelands near Amboseli, Kenya. *African Journal of Range and Forage Science* 22(1): 37- 46.
- Krebs, C. J. (1972)** Ecology: The Experimental Analysis of Distribution and Abundance. Harper and Row, New York.
- Krebs, C. J. (1999)** Ecological Methodology. Addison Wesley Longman, Inc., New York.
- Lane, P., Cansey, M., Gaj-Mackeever, R., Graham, M., Kenny, P., Lemoosa, P., Muiruri, V., Mutundu, K., Noran, T., Ogutu, B., Payton, R., Rutledge, A. M., Smith, B., Taylor, D. and Vaughan, C. (2005)** Landscape and Environmental Change in Semi-arid Regions of East and Southern Africa: Developing Interdisciplinary Approaches. British Institute in Eastern Africa, Nairobi.
- Lawton, J. H. (1983)** Plant architecture and the diversity of phytophagous insects. *Annual Review of Entomology* 28: 23- 39.
- Legilisho-Kiyiapi, J. (2003)** Koija, Tiamamut and Kijabe Group Ranches, Mukugodo Division of Laikipia district, Central Kenya. AWF supported community based NRM planning process, final report. AWF, Nairobi.
- Lenzi-grillini, C. R., Viskanic, P. and Mapesa, M. (1996)** Effects of 20 years of grazing exclusion in an area of the Queen Elisabeth National Park, Uganda. *African Journal of Ecology* 34: 333- 341.
- Lillesand, T. M. and Kiefer, R. W. (2000)** Remote Sensing and Image Interpretation. John Wiley and sons Inc., New York.
- Lind, E. M. and Morrison, M. E. S. (1974)** East Africa Vegetation. Longman Group Ltd., London.

- Ludwig, J. A., Tongway, D. J., Bastin G. N. and James, C. (2003)** Monitoring Ecological Indicators of Rangeland Functional Integrity and Biodiversity at Local and Regional Scales. Tropical Savanna CRC and CSIRO, Canberra.
- Lunt, I. D. (2005)** Effects of Stock Grazing on Biodiversity Values in Temperate Native Grasslands and Grassy Woodlands in SE Australia: a Literature Review. Technical Report 18. Environment ACT. Canberra.
- Lusigi, N. and Buursink, J. (1994)** Pastoral rangelands in Sub-Sahara Africa: strategies for sustainable development. *Findings, Africa Region 40, The World Bank Group*. In: Sahel Operational Review: Status and Lessons Learned. AFTES paper 11. Environmental Policy and Planning series. Technical Department, Africa Region. The World Bank, Washington D.C..
- MacArthur, R. H. and Wilson, E. O. (1967)** The Theory of Island Biogeography. Princeton University Press, Princeton.
- Malila W. A. (1980)** Change Vector Analysis: an Approach to Detecting Forest Changes with Landsat. Proceedings of the 16th International symposium on Machine proceeding of remotely sensed data, Purdue University, West Lafayette.
- Mapinduzi, A. L., Oba, G., Weladji, R. B. and Colman, J. E. (2003)** Use of indigenous ecological knowledge of the Maasai pastoralists for assessing rangeland biodiversity in Tanzania. *African Journal of Ecology* 41: 329- 336.
- Mather, P. M. (1999)** Computer Processing of Remotely Sensed Images. John Wiley and Sons, Chichester.
- Maundu, P., Berger, D. J., Ole Saitabau, C., Nasieku, J., Kipelian, M., Mathenge, S. G., Morimoto, Y. and Höft, R. (2001)** Ethnobotany of the Looita Maasai: Towards Community Management of the Forest of the Lost Child- Experiences from the Looita Ethnobotany Project. People and Plants Working Paper 8. UNESCO, Paris.
- McCoy, E. D. and Bell, S. S. (1991)** Habitat structure: the evolution and diversification of a complex topic. In: Habitat Structure: The Physical Arrangement of Objects in Space. Eds. By Bell S.S., McCoy E.D. and Mushinsky H.R.. Chapman and Hall, London.
- McIntyre, S., Heard, K. M. and Martin, T. G. (2003)** The relative importance of cattle grazing in subtropical grasslands: does it reduce or enhance plant biodiversity? *Journal of Vegetation Science*, 5: 521- 531.
- Means, R. (2000)** When livestock are good for the environment: benefit-sharing of the environmental goods and services. Workshop Paper for the Fourth World Bank Conference on Environmentally Sustainable Development, 27-28 September 1996, Washington D.C.

- Minja, M. M. J. (1999)** The Maasai wonder plants. "People and Plants" training workshop held at the Tropical Pesticides Research Institute, Arusha, Tanzania 15th -18th March 1999.
- Nhantumbo, I., Norfolk, S. and Pereira, J. (2003)** CBNRM in Mozambique: A Theoretical or Practical Strategy for Local Sustainable Development? The Case Study of Derre Forest Reserve. Research Paper 10, Sustainable livelihoods in Southern Africa, Mozambique.
- Niamir, M. (1999)** Traditional African Range Management Techniques: Implications for Rangeland Development. FODP, FAO, Rome.
- Nicol, A. (2000)** Adopting a Sustainable Livelihood Approach to Water Projects: Implications for Policy and Practice. Working paper 133, Overseas Development Institute (ODI), London.
- Ng'ethe, R., Kariuki, A. and Opondo, C. (2003)** Some Experience on Adaptive Research Input on Natural Resource Use: The Case of Gums and Resins in Mukugodo Rangelands, Laikipia District, Kenya. Applied Research Unit, Nanyuki.
- Oba, G. (2001)** Indigenous ecological knowledge of landscape change in East Africa. *IALE Bulletin Vol.9 (3):1- 3*.
- Oba, G. and Kotile, D.G. (2001)** Assessments of landscape level degradation in southern Ethiopia: pastoralist versus ecologist. *Land Degradation and Development 12: 461-475*.
- Oba, G., Post, E., Syvertsen, P. O. and Stenseth, N. C. (2000)** Bush cover and range condition assessments in relation to landscape and grazing in southern Ethiopia. *Landscape Ecology 15: 535-546*.
- Oba, G., Weladji, R. B., Lusigi, W. J. and Stenseth, N. C. (2003)** Scale dependent effects of grazing on rangeland degradation in Northern Kenya: A test of equilibrium and non-equilibrium hypotheses. *Land Degradation and Development 14: 83-94*
- Oguge, N., Hutterer, R., Odhiambo, R. and Verheyen, W. (2004)** Diversity and structure of shrew communities in montane forests of southeast Kenya. *Mammalian Biology 69: 289- 301*.
- Ogotu, B. O. (2004)** Land Cover Change Detection in a Savannah Ecosystem: A GIS and Remote Sensing Approach. A Case Study of Laikipia District, Kenya. MPhil Thesis, Cambridge University, Cambridge.
- Oindo, B. O. and Skidmore, A. K. (2000)** Inter-annual variability of NDVI and species richness in Kenya. *International Journal of Remote Sensing 23: 285-298*.

- Packer, M. J., Canney, S. M., McWilliam, N. C. and Abdallah, R. (1999)** Ecological mapping of semi-arid savanna. In: Mkomazi: The Ecology, Biodiversity and Conservation of a Tanzanian Savannah. Eds., Coe, M.J., McWilliam, N.C., Stone, G.N. and Packer, M.J.. RGS-IBG, London.
- Palmer, A. R. and Fortescue, A. (2003)** Remote Sensing and Change Detection in Rangeland. In: Proceedings of the VII International Rangelands Congress. Eds. Palmer, A.R., Milton, S.J., Krikman, K.P., Kerley, G.I.H., Hurt, C.R. and Brown, C.J.. 26th July- 1st August, 2003, Durban.
- Peredo, B. (2002)** Sustainable use of Andean wildlife for conservation of biodiversity and local development of rural communities in arid and semiarid zones. In: Promoting Best Practices for Conservation and Sustainable Use of Biodiversity of Global Significance in Arid and Semiarid Zones in the Developing World. Summaries of Selected Case Studies and Innovative Experiences Throughout the South. Third World Network of Scientific Organizations (TWNISO), United Nations Environment Programme (UNEP) and Global Environment Facility (GEF).
- Pickup, G., Bastin, G. N. and Chewings, V. H. (1994)** Remote-sensing-based condition assessment for non-equilibrium rangelands under large-scale commercial grazing. *Ecological Applications* 4(3): 497- 517.
- Redford, K. H., Taber, A. and Simonetti, J. A. (1990)** There is more to biodiversity than tropical rain forests. *Conservation Biology* 4: 328- 330.
- Ribeiro, A. (2001)** Natural Resource Management Policy in Mozambique: An Overview. Working paper number 7. Marena research project, Mozambique.
- Roe, D. (2001)** Community-based wildlife management: improved livelihoods and wildlife conservation? Bio-briefs No. 1, Biodiversity and Livelihoods Group, IIED, London.
- Roques, K. G., O'Connor, T. G. and Watkinson, A. R. (2001)** Dynamics of shrub encroachment in an Africa savanna: relative influences of fire, herbivory, rainfall and density dependence. *Journal of Applied Ecology*, 38: 268-280.
- Sabins, F. F. (1997)** Remote Sensing: Principles and Interpretation. W.H. Freeman and Company, New York.
- Sakaran, M., Ratnam, J. and Hanan, N. P. (2004)** Tree-Grass Coexistence in Savannas Revisited- Insights from an Examination of Assumptions and Mechanisms Invoked in Existing Models. *Ecology Letters* 7(6): 480- 490.
- Sala, O. E., Lauenroth, W. K., McNaughton, S. J., Rush, G and Zhang, X. (1996)** Biodiversity and ecosystem functioning in grasslands. In: Biodiversity: A Global Perspective. Eds., Mooney, H.A., Cushman, J.H., Medina, E., Sala, O.E. and Schulze, E.D. J. Wiley & Sons Ltd., Washington.

- Scholes, R. J. and Archer, S. R. (1996)** Tree-grass interactions in savannas. *Annual Review of Ecological Systems* 28: 517- 544.
- Serra, P., Pons, X. and Sauri, D. (2003)** Post-classification change detection with data from different sensor: some accuracy considerations. *International Journal of Remote Sensing. Vol. 24 (16): 1311-3340.*
- Shabaani, S. B., Walsh, M., Herlocker, D. and Walther, D. (1992)** Range Management Handbook of Kenya Volume III, 2. Ministry of Agriculture and Livestock Development and Marketing, Nairobi.
- Simpson, E. H. (1949)** Measurement of diversity. *Nature* 163: 688.
- Smyth, A. K. (2003)** Key Conceptual, Biophysical and Statistical Issues of Importance for Designing Biodiversity Monitoring Framework for the Rangelands. CSIRO, Canberra.
- Smyth, A. K. and James, C. D. (2004)** Characteristics of Australia's rangelands and key design issues for monitoring biodiversity. *Austral Ecology* 29: 3 -15.
- Solbrig, O. T. (1996)** The diversity of savanna ecosystems. In: Biodiversity and Savanna Ecosystem Processes. Eds., Solbrig, O.T., Medina, E. and Silva, J.F., Berlin.
- Soulé, P. T. and Knapp, P. A. (1999)** Western *Juniper* expansion on adjacent disturbed and near-relict sites. *Journal of Range Management* 52: 525- 533.
- Spellerberg, I. F. (1996)** Conservation Biology. Longman Group Ltd, Essex.
- Sullivan, S. and Rohde, R. (2002)** On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography* 29: 1595- 1618.
- Thurow, T. L. and Herlocker, D. (1993)** Users Guide for the Range Management Handbook of Kenya, Volume III, 5. Ministry of Agriculture, Livestock Development and Marketing, Nairobi.
- Tobler, M. N., Cochard, R. and Edwards, P. J. (2003)** The impact of cattle ranching on large-scale vegetation patterns in a coastal savanna in Tanzania. *Journal of Applied Ecology* 40: 430- 444
- Tucker, C. J. (1979)** Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8: 127-150.
- Tucker, C. J. (1986)** Maximum normalized difference vegetation index for sub-Saharan Africa for 1983-1985. *International Journal of Remote Sensing*, 7: 1383-1384.

- TWNSO, UNEP and GEF (2002)** Promoting Best Practices for Conservation and Sustainable Use of Biodiversity of Global Significance in Arid and Semi-arid in the Developing World. Summaries of Selected Case Studies and Innovative Experiences throughout the South. TWNSO (Third World Network of Scientific Organisations), UNEP (United Nations Environment Programme) and GEF (Global Environment Facility).
- USAID (2005)** Community-based natural resource management (CBNRM). In: Environmental Guidelines for Small-Scale Activities in Africa. Technical Paper 2005. Eds. SD Publication Series, Bureau of Africa, Office of Sustainable Development, Washington D.C..
- Vermeulen, S. and Koziell, I. (2002)** Integrating Global and Local Values: a Review of Biodiversity Assessment. IIED, London.
- Vesk, P. A., Leishman, M. R. and Westoby, M. (2004)** Simple traits do not predict grazing response in Australian dry shrublands and woodlands. *Journal of Applied Ecology* 41: 22- 31.
- Wang, F. (1993)** A knowledge based vision system of detecting land cover changes at urban fringes. *IEE Transactions on Geosciences and Remote Sensing* 31: 136- 145.
- Wessman, C. A., Archer, S., Johnson, L. C. and Asner, G. P. (2004)** Woodland expansion in US grasslands. Assessing land-cover change and biochemical impacts. In : Land Change Science. Eds. Guttman, G., Janeto, A. and Skoles, D.. Kluwer Academic Publishers, Amsterdam.
- Western, D. (1975)** Water availability and its influence on the structure and dynamics of a savannah large mammal community. *East Africa Wildlife Journal* 13: 265-286.
- Western, D. and Wright, R. M. (1994)** The background to community-based conservation. In: Natural Connections: Perspectives in Community-based Conservation. Eds. Western, D., White R.M. and Strum, S.C.. Island Press, Washington D.C..
- Williamson, D., Williamson, J. and Ngwamotsoko, K. T. (1988)** Wildebeest migration to the Kalahari. *Africa Journal of Ecology* 26: 269-280.
- Whitehead, P. J., Woinarski, J., Jacklyn, P., Fell, D. and Williams, D. (2000)** Defining and measuring the health of savanna landscape: A north Australian perspective. Tropical Savannas CRC, Discussion Paper, Australia.
- Young, J. and Prince, S. D. (2000)** Remote sensing of savanna vegetation changes in Eastern Zambia 1872-1989. *International Journal of Remote Sensing*, 21(2): 301-322.

APPENDICES

Appendix 1. Mammal species list and distribution

Common name	Scientific name	Maasai name	Group Ranch								
			Koiya			Tiamamat			Kijabe		
			Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
Black-backed jackal	<i>Canis mesomelas</i>	Embarie (jackal)	+	+	-	-	-	+	-	-	-
Bush duiker	<i>Sylvicapra grimmia</i>	-	-	-	-	+	-	+	-	+	-
Common genet	<i>Genetta genetta</i>	Olpilis	-	-	-	-	+	-	-	-	-
Common warthog	<i>Phacochoerus africanus</i>	Olbitir	+	+	-	-	-	-	-	-	-
Common zebra	<i>Equus quagga</i>	Oloitiko	+	+	+	+	+	+	-	+	+
Gerenuk	<i>Litocranius walleri</i>	Riigo	+	+	-	+	-	-	-	-	-
Grant's gazelle	<i>Gazella granti</i>	Wuargasin	+	+	-	+	+	+	-	+	+
Grevy's zebra *	<i>Equus grevyi</i>	Olkanka	+	-	+	-	+	-	-	-	-
Hare	<i>Lepus spp</i>	Enkitojo	+	+	+	+	+	+	+	+	+
Impala	<i>Aepyceros melampus</i>	Ntarakuet	+	+	+	+	-	+	-	+	-
Kirk's dikdik	<i>Madoqua kirkii</i>	Eronko	+	+	+	+	+	-	+	-	-
Klipspringer	<i>Oreotragus oreotragus</i>	Ikejeji/ moru	-	-	-	-	-	-	+	-	-
Leopard	<i>Panthera pardus</i>	Olouwuaru-keri	-	-	-	-	-	-	+	-	-
Lesser kudu	<i>Tragelaphus imberbis</i>	Olmalo	-	-	-	-	-	-	+	-	-
Mongoose	<i>Herpestes spp</i>	Sioj	+	+	-	-	+	+	+	-	+
Naked-sole gerbil	<i>Tatera ssp</i>	-	-	-	-	-	-	-	+	-	-

Con: Conservancy area; Gra: Grazing area; Set: Settlement area; + :unique species; * endangered

Appendix 2

Common name	Scientific name	Maasai name	Group Ranch								
			Koiya			Tiamamut			Kijabe		
			Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
Narrow-footed woodland mice	<i>Grammomys</i> spp	-	-	-	-	-	-	-	+	-	-
Olive Baboon	<i>Papio anubis</i>	Lotimi	-	-	-	-	-	-	+	-	-
Rock hyrax	<i>Procavia</i> spp	Enkinyanjur	-	-	-	+	-	+	+	-	-
Rufus elephant shrew	<i>Elephantulus rufescens</i>	-	-	-	+	-	-	-	-	-	-
Slender mongoose	<i>Herpestes sanguinea</i>	Sioj (mongoose)	+	+	+	-	+	-	-	-	-
Spiny mice	<i>Acomys</i> spp	-	+	+	+	-	-	-	+	-	-
Steinbuck	<i>Raphicerus campestris</i>	Lo-olgot/ olpurnas	-	-	-	+	+	-	+	+	+
Striped hyena	<i>Hyaena hyaena</i>	Oikonoi/ Olngojine	+	-	-	-	-	-	-	-	-
Thomson's gazelle	<i>Gazella rufifrons</i>	Nko-opera	-	-	+	+	+	+	-	+	+
Unstripped ground squirrel	<i>Xerus rutilus</i>	Karkoboo (squirrel)	+	+	+	+	-	+	+	-	-

Con: Conservancy area; Gra: Grazing area; Set: Settlement area; + : unique species; * endangered

Appendix 2. Vegetation species and distribution

Genus/ Species	Maasai name	Family	Growth form	Group Ranch								
				Kijabe			Tiamamut			Koiya		
				Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
<i>Abutilon sp</i>	-	Malvaceae	Shrub	+	-	-	+	+	-	-	+	+
<i>Acacia brevispica</i> ¹	Ngirigiri	Leguminosae subfam. Mimosoideae	Tree	+	-	-	-	-	-	+	+	+
<i>Acacia drepanolobium</i>	Eluai	Leguminosae subfam. Mimosoideae	Tree	-	+	+	-	+	+	-	-	-
<i>Acacia etbaica</i>	Nchakwai	Leguminosae subfam. Mimosoideae	Tree	+	+	+	+	+	+	+	+	+
<i>Acacia mellifera</i>	Monishoi	Leguminosae subfam. Mimosoideae	Tree	+	+	+	+	+	+	+	+	+
<i>Acacia nilotica</i> ¹	Nkiloriti	Leguminosae subfam. Mimosoideae	Tree	+	+	+	+	+	+	-	+	+
<i>Acacia reficiens</i> ¹	Oljakwai	Leguminosae subfam. Mimosoideae	Tree	-	-	+	+	-	+	+	+	+
<i>Acacia seyal</i>	Lerai	Leguminosae subfam. Mimosoideae	Tree	+	+	+	+	+	+	-	-	-
<i>Acacia tortolis</i>	Ltepes	Leguminosae subfam. Mimosoideae	Tree	+	+	+	+	+	+	+	+	+
<i>Aloe secundiflora</i>	Osuguroi	Liliaceae	Succulent herb	-	+	-	-	+	-	-	-	-
<i>Amaranthus sp</i>	-	Amaranthaceae	Annual herb	-	-	+	-	-	+	-	+	+
<i>Aristida sp</i>	Ilperesi	Gramineae	Annual herb	+	+	+	+	+	+	+	+	+
<i>Asparagus sp</i>	Lomei	Liliaceae	Climber	-	+	+	+	+	-	-	-	-
<i>Balanites sp</i>	Osarai	Balanitaceae	Shrub	-	-	-	+	+	+	+	+	-
<i>Barleria sp</i>	Suchai	Acanthaceae	Shrub	+	+	+	+	+	+	+	+	+
<i>Blepharis sp</i>	Olmarag	Acanthaceae	Perennial herb	-	-	-	+	+	-	+	+	+
<i>Boscia sp</i>	-	Capparaceae	Shrub	-	-	-	+	-	-	-	-	-
<i>Bothriochloa sp</i> ³	Talanguani	Compositae	Perennial herb	+	-	-	-	+	-	-	-	-
<i>Brachiaria sp</i> ²	-	Panicaceae	Perennial herb	+	-	+	+	+	+	+	-	+
<i>Carissa edulis</i>	-	Apocynaceae	Shrub	+	-	-	-	-	-	-	-	-
<i>Cenchrus sp</i>	-	Gramineae	Perennial herb	+	+	+	-	-	+	-	-	+
<i>Chloris sp</i> ²	Longuroreki	Gramineae	Perennial herb	+	-	+	-	-	-	-	-	-

1: invasive species; 2: decreaser species; 3: increaser species; Con: Conservancy area; Gra: Grazing area; Set: Settlement area; +: unique species

Genus/ Species	Maasai name	Family	Growth form	Group Ranch									
				Kijabe			Tiamamut			Koiya			
				Con	Gra	Set	Con	Gra	Set	Con	Gra	Set	
<i>Cissus sp</i> ¹	Laraiti	Vitaceae	Vine	+	-	-	-	+	+	+	+	+	+
<i>Codya monoca</i>	-	-	Tree	+	-	-	-	-	-	-	-	-	-
<i>Commelina bengalensis</i>	Nkateteia	Commelinaceae	Annual herb	-	+	-	-	-	-	-	-	-	-
<i>Commelina sp</i> ²	-	Commelinaceae	Annual herb	+	+	+	+	+	+	+	+	+	+
<i>Commiphora sp</i>	Loishimi	Burseraceae	Shrub	+	+	-	+	-	-	-	-	-	-
<i>Croton dichogamus</i> ¹	Lokirdingai	Euphorbiaceae	Shrub	+	-	-	-	-	+	+	+	+	-
<i>Cucumis sp</i>	-	Cucurbitaceae	Climber	-	-	-	-	-	-	+	-	-	-
<i>Cyathula sp</i>	Lorepirepi	Amaranthaceae	Perennial herb	+	+	+	+	+	+	+	+	+	+
<i>Cynodon sp</i> ³	Iperesi	Gramineae	Perennial herb	+	+	+	-	-	-	+	-	+	+
<i>Cyperus sp</i>	Nkomei	Cyperaceae	Shrub	+	+	-	+	+	+	+	+	+	+
<i>Cyphostemma adogensense</i>	Lorondo	Vitaceae	Climber	-	+	-	+	-	-	-	-	-	-
<i>Cyphostemma sp</i>	Longwaroi	Vitaceae	Climber	+	+	-	+	-	+	+	+	-	+
<i>Digitaria milanijana</i>	Ngaimuruai	Gramineae	Perennial herb	+	+	+	+	+	+	+	+	+	+
<i>Eragrostis sp</i>	Operesi	Gramineae	Annual herb	+	+	+	+	+	+	+	+	+	+
<i>Euphorbia sp</i> ¹	Olpopogi/Ngeleti	Euphorbiaceae	Shrub	-	+	+	-	+	+	+	+	+	+
<i>Ferrybels sp</i>	-	-	forb	-	-	-	-	-	-	-	-	+	+
<i>Grewia bicolor</i>	Siteti	Tiliaceae	Shrub	+	-	-	-	-	-	+	-	-	+
<i>Grewia sp</i>	-	Tiliaceae	Shrub	+	+	+	+	+	+	+	+	+	+
<i>Grewia sp</i>	Silapi	Tiliaceae	Shrub	-	-	-	-	-	-	+	-	-	-
<i>Grewia tembensis</i>	Irii	Tiliaceae	Shrub	+	+	+	+	-	-	+	+	+	+
<i>Harpachne sp</i> ³	-	Gramineae	Perennial herb	+	-	-	-	-	-	-	-	-	-
<i>Heliotropium sp</i>	Lmasikirai	Boraginaceae	forb	+	+	+	+	+	+	+	+	+	+
<i>Helycrisum sp</i> ³	-	Compositae	Shrub	+	-	-	-	-	-	-	-	-	-
<i>Hibiscus sp</i>	Ngarani	Malvaceae	forb	+	+	+	+	+	+	+	+	+	+

1: invasive species; 2: decreaser species; 3: increaser species; Con: Conservancy area; Gra: Grazing area; Set: Settlement area; +: unique species

Genus/ Species	Maasai name	Family	Growth form	Group Ranch								
				Kijabe			Tiamamut			Koiya		
				Con	Gra	Set	Con	Gra	Set	Con	Gra	Set
-	Ilgalai	-	Shrub	-	-	-	-	-	-	+	+	-
<i>Indigofera sp</i> ³	Nkulu	Leguminosae subfam. Papilionoideae	forb	+	+	+	+	+	+	+	+	+
<i>Ipomoea sp</i> ¹	Ngululu	Convolvulaceae	forb	+	+	+	+	+	+	+	+	+
<i>Ipomoea kituiensis</i> ¹	Lokitengi	Convolvulaceae	Shrub	+	+	+	+	+	+	+	+	+
<i>Justicia sp</i>	-	Acanthaceae	forb	+	+	+	+	-	-	-	-	+
<i>Kleinia sp</i>	-	Compositae	forb	-	-	-	-	-	-	+	-	-
<i>Kyllinga sp</i>	kuroot-lesirikoi	Cyperaceae	grass-like forb	+	+	+	-	+	+	+	+	+
-	Lmasei	-	Shrub	+	-	-	-	-	-	-	-	-
-	Lminyol	-	Shrub	+	-	-	-	-	-	-	-	+
-	Longoltim	-	Shrub	+	+	-	-	-	-	-	-	-
<i>Lycium shawii</i>	Nkokii	Solanaceae	Shrub	+	+	-	+	-	-	-	-	-
<i>Lycium sp</i>	Merepari	Solanaceae	Shrub	+	+	+	+	+	+	+	+	+
<i>Maerua sp</i>	-	Capparaceae	Shrub	+	-	-	+	-	-	-	+	-
<i>Maytenus sp</i>	Laimurai	Celastraceae	Shrub	+	+	+	+	-	-	-	-	-
<i>Microchloa kumthii</i>	Engoijita ng'iro	Gramineae	Perennial herb	+	+	+	+	+	+	+	+	+
-	Nchekecheke	-	forb	+	-	-	-	-	-	-	-	-
-	Nterere	-	forb	-	-	-	+	-	+	+	-	-
<i>Oldenlandia sp</i>	-	Rubiaceae	Perennial herb	-	-	+	-	-	-	-	-	-
<i>Olea europaea</i>	Oloirien	Oleaceae	Tree	+	-	-	-	-	-	-	-	-
<i>Opuntia vulgaris</i>	-	Cactaceae	Cactus	-	-	-	-	-	-	-	-	+
<i>Oretrogon capense</i>	-	-	Annual herb	-	-	-	-	-	-	+	-	-
<i>Oxygonum sp</i>	Ngachicho	Polygonaceae	Annual herb	+	-	+	+	+	-	+	+	+
<i>Pennisetum mezianum</i>	Ngurume	Gramineae	Perennial herb	-	+	+	+	+	+	-	+	+
<i>Phalanthus sp</i>	-	-	forb	-	+	+	-	-	-	-	-	-

1: invasive species; 2: decreaser species; 3: increaser species; Con: Conservancy area; Gra: Grazing area; Set: Settlement area; + :unique species

Genus/ Species	Maasai name	Family	Growth form	Group Ranch									
				Kijabe			Tiamamut			Koiya			
				Con	Gra	Set	Con	Gra	Set	Con	Gra	Set	
<i>Portulaca sp</i>	-	Portulacaceae	Annual herb	-	+	-	+	+	+	+	+	+	+
<i>Potuluca oleracea</i>	-	Portulacaceae	Annual herb	-	-	-	-	+	-	-	-	-	-
<i>Rhus vulgaris</i>	-	Anacardiaceae	Shrub	-	-	-	-	-	-	-	+	-	-
<i>Saido ovata</i>	-	-	Shrub	-	-	-	-	-	-	-	+	+	+
<i>Sansivieria sp</i> ¹	Oldupai	Agavaceae	Perennial herb	-	-	+	+	+	-	-	+	+	+
<i>Sesbania sp</i>	-	Papilionoideae	Shrub	+	-	-	-	-	-	-	-	-	-
<i>Solanum sp</i> ¹	Ntulelei	Solanaceae	Shrub	+	+	+	+	+	+	+	+	+	+
<i>Tetrapogon sp</i>	-	Gramineae	Annual herb	-	-	-	-	-	-	+	+	-	-
<i>Themeda triandra</i> ²	Longororeki	Andropogoneae	Perennial herb	+	-	-	-	-	-	-	-	-	-
<i>Tragus sp</i>	Nariripud	Zoizieae	Annual herb	+	+	+	+	+	+	+	+	+	+
<i>Tribulus sp</i>	Laimereruak	Zygophyllaceae	Annual herb	+	+	+	+	+	+	+	+	+	+
<i>Unitho sp</i>	-	-	forb	-	-	-	-	-	-	+	-	-	-
<i>Wahlenbergia sp</i>	Loduaporo	Campanulaceae	forb	+	+	+	-	-	-	-	-	-	-
<i>Zaleya sp</i>	-	Aizoaceae	forb	-	-	+	-	-	+	-	+	+	+
Total number of species				55	43	41	41	38	37	43	43	45	
Number of invasive species				6	4	6	5	6	7	8	9	8	
Number of unique species				9	1	1	1	1	0	5	1	1	

1: invasive species; 2: decreaser species; 3: increaser species; Con: Conservancy area; Gra: Grazing area; Set: Settlement area; + :unique species

Blundell (1992); Lind, E.M. & Morrison, M.E.S. (1974); Mapinduzi *et al* (2003); Maundu *et al* (2001); Minja (1999); Ng'ethe *et al* (2003)

Appendix 3. Community perceptions questionnaire

1 Are there certain areas that you don't graze in? YES / NO

1.1 Where are these places? (PLEASE LIST IN CHART BELOW.) Why don't you graze there? (TICK WHERE APPROPRIATE IN CHART.)

REASONS FOR NOT GRAZING (TICK WHERE APPROPRIATE).

PLACE	Conflicts with wildlife	Distance to water point	Sacred place	Poor land quality	To preserve it for the future	Conflict with Samburu cattle	Other (PLEASE DESCRIBE.)

1.2 Did people EVER bring their livestock to graze in these areas? YES / NO

1.3 If YES, which areas? (PLEASE PUT A STAR ON THE CHART ABOVE, NEXT TO EACH PLACE MENTIONED.)

1.4 How many years ago did these changes happen? _____

2 Are there conflicts between wildlife and livestock over grazing land? YES / NO

2.1 How do you usually resolve these conflicts (probe: *kill the animal? Move? Etc.*)?

3 Are there MORE or FEWER conflicts over grazing land than there were 20 years ago?
MORE FEWER

4 Why has this happened? (PLEASE RANK THE FIRST 2 THAT ARE MENTIONED: 1 IS MENTIONED FIRST, 2 IS MENTIONED SECOND.)

- | | |
|----------------------------------|----------------------------------|
| ___ more wildlife using the land | ___ less wildlife using the land |
| ___ more people on the land | ___ fewer people on the land |
| ___ more livestock on the land | ___ fewer livestock on the land |
| ___ less overall water available | ___ water is available |
| ___ other (specify) _____ | |

5 Is grazing land BETTER, WORSE, or the SAME as it was 10 years ago?
BETTER WORSE SAME

6 How do you think the establishment of the conservancy has influenced :

6.1 The overall livelihood of the group ranch?

BETTER NOW WORSE NOW NO EFFECT

6.2 The health of your livestock?

BETTER NOW WORSE NOW NO EFFECT

6.3 The number of livestock you can keep)

HAVE LESS NOW HAVE MORE NOW NO EFFECT

6.4 The vegetation cover of the group ranch?

BETTER NOW WORSE NOW NO EFFECT

6.5 The species of wildlife you encounter?

BETTER NOW WORSE NOW NO EFFECT

6.6 The overall quality of your grazing areas?

BETTER NOW WORSE NOW NO EFFECT

7 Are there MORE or FEWER wild animals now than there were 20 years ago?

MORE FEWER SAME

7.1 Do you ever kill wildlife? YES / NO

7.2 If yes, why? If no, why not?

7.3 Is it important to you that wildlife is protected? YES / NO

7.3.1 If so, why is wildlife important to protect? (TICK WHERE APPROPRIATE.)

the community gets money from people who study and protect wildlife

wildlife has traditionally been protected and is part of the traditional life

wildlife has spiritual value

wildlife protects our community

we use parts of certain animals for food, or to sell, or to make things

other _____

7.4 If not, why not?

8 What resource conservation groups are in your area? (IF NONE MENTIONED JUST WRITE AWF)

8.1 What does each one do?

9 Do you think they are necessary? YES NO

9.1 What are the benefits of such programs? (CHECK ALL THAT APPLY.)

- we get money from them
 to protect land and water that we need for survival
 to protect wildlife
 other
-

GATHER BASIC HOUSEHOLD INFORMATION.

Name of Respondent _____	Date _____
Group Ranch _____	Settlement centre _____
Gender of respondent M F	Approximate age of respondent _____
# of people in household (including respondent) _____	
Last/highest level of schooling completed by respondent _____	
Approximate number of livestock owned by the family: Goats? _____ Chickens? _____ Donkeys? _____ Cows? _____ Sheep? _____ Camels? _____	
Is respondent the primary decision-maker within the family? YES NO	
Is respondent the primary caregiver for the children? YES NO	

NOTES AND COMMENTS: