

Linkages between Land-use, Land Degradation and Poverty in Semi-Arid Rangelands of Kenya: The Case of Baringo District

BY

Wasonga, Vivian Oliver (B.Sc., M.Sc.)

A thesis submitted to the Board of Postgraduate Studies in fulfilment of the requirements for the degree of Doctor of Philosophy in the Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi

University of NAIROBI Library



0501624 1

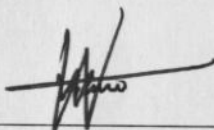
© September, 2009

**UNIVERSITY OF NAIROBI
LIBRARY**

DECLARATION

THIS THESIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY.

SIGNATURE:



DATE:

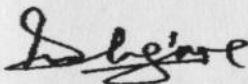
07/09/09

VIVIAN OLIVER WASONGA

Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi

THIS THESIS HAS BEEN SUBMITTED FOR EXAMINATION WITH OUR APPROVAL AS UNIVERSITY SUPERVISORS.

SIGNATURE:



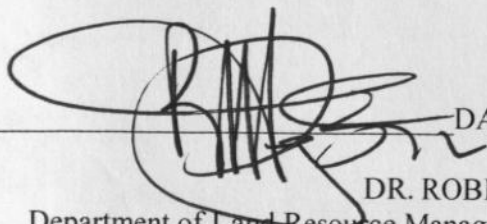
DATE:

01/09/09

PROF. DICKSON M. NYARIKI

Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi

SIGNATURE:



DATE:

01/09/09

DR. ROBINSON. K. NGUGI

Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi

ACKNOWLEDGEMENT

Dear mum and dad, I know you have been waiting for this thesis for so long. I therefore dedicate it to you, Edward and Lorna Wasonga.

I would like to thank my supervisors and mentors Prof. Dickson M. Nyariki and Dr. Kwamboka for their support and guidance that gave rise to this thesis. I owe a lot to Dr. Kwamboka for mentoring me through my M.Sc. programme to date. The quality of his supervision laid the foundation for my Ph.D. study and my career today. I wish to thank Prof. Nyariki for his flexibility and proactive approach to supervision. He spared time to discuss my work, sometimes late in the evening and during weekends. In my view, that was the epitome of modern supervision. It was a great privilege working with him. I feel indebted to my parents who, being teachers motivated me and provided both moral and financial support throughout my studies. I wish to thank my brothers and sisters for their support and presence.

I am greatly indebted to Mr. Philimon Kemel, Mr. Laban Labat and Mr. Josephat Mauna of the Ministry of Agriculture and Livestock Development, Emburu. This project would not have been possible without their support in the field. I express my gratitude to the proprietors who gave me permission to set my experiments and collect soil and vegetation samples in their enclosures. I extend my appreciation and thanks to my field assistant, Peter Ayuel. I wish to thank Mr. Shams and Mrs. Njoro of DRSRS for assisting me in GIS analysis, and Mr. Yvair Muzembi and Ferdinand of the Department of LARMAT for assisting in soil and vegetation analysis.

My gratitude goes to PRINPSIDA and the University of Nairobi for awarding me a PhD scholarship. I also thank EPCS and PINEP for offering me a fellowship at Linköping University in Sweden at the beginning of my PhD programme. This provided me with the much needed opportunity to interact with other PhD students and scientists as well a chance to take a few relevant courses. It is impossible to mention everyone, but to my friends, relatives and all who appreciated in any way towards the success of my PhD course, thank you very much.

I am not more eloquent. I realized that God is all-powerful and bring me this far if He had no intention of taking me through, so thank you God.

ACKNOWLEDGEMENT

My special thanks go to my supervisors and mentors, Prof. Dickson M. Nyariki and Dr. Robinson K. Kinuthia for the excellent tutelage throughout my study. Their comments and criticisms constituted the quality mentorship that gave rise to this thesis. I owe a lot to Dr. Kinuthia for mentoring me through my M.Sc. programme to date. The quality of his supervision laid the foundation for my Ph.D. study and my career today. I wish to thank Prof. Nyariki for his friendly and proactive approach to supervision. He spared time to discuss my work, sometimes late in the evening and during weekends. In my view, that was the epitome of student supervision. It was a great privilege working with him. I feel indebted to my parents who, being teachers motivated me and provided both moral and financial support throughout my studies. I wish to thank my brothers and sisters for their support and patience.

I'm greatly indebted to Mr. Philemon Kemei, Mr. Laban Labatt and Mr. Josephat Maina of the Ministry of Agriculture and Livestock Development, Kabarnet. This project would not have been possible without their support in the field. I express my gratitude to the pastoralists who gave me permission to set my experiments and collect soil and vegetation samples in their enclosures. I extend my appreciation and thanks to my field assistant, Peter Ayabei. I wish to thank Mr. Situma and Mrs. Njino of DRSRS for assisting me in GIS analysis, and Mr. Tirop, Musembi and Ferdinand of the Department of LARMAT for assisting in soil and vegetation analyses.

My gratitude goes to PINEP/SIDA and the University of Nairobi for awarding me a PhD scholarship. I also thank EPOS and PINEP for offering me a fellowship at Linköping University in Sweden at the beginning of my PhD programme. This provided me with the much needed opportunity to interact with other PhD students and scientists as well a chance to take a few relevant courses. It is impossible to mention everyone, but to my friends, relatives and all who contributed in any way towards the success of my PhD course, thank you very much.

Last but most important, I realized that God would never bring me this far if He had no intention of taking me through, so thank you God.

TABLE OF CONTENTS

INTRODUCTION	1
DECLARATION	11
DEDICATION	111
ACKNOWLEDGEMENT	117
LIST OF ABBREVIATIONS	121
LIST OF FIGURES	121
LIST OF TABLES	121
LIST OF REFERENCES	121

'THE LAND DOES NOT LIE'

Land degradation in Baringo District has a long history dating back to late 19th century. ".....A dreary, dusty neighbourhood.....devoid of grass". Rivers flowing into Lake Baringo had "brick red waters" whilst the lake flats were "seamed with deep ruts in every direction". These were comments of Höhnel von (1894) when he arrived in Njemps Flats at the end of a long drought. ".....Agricultural slum of Kenya colony" (Maher, 1937); "ecological emergency area" (RoK, 1974); ".....Lake Baringo is silting up at astonishing rate.....studies indicate that in the near future only a swamp will remain" (de Groot, 1992). These are the kind of phrases that have been used by authors to describe the ecological trends in the Njemps Flats in the last two centuries. When asked whom to blame for the land degradation, an old Il Chamus man gives an answer similar to that of Lowdermilk (1948) that ".....in actual sense, the land does not lie; it bears a record of what a nation and civilization write on it—a record that is easy to read by all of us who understand the simple language of the land. After an 18-month tour of Western Europe, North Africa, and the Middle East to study soil erosion and land-use, Lowdermilk concluded ".....that land degradation in North Africa is due to a change in a people and more especially to a change in culture and methods of use of land that replaced a highly developed and intensive agriculture and that allowed erosion to waste away the land and to change the regime of waters." Baringo is no exception to these worldwide trends, 'let us read together some of the records that have been written on the Njemps Flats through a period of four decades.'

1.1 ORGANIZATION OF THE STUDY	9
CHAPTER TWO	12
2.0 LITERATURE REVIEW	12
2.1 LAND-USE AND LAND DEGRADATION IN PASTORAL ECOSYSTEMS	12
2.2 LAND DEGRADATION AND POVERTY	15
2.3 LAND DEGRADATION AND CHRONOLOGY OF EFFORTS TO COMBAT IT IN KENYA	16

TABLE OF CONTENTS

TITLE.....	i
DECLARATION.....	ii
DEDICATION.....	iii
ACKNOWLEDGEMENT.....	iv
‘THE LAND DOES NOT LIE’.....	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	xii
LIST OF FIGURES.....	xiv
LIST OF PLATES.....	xvi
ACRONYMS AND ABBREVIATIONS.....	xvii
ABSTRACT.....	xx
CHAPTER ONE.....	1
1.0 INTRODUCTION.....	1
1.1 BACKGROUND.....	1
1.2 DEFINITIONS OF LAND-USE, LAND DEGRADATION AND POVERTY.....	2
1.2.1 Land-use and land degradation.....	2
1.2.2 Poverty.....	4
1.3 RESEARCH PROBLEM.....	5
1.4 RATIONALE OF THE STUDY.....	7
1.5 BROAD STUDY OBJECTIVE.....	8
1.6 SPECIFIC OBJECTIVES.....	8
1.7 HYPOTHESES.....	9
1.8 ORGANIZATION OF THE STUDY.....	9
CHAPTER TWO.....	12
2.0 LITERATURE REVIEW.....	12
2.1 LAND-USE AND LAND DEGRADATION IN PASTORAL ECOSYSTEMS.....	12
2.2 LAND DEGRADATION AND POVERTY.....	15
2.3 LAND DEGRADATION AND CHRONOLOGY OF EFFORTS TO COMBAT IT IN KENYA.....	16

2.4 THE ANALYTICAL FRAMEWORK FOR LAND DEGRADATION IN BARINGO DISTRICT	18
2.5 LAND DEGRADATION IN THE SEMI-ARID LOWLANDS OF BARINGO DISTRICT	23
CHAPTER THREE	26
3.0 THE STUDY AREA AND METHODOLOGY	26
3.1 STUDY AREA	26
3.1.1 Location and geo-physical characteristics	26
3.1.2 Climate.....	26
3.1.3 Vegetation.....	30
3.1.4 Soils and water resources	30
3.1.5 Land-use	31
3.1.6 The people	31
3.2 METHODOLOGY	32
3.2.1 Site selection for ecological data collection	32
3.2.2 The semi-nomadic pastoral land-use system (SNL) site	33
3.2.3 The sedentary agro-pastoral land-use system (SAL) site	33
3.2.4 Experimental layout.....	34
3.2.5 Procedure for socio-economic data collection.....	36
3.3 REFERENCES	38
CHAPTER FOUR	47
4.0 SPATIAL AND TEMPORAL RELATIONSHIP BETWEEN LAND COVER, RAINFALL, HUMAN AND LIVESTOCK POPULATIONS IN THE NJEMPS FLATS..	47
4.1 ABSTRACT	47
4.2 INTRODUCTION	47
4.3 METHODS	50
4.3.1 Data collection and analysis.....	50
4.3.1.1 Land cover	50
4.3.1.2 Rainfall data.....	52
4.3.1.3 Livestock population	53
4.3.1.4 Human population	53

4.4 RESULTS AND DISCUSSIONS	54
4.4.1 Land cover trends	54
4.4.2 Rainfall trends.....	63
4.4.3 Livestock population trends.....	67
4.4.4 Human population trends.....	73
4.5 CONCLUSIONS AND RECOMMENDATIONS	77
4.6 REFERENCES	79
5.0.3.3. Degradation of porosity	115
CHAPTER FIVE	83
5.0 A LOCAL PERCEPTIONS ANALYSIS OF THE SOCIO-ECOLOGICAL TRENDS IN THE NJEMPS FLATS	83
5.1 ABSTRACT	83
5.2 INTRODUCTION	83
5.3 METHODS	86
5.3.1 Data collection	87
5.3.2 Data analysis.....	88
5.4 RESULTS AND DISCUSSIONS	88
5.4.1 Livelihood trends	88
5.4.2 Demographic trends.....	90
5.4.3 Climatic and hydrological trends.....	93
5.4.4 Vegetation and soil change dynamics	94
5.4.5 Traditional natural resources management practices.....	98
5.4.6 Local perceptions on land degradation.....	99
5.5 CONCLUSIONS AND RECOMMENDATIONS	101
5.6 REFERENCES	103
7.3 STANDING HERBACEOUS BIOMASS AND COVER	132
CHAPTER SIX	107
6.0 IMPACTS OF LAND-USE ON SOIL PHYSICAL PROPERTIES IN THE NJEMPS FLATS OF BARINGO DISTRICT, KENYA.....	107
6.1 ABSTRACT	107
6.2 INTRODUCTION	107
6.3 SOIL AGGREGATE STABILITY	108
6.4 SURFACE RUN-OFF	109

6.5 SOIL LOSS.....	110
6.6 METHODS.....	112
6.6.1 Data collection.....	112
6.6.1.1 Determination of soil aggregate stability.....	112
6.6.1.2 Measurements of surface run-off and soil loss.....	112
6.6.1.3 Related soil and surface characteristics.....	114
6.6.1.3.1 Determination of soil bulk density.....	114
6.6.1.3.2 Determination of porosity.....	115
6.6.1.3.3 Determination of soil organic carbon.....	115
6.6.1.3.4 Determination of soil texture.....	116
6.6.1.3.5 Measurement of herbaceous cover.....	116
6.6.2 Data analysis.....	117
6.7 RESULTS AND DISCUSSIONS.....	117
6.7.1 Effects of land-use on soil aggregate stability.....	118
6.7.2 Effects of land-use on surface run-off.....	120
6.7.3 Effects of land-use on soil erosion.....	124
6.8 CONCLUSIONS AND RECOMMENDATIONS.....	126
6.9 REFERENCES.....	128
RESULTS AND DISCUSSIONS.....	129
CHAPTER SEVEN.....	131
7.0 EFFECTS OF LAND-USE ON HERBACEOUS BIOMASS PRODUCTION, COVER AND SPECIES DIVERSITY IN THE NJEMPS FLATS, BARINGO DISTRICT, KENYA.....	131
7.1 ABSTRACT.....	131
7.2 INTRODUCTION.....	131
7.3 STANDING HERBACEOUS BIOMASS AND COVER.....	132
7.4 HERBACEOUS SPECIES DIVERSITY AND RICHNESS.....	133
7.5 METHODS.....	135
7.5.1 Data collection.....	135
7.5.1.1 Estimation of herbaceous cover, standing biomass and diversity.....	135
7.5.2 Data analysis.....	137
7.6 RESULTS AND DISCUSSIONS.....	137
7.6.1 Effects of land-use on standing herbaceous biomass production.....	137

7.6.2 Effects of land-use on herbaceous vegetation cover.....	141
7.6.3 Effects of land-use on diversity of herbaceous plants	144
7.7 CONCLUSIONS AND RECOMMENDATIONS	149
7.8 REFERENCES	151
CHAPTER EIGHT	156
8.0 THE DETERMINANTS OF HOUSEHOLD POVERTY IN THE NJEMPS FLATS OF BARINGO DISTRICT, KENYA	156
8.1 ABSTRACT	156
8.2 INTRODUCTION	157
8.3 METHODS	159
8.3.1 Data collection	159
8.3.2 Data analysis	159
8.3.3 Determinants of poverty in the Njemps Flats	159
8.3.4 Description of the hypothesized variables.....	160
8.3.5 Model Specification.....	168
8.3.5.1 Determination of poverty level.....	168
8.3.5.2 Determination of poverty incidence.....	169
8.4 RESULTS AND DISCUSSIONS	170
8.4.1 Descriptive statistics	170
8.4.2 Results of the OLS, WLS regression models	174
8.4.3 Results of the binary logit regression models.....	176
8.5 CONCLUSIONS AND RECOMMENDATIONS	184
8.6 REFERENCES	186
CHAPTER NINE	191
9.0 CONCLUSIONS AND RECOMMENDATIONS	191
9.1 CONCLUSIONS	191
9.2 RECOMMENDATIONS.....	194
9.2.1 Policy implications	194
9.2.2 Further research	196

CHAPTER TEN.....	198
10.0 APPENDICES	198
10.1 APPENDIX I: QUESTIONNAIRE FOR INVESTIGATION OF LOCAL KNOWLEDGE AND PERCEPTIONS IN THE NJEMPS FLATS	198
10.2 APPENDIX II: CHECKLIST FOR FOCUS GROUP DISCUSSIONS AND KEY INFORMANT INTERVIEWS ON SOCIAL AND ECOLOGICAL TRENDS IN THE NJEMPS FLATS DURING THE LAST 40 YEARS.....	204
10.3 APPENDIX III: PROFILE DESCRIPTION OF SOILS IN THE NJEMPS FLATS..	207
10.4 APPENDIX IV: QUESTIONNAIRE FOR INVESTIGATION OF THE DETERMINANTS OF POVERTY IN THE NJEMPS FLATS	210

Table 3.6: Drivers of land degradation at the study area as perceived by local communities.....	99
Table 3.7: Measures to control land degradation suggested by local communities.....	101
Table 6.1: Physical soil and surface cover characteristics at the Njemps Flats.....	117
Table 6.2: Mean soil aggregate stability (30 min-60 and 60min h ⁻¹) soil loss (g m ⁻²) inside and outside enclosures under secondary agro-pastoral and semi-aridic pastoral land-use systems; and in the wet and dry seasons.....	118
Table 6.3: Factors influencing soil aggregate stability in the Njemps Flats.....	119
Table 6.4: Factors influencing soil loss in the Njemps Flats.....	122
Table 6.5: Factors influencing soil loss in the Njemps Flats.....	125
Table 7.0: Mean herbaceous biomass production (g m ⁻² or SE) inside and outside enclosures; under secondary agro-pastoral and semi-aridic pastoral land-use systems; and in the wet and dry seasons.....	138
Table 7.1: Factors influencing herbaceous biomass production in the Njemps Flats.....	139
Table 7.2: Mean herbaceous cover (% ± SE) inside and outside enclosures; under secondary agro-pastoral and semi-aridic pastoral land-use systems; and in the wet and dry seasons.....	142
Table 7.3: Factors influencing herbaceous cover in the Njemps Flats.....	143
Table 7.4: Mean dominant species composition (% ± SE) inside and outside enclosures; under secondary agro-pastoral and semi-aridic pastoral land-use systems; in the wet and dry seasons.....	146

LIST OF TABLES

Table 5.0: Sources of livelihood in the study area	88
Table 5.1: Reasons for the observed trends in livelihoods	90
Table 5.2: Reasons for the observed trends in human and animal populations as perceived by local communities	92
Table 5.3: Reasons for the observed trends in vegetation and soil characteristics	96
Table 5.4: Plant species that have declined in abundance in the past 40 years	97
Table 5.5: Factors that undermine traditional institutions and practices as perceived by local communities	99
Table 5.6: Drivers of land degradation in the study area as perceived by local communities	99
Table 5.7: Measures to combat land degradation suggested by local communities	101
Table 6.0: Physical soil and surface cover characteristics in the Njemps Flats.....	117
Table 6.1: Mean soil aggregate stability (%), run-off and (mm h^{-1}) soil loss (g m^{-2}) inside and outside enclosures; under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems; and in the wet and dry seasons	118
Table 6.2: Factors influencing soil aggregate stability in the Njemps Flats	119
Table 6.3: Factors influencing surface run-off in the Njemps Flats	122
Table 6.4: Factors influencing soil loss in the Njemps Flats	125
Table 7.0: Mean herbaceous biomass production ($\text{g m}^{-2} \pm \text{SE}$) inside and outside enclosures; under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems; and in the wet and dry seasons.....	138
Table 7.1: Factors influencing herbaceous biomass production in the Njemps Flats.....	138
Table 7.2: Mean herbaceous cover ($\% \pm \text{SE}$) inside and outside enclosures; under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems; and in the wet and dry seasons	142
Table 7.3: Factors influencing herbaceous cover in the Njemps Flats	143
Table 7.4: Percent herbaceous species composition ($\% \pm \text{SE}$) inside and outside enclosures; under sedentary agro-pastoral and semi-nomadic pastoral land-use systems; in the wet and dry seasons	146

Table 7.5: Mean Shannon-Weinner diversity index ($H' \pm SE$) and species richness (Mean \pm SE) inside and outside enclosures; under sedentary agro-pastoral and semi-nomadic pastoral land-use systems; in the wet and dry seasons 146

Table 7.6: Factors influencing plant species diversity in the Njempis Flats..... 146

Table 7.7: Factors influencing plant species richness in the Njempis Flats..... 147

Table 7.8: Mean Sørensen’s quotient of similarity ($SC_s \pm SE$) between herbaceous vegetation communities in the two land-use systems and in the wet and dry seasons 147

Table 7.9: Mean Sørensen’s quotient of similarity ($SC_s \pm SE$) between herbaceous vegetation communities inside and outside enclosures, and in the wet and dry seasons..... 147

Table 8.0: A summary of the variables used in the models and descriptive statistics 171

Table 8.1: Factors influencing poverty in SAL: OLS estimation using poverty index as the regressand..... 175

Table 8.2: Factors influencing poverty in SNL: OLS estimation using poverty index as the regressand..... 175

Table 8.3: Factors influencing poverty in SAL: WLS estimation using poverty index as the regressand and herd size as the weighting variable 176

Table 8.4: Factors influencing poverty in SNL: WLS estimation using poverty index as the regressand and herd size as the weighting variable 176

Table 8.5: Factors influencing poverty in SAL: Logit estimation using per capita daily income as the regressand..... 177

Table 8.6: Factors influencing poverty in SNL: Logit estimation using per capita daily income as the regressand..... 178

Figure 4.10: Land cover map for the sedentary agro-pastoral land use system in the Njempis Flats in (a) 2008 and (b) 2000 51

Figure 4.11: Long term (1966 – 2008) mean annual rainfall for Parkera Station in the Njempis Flats 63

Figure 4.12: Long term (1966 – 2008) mean monthly rainfall for Parkera Station 64

Figure 4.13: Long term (1966 – 2008) mean annual rainfall for Snake Park Station 65

Figure 4.14: Long term (1966 – 2008) mean monthly rainfall for Snake Park Station 65

Figure 4.15: Long term (1966 – 2008) total annual rain-days in the Njempis Flats 66

Figure 4.16: Livestock population in the Njempis Flats in 1977, 1986 and 1994 67

Figure 4.17: Livestock population in the semi-nomadic pastoral land-use system in the Njempis Flats in 1977, 1986 and 1994 68

LIST OF FIGURES

Figure 1.0: Thesis plan	11
Figure 2.0: A Driving force-Pressure-Activity-State-Impact-Response (DPASIR) Model for the Njemps Flats.....	21
Figure 3.0: The study area (Njemps Flats).....	27
Figure 3.1: Topographic model of the study area	27
Figure 4.0: Aster image for 2008 (a) and LANDSAT-ETM image for 2000 (b)	51
Figure 4.1: LANDSAT-ETM image for 1986 (a) and 1973 (b)	52
Figure 4.2: Land cover in the Njemps Flats during 1973 – 2008.....	55
Figure 4.3: Land cover under semi-nomadic pastoral land-use system in the Njemps Flats during 1973 – 2008	56
Figure 4.4: Land cover under sedentary agro-pastoral land-use system in the Njemps Flats during 1973 – 2008	57
Figure 4.5: Land cover map for the Njemps Flats in (a) 1986 and (b) 1973	58
Figure 4.6: Land cover map for the semi-nomadic pastoral land-use system site in the Njemps Flats in (a) 1986 and (b) 1973	58
Figure 4.7: Land cover map under the sedentary agro-pastoral land use system in the Njemps Flats in (a) 1986 and (b) 1973	59
Figure 4.8: Land cover map for the Njemps Flats in (a) 2008 and (b) 2000	60
Figure 4.9: Land cover map under the semi-nomadic pastoral land use system in the Njemps Flats in (a) 2008 and (b) 2000	61
Figure 4.10: Land cover map for the sedentary agro-pastoral land use system in the Njemps Flats in (a) 2008 and (b) 2000	61
Figure 4.11: Long term (1966 – 2008) mean annual rainfall for Perkerra Station in the Njemps Flats	63
Figure 4.12: Long term (1966 – 2008) mean monthly rainfall for Perkerra Station.....	64
Figure 4.13: Long term (1966 – 2008) mean annual rainfall for Snake Park Station.....	65
Figure 4.14: Long term (1966 – 2008) mean monthly rainfall for Snake Park Station	66
Figure 4.15: Long term (1966 – 2008) total annual rain-days in the Njemps Flats.....	66
Figure 4.16: Livestock population in the Njemps Flats in 1977, 1986 and 1994	67
Figure 4.17: Livestock population in the semi-nomadic pastoral land-use system in the Njemps Flats in 1977, 1986 and 1994.....	68

Figure 4.18: Livestock population in the sedentary agro-pastoral land-use system in the Njemps Flats in 1977, 1986 and 1994.....	69
Figure 4.19: Livestock density (TLU/km ²) in the Njemps Flats in 1977	70
Figure 4.20: Livestock density (TLU/km ²) in the Njemps Flats in 1986	71
Figure 4.21: Livestock density (TLU/km ²) in the Njemps Flats in 1994	72
Figure 4.22: Human population and number of households in the Njemps Flats in 1973, 1989 and 1999	73
Figure 4.23: Human population density (persons/km ²) in the Njemps Flats in 1979.....	73
Figure 4.24: Human population density (persons/km ²) in the Njemps Flats in 1989.....	75
Figure 4.25: Human population density (persons/km ²) in the Njemps Flats in 1999.....	76
Figure 5.0: Trends of livelihood sources as perceived by local communities	89
Figure 5.1: Human and animal population trends in the Njemps Flats during the last 40 years as perceived by local communities	91
Figure 5.2: Climatic trends during the last 40 years as perceived by local communities.....	94
Figure 5.3: Vegetation and soil change trends in the past 40 years as perceived by local communities	95
Figure 6.0: Soil aggregate stability in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period	119
Figure 6.1: Run-off (mm h ⁻¹) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period.....	122
Figure 6.2: Soil loss (g m ⁻²) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period.....	125
Figure 7.0: Standing herbaceous biomass production in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period.....	138
Figure 7.1: Herbaceous cover in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period.....	143

ACRONYMS AND ABBREVIATIONS

LIST OF PLATES

Plate 3.0: An enclosure of naturally regenerated pasture dominated by <i>Digitaria gayana</i> and <i>Eriochloa meyerianum</i> (background) and adjacent open bare ground (foreground) in Maoi, Njemps Flats	35
Plate 3.1: An enclosure reseeded with <i>Cenchrus ciliaris</i> (background) and adjacent open bare ground (foreground) in Lamalok, Njemps Flats	35
Plate 6.0: The Kamphorst rainfall simulator	113
Plate 6.1: Soil slaking (a) and crusting (b) following rains in the Njemps Flats	123
Plate 10.0: Soil profile pit at Endao	207
Plate 10.1: Soil profile pit at Kaplelechony	209

DRSRF	Department of Resource Surveys and Remote Sensing
EPoS	Environmental Policy and Society
ESRI	Environmental Systems Research Institute
FAO	United Nations Food and Agriculture Organization
FGD	Focus Group Discussions
FSO	Fruit Sale Operators
GEF	Global Environment Facility
GIS	Geographic Information System
GPS	Global Positioning System
GTZ	German Technical Co-operation Agency
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRAF	International Centre for Research in Agroforestry/World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IIDD	International Institute for Environment and Development
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
IPAL	Integrated Project on Arid Lands
IPCC	Intergovernmental Panel on Climate Change

ACRONYMS AND ABBREVIATIONS

ACTS	African Centre for Technology Studies
ALDEV	African Land Development Board
ALRMP	Arid Lands Resource Management Programme
ANOVA	Analysis of Variance
ASAL	Arid and Semi-Arid Lands
BFFP	Baringo Fuel and Fodder Project
BSAP	Baringo Semi-Arid Project
CIAT	International Centre for Tropical Agriculture
DPASIR	Driving forces-Pressure-Activity-State-Impact-Response
DRSRS	Department of Resource Surveys and Remote Sensing
EPOS	Environmental Policy and Society
ESRI	Environmental Systems Research Institute
FAO	United Nations Food and Agriculture Organization
FGD	Focus Group Discussions
FSO	Front Seat Observers
GEF	Global Environment Facility
GIS	Geographic Information System
GPS	Global Positioning System
GTZ	German Technical Co-operation Agency
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRAF	International Centre for Research in Agroforestry/World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
IPAL	Integrated Project on Arid Lands
IPCC	Intergovernmental Panel on Climate Change

ISO	International Organization for Standardization
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for Conservation of Nature and Natural Resources/World Conservation Union
JICA	Japanese International Co-operation Agency
KARI	Kenya Agricultural Research Institute
KLDP	Kenya Livestock Development Programme
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KREMU	Kenya Rangeland Monitoring Unit
LANDSAT-ETM	Land Satellite-Enhanced Thematic Mapper
LARMAT	Department of Land Resource Management and Agricultural Technology
LM	Lower Midland
LPM	Linear Probability Model
LUCID	Land-Use Change Impacts and Dynamics
LULCC	Land-Use and Land Cover Change
MLE	Maximum Likelihood Estimation
MOARD	Ministry of Agriculture and Rural Development
MRDASAW	Ministry of Reclamation and Development of Arid and Semi-Arid Areas and Wastelands
NGO	Non Governmental Organization
NRCS	Natural Resources Conservation Service
ODI	Overseas Development Institute
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PANESA	Pasture Network for Eastern and Southern Africa
PARIMA, GL-CRSP	Pastoral Risk Management, Global Livestock Collaborative Research Support Program
PINEP	Pastoral Information Network Programme
PSIR	Pressure-State-Response
RAE	Rehabilitation of Arid Environments
RELMA	Regional Land Management Unit

RMH	Range Management HandBook
ROK	Rebuplic of Kenya
RSO	Rear Seat Observers
SAL	Sedentary Agro-Pastoral Land-use
SAREC	Swedish Agency for Research Cooperation with Developing Countries
SCOPE	Scientific Committee on Problems of the Environment
SIDA	Swedish International Development Cooperation Agency
SNL	Semi-Nomadic Pastoral Land-use
SRF	Systematic Reconnaissance Flight
TLU	Tropical Livestock Unit
TSBF	Tropical Soil Biology and Fertility Programme
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UNSO	United Nations Development Programme's Office to Combat Desertification and Drought
USDA	United Sates Department of Agriculture
WDCD	World Day to Combat Desertification
WLS	Weighted Least Squares

ABSTRACT

Rangeland degradation and impoverishment of pastoral communities are worldwide problems that are closely linked to land-use activities. An explicit understanding of the links between land-use, land degradation and poverty is, therefore, key to targeting and prioritizing options for conserving rangelands and improving pastoral livelihoods. This study was conducted in the Njemps Flats, a semi-arid rangeland in Baringo District of Kenya to: a) determine the temporal and spatial interrelationship between land cover, land-use, rainfall variability; and human and livestock populations; b) determine the effects of land-use on soil physical properties; c) determine the impacts of land-use on herbaceous standing biomass, cover and diversity; c) assess the potential of enclosures to restore degraded semi-arid rangelands; and d) identify the determinants of household poverty in the study area. The study area was divided into two sites based on the dominant land-use types—semi-nomadic pastoral and sedentary agro-pastoral land-use systems. Socio-economic data were collected from the two land-use systems using a questionnaire and group discussions. Ecological data were collected randomly at four points in each of the six paired plots located in each of the two land-use sites. Sampling was carried out at the peak of the wet (April) and dry (January) seasons, and at the end of wet (June) and dry (February) seasons. This was repeated to capture two wet and two dry seasons during the 2005 – 2006 study period. Secondary data were obtained from the Kenya National Bureau of Statistics (KNBS), Department of Resource Surveys and Remote Sensing (DRSRS) and Kenya Meteorological Department (KMD) in Nairobi.

The geo-spatial analysis of the Njemps Flats landscape shows a close link between the declining herbaceous cover and rising human and livestock populations. The difference in vegetation structure between the two land-use systems is evident with the sedentary agro-pastoral land-use system showing an increase in closed woodland as opposed to increase in bare ground with scattered shrubs under the semi-nomadic pastoral land-use system. The expansion of the area under closed woodland is partly attributed to the invasion of the study area by *Prosopis juliflora*, an alien species introduced in the 1980s. While the mean annual rainfall showed high variability and a slight increase between 1966 and 2008, the total number of rain-days declined over the same period.

Soil aggregate stability was significantly higher ($P \leq 0.05$) under semi-nomadic pastoral land-use system (4.18 ± 0.92 %) than in sedentary agro-pastoral land-use system (1.01 ± 0.25 %). Surface run-off was found to be significantly lower ($P \leq 0.05$) in semi-nomadic pastoral land-use system (1120 ± 54.92 mm h⁻¹) than in sedentary agro-pastoral land-use system (1326 ± 54.45 mm h⁻¹). Soil erosion was significantly higher ($P \leq 0.05$) in sedentary agro-pastoral land-use system (992 ± 81.69 g m⁻²) than in semi-nomadic pastoral land-use system (365 ± 46.21 g m⁻²). Herbaceous cover was significantly higher ($P \leq 0.05$) under semi-nomadic pastoral land-use (36.8 ± 2.50 %) than under sedentary agro-pastoral land-use (26.6 ± 2.54 %). However, land-use system did not have significant influence ($P \leq 0.05$) on herbage production and herbaceous plant diversity. Although enclosures did not affect soil aggregate stability and herbaceous species diversity, run-off was significantly higher ($P \leq 0.05$) outside (1390 ± 58.79 mm h⁻¹) than inside (1056 ± 42.28 mm h⁻¹) enclosures. Soil loss was twice as high ($P \leq 0.05$) in the open grazing areas (905 ± 77.47 g m⁻²) as inside enclosures (452 ± 69.35 g m⁻²). Enclosures had significantly higher ($P \leq 0.05$) herbaceous biomass (131.9 ± 7.11 %) than the open grazing areas (72.9 ± 5.62 %). Similarly, herbaceous cover was found

to be significantly higher inside the enclosures ($37.8 \pm 2.66 \%$) than in the adjacent open areas ($25.6 \pm 2.27 \%$).

The parametric estimates of the determinants of poverty indicate that the number of livelihood sources, herd splitting, distance to pasture, ownership of enclosure, and age of the household head, household size, distance to nearest market and relief food are the most important determinants of poverty in the Njemp's Flats. The number of livelihood sources, distance to pasture and age of the household head were found to be positively related to per capita daily income. The households that practiced herd splitting were better off than those which did not. However, in contrast to the *á priori* expectation, a negative relationship was observed between per capita daily income and household size and ownership of enclosure in sedentary agro-pastoral system. The distance to nearest market and relief food had negative influences on poverty level.

The results of the current study depict land-use system and associated human and livestock population pressure as the major determinants of vegetation cover, surface run-off, soil erosion, and species richness. However, the positive relationship between rainfall and the vegetation dynamics underscores the disequilibrium state of the semi-arid pastoral ecosystems. These results also indicate that enclosure system is an effective way of restoring degraded semi-arid environments. Despite living in more degraded environments, settled pastoralists were found to be wealthier than the nomadic ones, implying that poverty decreased with the increase in sedentarization and land degradation. This scenario is explained by the enhanced diversification of livelihoods among settled pastoral households compared to their semi-nomadic counterparts. This study recommends use of enclosures to reverse range degradation, and diversification of pastoral economies to reduce poverty and relieve pressure on land as the primary source of livelihood in the semi-arid rangelands of Kenya.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Global concerns regarding changes in land-use and land cover have emerged due to the realization that land surface processes influence climate and impact on ecosystem goods and services (Maitima *et al.*, 2004; Sivakumar and Ndiang'ui, 2007). The impacts that have been of primary concern are the effects of land-use change on biological diversity, soil degradation, and the ability of biological systems to support human needs. The impacts of land degradation on global food security and the quality of the environment are of major concerns when one considers that only about 11% of the global land surface can be considered as prime land, yet this must feed the 6 billion people inhabiting the world today and the 8.2 billion expected by the year 2020 (Sivakumar and Ndiang'ui, 2007). In pastoral areas, grazing lands have become less and less productive resulting from land-use intensification due to population pressure and overstocking. Conflicts over the use of land have increased due to increased demand for land by different sectors of the economy (Young *et al.* 2009).

The transformation of traditional land-use systems in the arid and semi-arid lands (ASAL) to meet the demands of dynamic economies and escalating human populations, and the inherent climatic variabilities are responsible for the negative consequences on the natural environment and livelihoods of most of the world's rural populations. The growing population combined with limited land availability in the agriculturally productive highlands have led to increasing immigration to marginal areas in spite of their ecological limitations. Since these marginal and moisture deficit regions are vulnerable to the increased population, the exerted pressure has often resulted in severe degradation of land, soil erosion and sedimentation of open water bodies. Cumulatively, changes have decreased biological diversity, biotic potential, and the quality of water resources over a variety of scales (Jones *et al.*, 2001; Turner *et al.*, 1990).

Land-use, land degradation and poverty have become major concerns worldwide than ever before. Land degradation in pastoral Africa has been largely attributed to climatic variability and human actions, which include the direct effects of land-use activities and wider political and structural changes that cause disruption and changes to previously successful traditional land-use systems (Thomas, 1998). Among the direct human causal factors are over-cultivation, overgrazing, deforestation, and poor irrigation practices. Such practices are generally caused by economic and social pressure, ignorance, war, and drought (UNCCD, 2003a). Landscapes throughout the world undergo transformation processes that include some form of natural degradation, but these processes are usually compensated for and counterbalanced by nature's inherent recovery ability. Net degradation occurs whenever the degradation processes significantly exceed nature's restorative capacity (UNCCD, 2003a).

1.2 DEFINITIONS OF LAND-USE, LAND DEGRADATION AND POVERTY

1.2.1 Land-use and land degradation

Land-use and land-cover change (LULCC) also known as land change is a general term for the human modification of earth's terrestrial surface (Ellis, 2007). Though humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of LULCC are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. These changes encompass the greatest environmental concerns of human populations today. Land-use refers to the social and economic purposes for which land (or water) is managed, such as grazing, timber extraction, conservation, irrigation, and farming (UNEP, 2008). Paré (2008) defines land-use as the intention underlying anthropogenic exploitation of land cover, while land cover refers to the biophysical state of the earth's surface and immediate sub-surface, e.g., biota, surface water, ground water, soil, topography, and human structures. Land-use is characterized by the arrangements by activities and inputs people undertake in certain land cover type to produce, change or maintain it. Land-use system is therefore defined as a specified land utilization type practiced on a given land unit, and associated with inputs, outputs and possibly land improvement (Choudhury and Jansen, 1999). On the other hand, land degradation is defined as the reduction of resource potential by one or a combination of processes acting on the land, such as soil erosion by wind and/or water;

deterioration of the physical, chemical, and biological or economic properties of soil; and long term loss of natural vegetation (Sivakumar and Ndiang'ui, 2007; UNEP/GEF, 2005; UNCED, 1992).

Land degradation, like the term desertification, has been defined in a multitude of contradictory ways (Dahlberg, 1994). As Behnke and Scoones (1992) point out, a clear definition of this term is, however, important both because the issue of land degradation is emotionally charged and because the meaning which is ascribed to the term largely determines the choice of the diagnostic criteria that are used to measure its occurrence. According to UNCED (1992), UNEP/GEF (2005), and Toulmin (1993), desertification is a form of land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Another allied term, range degradation is generally equated with the long-lasting or permanent loss of rangeland productivity. Blaike (1989) define rangeland degradation as an effectively permanent decline in the rate at which land yields livestock products under a given system of management. 'Effectively' means that natural processes will not rehabilitate the land within a time scale relevant to humans, and that capital or labour invested in rehabilitation is not justified (Behnke and Scoones, 1993). This definition of degradation excludes reversible vegetation changes even if these lead to temporary declines in secondary productivity. It includes effectively irreversible changes in both soils and vegetation.

Nelson (1988) in his definition of land degradation, though concurs that degradation reduces productive potential to an extent which can neither be readily reversed by removing the cause nor easily reclaimed without substantial investment, points out that even severely stressed land can revert to a less degraded state, given enough time. Definition of land degradation should, however, be broadened to include man-induced decreases in productivity if they have a lasting impact on productivity. This introduces some additional important points, namely that declining productivity can only be judged in relation to a specified land-use, and that damage to the environment must be related to the cost of rehabilitation. Long term effects of land degradation and, in particular, the reversibility of land degradation processes and the resilience of ecosystems are, however, subject to debate. As noted by Steinfeld *et al.* (2006), the reversal of the land degradation process often requires substantial investments, which may fall beyond investment capacity or not grant

satisfactory return under current economic conditions. Several other concepts are important to these definitions: sustainability or the ability of the land to continue to produce indefinitely; resilience or that quality of a resource that makes it sustainable or resistant to degradation; and carrying capacity or the number of people and animals the land can normally support without being significantly stressed.

It is clear that while the magnitude of the problem is widely shared, there are a number of definitions for land degradation, interpreted in different ways among various disciplinary groups. However, it is important to look at land degradation from both ecological and socio-economics point of view. The foregoing views notwithstanding, this study incorporates the definition by Biot (1991). He emphasizes the role played by economics, and defines land degradation as “an environmental process which occurs when the ability of the land to produce the goods and/or services people demand from it are found to be declining”. The current study has adopted the definition by ISO (1996) that a degraded land is one that due to natural processes or human activity is no longer able to properly sustain an economic function and/or the original natural ecological function.

Behnke and Scoones (1993, 1992) list the soil indicators of range degradation as decreased soil fertility, decreased water holding capacity, decreased infiltration, and soil loss significantly in excess of soil formation. Vegetation indicators include changes in vegetation productivity over time that are unrelated to rainfall patterns, changes in vegetation cover, changes of plant species composition of use to animals, and shifts between vegetation transition states that result in decreased fodder (e.g. severe bush encroachment).

1.2.2 Poverty

Poverty is a multidimensional phenomenon, which requires the use of a number of measures and definitions to adequately understand. Absolute poverty can be narrowly defined as “the sustained lack or deficiency of basic needs required to sustain human life”. Those falling below an overall or absolute poverty line constitute the poor, where the poverty lines are based on the cost of purchasing a basket of basic food items representing the amount of calories sufficient for survival (a daily allowance of 2, 250 calories per adult) and of essential non-food items, such as clothing, shelter and transport (RoK, 2005). The new

poverty line released by the World Bank is US\$1.25 per capita per day (Chen and Ravallion, 2008). People's perception of poverty is, however, widely varied among communities, societies and environment.

Land-use activities, land degradation and impoverishment of pastoral households are interlinked and have direct influence on sustainable development. Therefore, the answer to sustainable use and management of natural resource base and improved pastoral livelihoods lies in the understanding of the linkages between land-use, land degradation and poverty.

1.3 RESEARCH PROBLEM

Rangeland degradation and impoverishment of pastoral communities are worldwide problems that are closely linked to land-use activities. Land degradation has increasingly attracted attention in the recent past than before, probably because of its global dimensions and the very fact that it undermines the United Nations' Agenda 21—a multifaceted blue print for achieving sustainable development worldwide. As indicated in Article 1 of the UNCCD, it is a global crisis directly affecting a third of the earth's land surface and the livelihoods of about two billion people who depend on land for most of their needs, largely the world's poorest (UNEP/GEF, 2005; Millenium Ecosystem Assessment, 2003). Despite being a global concern, land degradation is more pronounced in Africa, where two-thirds of the continent is desert or dryland. According to UNCCD (2003a), land degradation in dryland regions has continued to worsen over the past two decades. Steinfeld *et al.* (2008) reported that an estimated 20% of the total land used for livestock production is being degraded by grazing activities, and 70% of land degradation occurs in arid regions. Reduction of land productive potential, though locally linked to destructive human activities, is also associated with human-induced global warming and climate change on a worldwide scale (Millenium Ecosystem Assessment, 2003; IPCC, 2007, 2001; Thomas, 1998; UNCCD, 2003b). These trends have prompted the need for better understanding of the causal pathways, and to develop more effective approaches to sustainable management of the vast dryland ecosystems.

Kenya's rangelands, which are either arid or semi-arid, are no exception to the widely documented threat of land degradation. The rangelands of Kenya cover over 80% of total

land surface (Nyariki *et al.*, 2005; Kiriro, 2003; Herlocker, 1999; Pratt and Gwynne, 1977). These areas support more than 30% of the national human population, mostly pastoralists who depend directly on the natural resource base for their livelihoods, and over 60% of the country's livestock (RoK, 2002a; RoK, 1997). Besides being the main water catchments, they also provide habitat for over 67% of the wildlife—the stronghold of Kenya's tourism industry (Herlocker, 1999). Unfortunately, as indicated by various authors, most arid and semi-arid districts in Kenya such as Marsabit (Keya, 1998), Kajiado (Krugmann, 1996), and Baringo (Meyerhoff, 1991; de Groot *et al.*, 1992; Onyando *et al.*, 2005; Johansson and Svensson, 2002), are undergoing land degradation.

The Njemps Flats of Baringo District provide a good example of the problems faced in most marginal semi-arid areas in Kenya as well as Africa. Constant water shortages and environmental deterioration restrict local people's primary livelihoods (Tokida, 2001). Land degradation in the rangelands of Baringo may have started in the 1920s (Otieno and Rowntree, 1986), but only received attention after the droughts of the 1930s and 1940s, which triggered contentious debates on environmental degradation in the northern Kenya rangelands. The colonial government responded with the installation of the World Bank funded Arid Lands Development (ALDEV) and later Kenya Livestock Development Programme (KLDP) (RoK, 2002b), which introduced controlled grazing schemes, culminating in the first ten-year development plan (1946-1955) aimed at rehabilitating the rangelands (Onyando *et al.*, 2005; Migot-Adholla and Little, 1981; Dietz, 1987). However, the concern over environmental deterioration re-emerged in the 1970s, when Baringo was described in the District's Development Plan as an 'ecological emergency area' (Meyerhoff, 1991; de Groot *et al.*, 1992). Since then, the District has permanently become a target for ASAL intervention programmes, with various organizations getting involved in land rehabilitation, notably, the Rehabilitation of Arid Environments (RAE), formerly Baringo Fuel and Fodder Project (BFFP), and Baringo Semi Arid Project (BSAP) (Onyando *et al.*, 2005; Kipkorir, 2001; Meyerhoff, 1991). The rangelands of Baringo, as observed by Meyerhoff (1991), have been experiencing frequent famines and droughts, and relief food has become commonplace in the area.

1.4 RATIONALE OF THE STUDY

Besides time-long interventions, the state of Njemps Flats has triggered several studies, some of them describing the current plight of the pastoralists (Mango *et al.*, 2004; Onyando *et al.*, 2005; Crawley, 1999, 2001; Kipkorir, 2002, de Groot *et al.*, 1992; Meyerhoff, 1991), while others exploring landscape change dynamics in the Lake Baringo Basin (Kiage *et al.*, 2007; Mwasi, 2004; Johansson and Svensson, 2002; Tarras-Wahlberg, 2003; Odada and Olago, 2004). All of these studies point out the on-going land degradation, and blame overgrazing and drought for the range condition trend in Baringo. However, none of them has attempted to analyse the interplay between the various factors that are believed to be driving the process in the area. Also, studies on the nexus of land-use, land degradation and poverty have been lacking or weak at their best.

In an attempt to bridge the apparent gap in knowledge, the current study adopted the systems approach to establish the long-term socio-ecological trends, current range condition and the determinants of household poverty in the semi-arid Njemps Flats of Baringo District, Kenya. Satellite images were used to analyse changes in land-use and land cover in the study area during the last four decades. Long-term rainfall, human and livestock populations data were used to analyse time trends during the same period. The study also made use of local knowledge to explore perceptions on ecological and socio-economic trends in the study area in the past 40 years. Through ground measurements, the study examined the current condition of the vegetation and soil with respect to land-use system. To determine the potential of enclosures in reclamation of degraded land, soil and vegetation attributes were assessed inside and outside enclosures. In order to identify the determinants of poverty, data were collected on selected attributes that were perceived to reflect the social and economic well-being of pastoral households.

1.5 BROAD STUDY OBJECTIVE

The overall objectives of this study were to: a) explore the social and ecological trends in the semi-arid rangelands of Baringo over the last four decades; b) assess the current condition of the range with respect to land-use; c) determine the potential of enclosures to restore degraded rangelands; and d) identify the determinants of household poverty in the study area. The main objectives of this study were to attempt to answer the following research questions:

- a) Does land-use degrade the soil and vegetation in the Njemps Flats? If yes, what are the indicators?
- b) Does the knowledge of the local communities in the Njemps Flats have the potential to compliment the conventional socio-ecological historical data?
- c) How does land-use and land cover dynamics relate to long-term rainfall, human and livestock population trends in the study area?
- d) What possibilities exist for the restoration of degraded grazing lands through enclosures in the Njemps Flats?
- e) What are the determinants of household poverty in the study area?
- f) What are the available options or opportunities for conserving the environment at the same time reducing poverty of pastoral households in the study area?

1.6 SPECIFIC OBJECTIVES

In order to answer the above research questions, the specific objectives of this study were to:

1. Assess the longitudinal relationship between land-use and land cover, rainfall, human and livestock populations using GIS techniques.
2. Determine the social and ecological trends in the Njemps Flats during the last four decades using local knowledge and perceptions.
3. Assess the effects of land-use and enclosures on soil aggregate stability, run-off and soil loss, as indicators of physical degradation of soils in the Njemps Flats.
4. Determine the impacts of land-use and enclosures on herbaceous biomass production, cover and species diversity as indicators of vegetation degradation in the study area.
5. Identify the determinants household poverty in the Njemps Flats.

1.7 HYPOTHESES

The current study was based on the hypotheses that:

1. The landscape change dynamics observed in the Njemps Flats during the last 40 years are related to land-use, demographic factors and rainfall variability.
2. Pastoral communities in the Njemps Flats possess a wealth of knowledge that can be used to compliment conventionally generated information.
3. Soils under sedentary agro-pastoral system are more susceptible to physical degradation than those under semi-nomadic pastoral land-use system.
4. Enclosures reduce soil susceptibility to erosion and restore vegetation productivity, cover and diversity.
5. The current vegetation characteristics in the Njemps Flats reflect the dorminant land-use systems in the area.
6. There is a positive feedback linkage between land-use, land degradation and poverty in the Njemps Flats.

1.8 ORGANIZATION OF THE STUDY

The presentation of this study is divided into eight chapters (Figure 1.0). The first chapter presents the general background information to the study concerning the trends in land-use and land degradation as a consequence. In this chapter, land-use, land degradation and poverty are defined and the links between them introduced. Chapter One also presents the research problem under investigation, objectives and hypotheses. Literature reviewed, the conceptual and analytical frameworks adopted for this study are presented in Chapter Two. The description of the study area and general procedure used for selecting the sample populations for the ecological and socio-economic data collection is presented in Chapter Three. Chapters Four, Five, Six, Seven and Eight present the abstracts, introductions, methodologies and results of analyses and interpretations of the data sets collected under the above five study objectives. Chapter Nine summarises the findings of this study and gives conclusions, policy implications and further research needs based on the major findings.

Chapter Four presents a geo-spatial analysis of the longitudinal relationship between land-use, land cover, rainfall, human and livestock populations in the Njemps Flats. Indicators of land degradation (changes in land-use and land cover) were determined through analyses of remotely sensed data and other secondary data to obtain the following: i) trends in spatial and temporal ground cover for different vegetation classes; ii) trends in human and livestock populations; and iii) rainfall trends during the last four decades. In this chapter, the hypothesis that the land cover trend in the study area is closely linked to rainfall variability, human and livestock populations was tested. In Chapter Five, social and ecological trends observed in the lowlands of Baringo District over the last four decades are documented. This chapter is based on information gathered through interviews and discussions on the general changes in the environment and perceptions of the local communities on the observed dynamics. The chapter tests the hypothesis that the social and ecological change dynamics in the Njemps Flats are interlinked, and that local knowledge and perceptions corroborate the conventional information on the trends.

The hypothesis that soil physical properties are likely to be better under semi-nomadic pastoral land-use system than in the sedentary agro-pastoral system, was tested in Chapter Six. Also tested in this chapter was the hypothesis that enclosures improve the soil physical properties. Key physical soil fertility indicators including aggregate stability, soil loss and surface run-off were determined. In Chapter Seven, the hypothesis that vegetation productivity, cover and diversity are a reflection of the dominant land-use of a given area was tested. The hypothesis that enclosures improve vegetation productivity, cover and diversity was also tested in this chapter. In Chapter Eight, the hypothesis that there is a positive feedback linkage (downward spiral relationship) between land-use, land degradation and poverty was tested. In this chapter, determinants of poverty in the Njemps Flats were identified.

Chapter Nine is a general discussion that summarises the research findings and conclusions from all the chapters, and sums up the understanding of the socio-ecological processes in the semi-arid lowlands of Baringo. This chapter also provides suggestions for future research directions. Also presented in this chapter are the general implications of changes in land-use, land cover, and land degradation for the future viability of pastoral production systems in Baringo and similar semi-arid rangelands in Kenya.

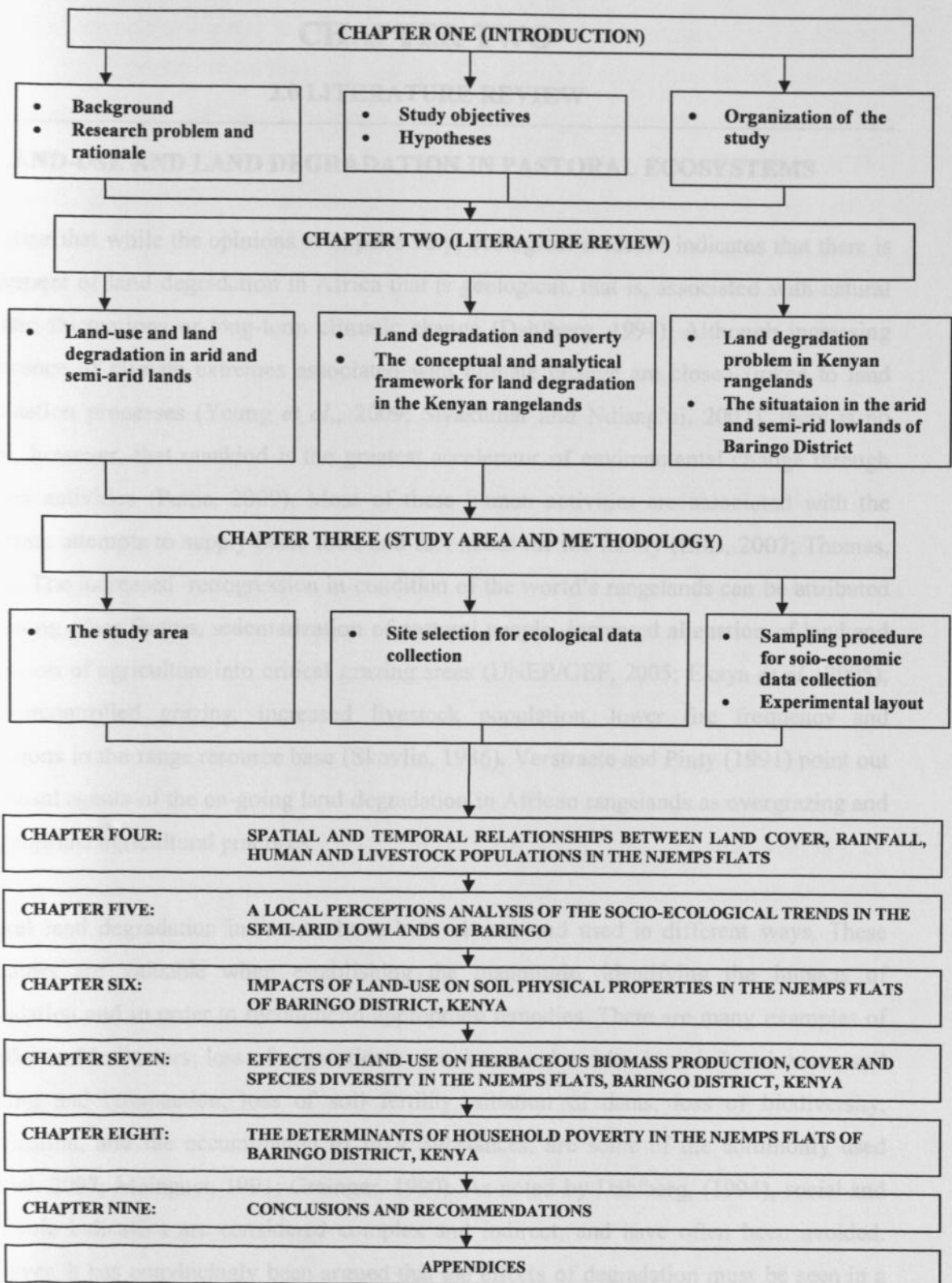


Figure 1.0: Thesis plan

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 LAND-USE AND LAND DEGRADATION IN PASTORAL ECOSYSTEMS

It is clear that while the opinions of experts vary, ecological evidence indicates that there is an element of land degradation in Africa that is geological, that is, associated with natural climatic fluctuations or long-term climatic change (Dahlberg, 1994). Although increasing occurrence of climate extremes associated with climate change are closely linked to land degradation processes (Young *et al.*, 2009; Sivakumar and Ndiang'ui, 2007), there is no doubt, however, that mankind is the greatest accelerator of environmental change through various activities (Pattie, 2009). Most of these human activities are associated with the desperate attempts to supply basic food and fuel needs for the family (Ellis, 2007; Thomas, 1986). The increased retrogression in condition of the world's rangelands can be attributed to, among other factors, sedentarization of pastoral people, increased alienation of land and expansion of agriculture into critical grazing areas (UNEP/GEF, 2005; Ekaya *et al.*, 2005); and uncontrolled grazing, increased livestock population, lower fire frequency and reductions in the range resource base (Skovlin, 1986). Verstraete and Pinty (1991) point out the causal agents of the on-going land degradation in African rangelands as overgrazing and inappropriate agricultural practices.

Several land degradation indicators have been chosen and used in different ways. These indicators are valuable when establishing the magnitude, identifying the impacts of degradation and in order to recommend appropriate remedies. There are many examples of bio-physical indicators; loss of vegetation cover, increased erosion by wind and water, soil crusting and compaction, loss of soil fertility, siltation of dams, loss of biodiversity, salinization, and the accumulation of toxic substances, are some of the commonly used (Safriel, 2007; Mainguet, 1991; Grainger, 1990). As noted by Dahlberg, (1994), social and economic indicators are considered complex and indirect, and have often been avoided. However, it has convincingly been argued that the effects of degradation must be seen in a broader context, constituting "a complex phenomenon embracing physical and biological aspects, including the human and social dimensions" (Mabutt, 1986).

When land degradation occurs, the land loses its biodiversity thus weakening the ecological linkages (Ellis, 2007). The ability of land to raise pasture, crops and wood is lost and carrying capacity of the land is reduced leading to loss of ecosystem functions. It has immediate and long-term socio-economic consequences on the affected populations. The common features of land degradation in world rangelands include deterioration in quality and quantity of pasture, generally associated with a diminution of cover and invasion of woody species with no pastoral value. Other important indicators are structural changes in vegetation cover, notably the loss of trees; changes in soil surface properties, leading to deterioration of soil-plant-water relationships; and accelerated wind and water erosion and eventual exposure of barren hard soil which cannot support vegetation (RoK/UNEP, 1997).

Most experts blame deterioration of rangelands on the changing socio-economic and demographic trends. These changes are believed to have completely altered the fragile balance of traditional grazing patterns, which are based on conventional wisdom of the local ecology. Gintzburger (1986) argues that through the realignment of political and administrative boundaries, the development of forest reserves and national parks, the establishment of commercial ranches, there has been a restriction of the movement of nomadic people and a reduction of the land they formerly occupied. Traditional antagonisms between tribes are also blamed for further compression of some tribal groups into a fraction of their former ranges for fear of tribal raiding. Another distinctive feature, probably the most important, is the burgeoning human population, which is seen as a major reason for the reduced human support capacity of the Kenya's arid lands. The human population pressure in Kenyan rangelands is further aggravated by immigrations from high potential areas (Campbell *et al.*, 2003; Kristjanson *et al.*, 2002; Krugmann, 1996). Human population growth has also been accompanied by an increase in livestock numbers exerting pressure on the grazing resource (de Leeuw and Tothill, 1990). Other trends of far reaching consequence for land-use include the excessive demand on woody vegetation for house construction, cattle enclosures and fuel; sedentarization of population into centers of human and livestock concentrations; and periodic droughts.

Despite nomadism being considered a sort of natural rational grazing system, overstocking, encouraged by factors such as the provision of new water points and sedentarization, has resulted in widespread deterioration of rangelands (Musimba and Nyariki, 2003; Herlocker,

1999). There are differing views among experts as to whether nomadism or settlement is the best for the pastoralists and their natural resources. It is obvious that each has advantages and drawbacks depending on how each of them is practiced. Degradation of the rangelands in Kenya has been ascribed to centuries of uncontrolled heavy grazing, but recent examinations suggest that significant damage to the range resource began around the turn of the century. As noted by Lusigi (1986) and Sanford (1983), in the past there was a relative equilibrium between the carrying capacity and stocking rate on rangelands. When rangelands were overstocked, in a self-regulating manner, nature intervened mainly through droughts and diseases and led to reduction of livestock population. This pattern has changed as a result of increased availability of water from the newly established water points and introduction of veterinary services. The result is a tremendous increase in livestock numbers and widespread overgrazing in the nomadic areas in arid and semi-arid rangelands (Lusigi, 1986).

Sandford (1983), like other protagonists of nomadic pastoralism, argues that in African rangelands, pastoral systems based on the communal use of land are no more destructive of resources and produce more food per unit area than any other animal based arid land-use system. He further notes that communal use of land is not "free for all" that many people think it is, and that communal grazing areas are generally divided into specific grazing territories, each with its own rights of access and set of water points, and various controls are maintained on inter-area movements. The goods and services produced from the communal areas, he adds, compare favourably with production from the large-scale commercial sector.

Although pastoral nomadism is considered environmentally sound, mounting pressure on Kenya's remaining pastoral rangeland makes it clear that the grazing resource can no longer be maintained by traditions of seasonal use. Permanent homesteads are increasing in favour of migration, except under drought conditions and in very arid areas. The problem of deterioration of Kenya's rangelands is therefore a very complex phenomenon. It concerns the plight of people who are using the only traditional means they have known to cope with a vast problem that has been caused to a great extent by modern influence. Human and animal population pressures are forcing unacceptable levels of land-use because social re-

organization is not keeping pace with improvements in health and veterinary services (O'brien, 1986).

From the foregoing, it can be deduced that deterioration of the rangelands observed in Kenya cannot be attributed to lack of proper strategies for range utilization, but rather to modern developments that initiate a chain of both social and bio-physical processes. The complexity of the cause-effect phenomenon in the processes of land degradation calls for understanding of the linkages that constitute the entire ecosystem.

2.2 LAND DEGRADATION AND POVERTY

Processes that lead to land degradation involve complex interactions between societal factors, such as poor land management and increasing population pressures, and natural climatic factors such as cyclical, short-term droughts (UNCCD, 2003a). Land degradation reduces the land's resilience to natural climate variability with both physical and socio-economic consequences. It is considered a major global environmental issue largely because of the link between dryland degradation and food production. It is likely that if the process of land degradation is not stopped and reversed, food yields in many affected areas will decline and malnutrition, starvation and ultimately famine may result. UNCCD (2003b) indicates that famine typically occurs in areas that also suffer from poverty. The World Bank (1990) defines poverty as the inability to attain a minimal standard of living and housing. There exist pre-determined standard levels of consumption (poverty lines) below which one is deemed poor. Food poverty is defined by Seaman *et al.* (2000) as a condition of lacking the resources to acquire a nutritionally adequate diet. However, other than food, there are several goods and services from the natural ecosystems that are crucial for the livelihoods of the rural poor. These include fuelwood, timber, medicine, cultural values, among others. Loss of these goods and services through land degradation equals loss of livelihoods, and therefore poverty.

While it is common knowledge that human actions are responsible for the process of land degradation, the big question is whether the pastoralists' current activities on land are by their own choice. If no, then what are the reasons underlying their actions? Human adaptations are seen to be the hub of functionality of the rangeland ecosystems, and constraints to these survival strategies form the basis for change in both the environment and societal welfare. The argument is that when survival strategies such as mobility is curtailed,

pastoralists are compelled by poverty to overexploit the grazing resources thereby inducing land degradation. According to UNCCD (2003b) there is a positive feedback between poverty and the processes of land degradation, through diminution of land capacity to produce, the latter causes poverty among the communities which rely on the land for their livelihoods. Land degradation is thus perceived as both the cause and consequence of poverty, and any effective strategy aimed at checking it must address poverty at its very centre and take into account the social structures (ICARDA/ICRISAT, 2002; Ekbom and Bojo, 1999; Millenium Ecosystem Assessment, 2003; IFAD, 2002).

Fouad (1993) and Umar (1997) reckon that land degradation contributes significantly to water scarcity, famine, internal displacement of people, migration, and social breakdown. There is now increased awareness of the relationship between land degradation, movements of people, and conflicts in Africa, where many people have become internally displaced or forced to migrate to other countries due to war, drought, and dryland degradation (Umar, 1997). The environmental resources in and around the cities and camps where these people settle come under severe pressure. Difficult living conditions and the loss of cultural identity further undermine social stability of the sedentary pastoralists. UNCCD (2003b) indicates that at the global level, it is estimated that the annual income foregone in the areas immediately affected by land degradation amounts to approximately US\$ 42 billion each year. The report however indicates that indirect economic and social costs suffered outside the affected areas, including the influx of "environmental refugees" and losses to national food production, may be much greater.

2.3 LAND DEGRADATION AND CHRONOLOGY OF EFFORTS TO COMBAT IT IN KENYA

Kenya has along history of activities to combat desertification and mitigate the effects of drought dating back to 1940s. The report of the National Action Plan to combat desertification in Kenya indicates that land degradation is intensifying and spreading in Kenya, severely reducing productivity of the land, and is threatening millions of people (RoK/UNEP, 2002). According to UNEP (2008), RoK/UNEP (2002, 1997), the problem is due to a growing imbalance between population, resources, development and environment. Among the major factors exacerbating the existing food crises and land degradation are

rapid population growth, deforestation, poor land-use systems and inappropriate farming methods. Drought and population pressure are considered as key in accelerating land degradation in Kenya. Its effects are amplified by ineffective social responses and inappropriate land-use practices. As observed by Yassoglou (2000), severe drought in combination with poor land-use practices often result in serious land degradation and loss of land productivity and thus its ability to support human and animal populations.

Several institutions, including governmental, inter-governmental, non-governmental and donor agencies have been involved in initiatives to combat land degradation and mitigate the effects of droughts in Kenya. Following the droughts of 1933 – 1934, African Land Development Board (ALDEV) was created in 1946 to address the serious effects of land degradation. Later came the World Bank funded Kenya Livestock Development Programme (KLDP), which continued with the grazing schemes introduced by ALDEV (Musimba and Nyariki, 2003; Herlocker, 1999; Evangelou, 1984). When KLDP was abandoned after independence due to resistance from the pastoralists, a Range Management Division was created in the Ministry of Agriculture to ensure proper grazing management and conservation of rangelands. The Kenya Rangeland Ecological Monitoring Unit (KREMU) was established in 1975 to monitor ecological changes in the drylands. It later evolved to become the Department of Resource Surveys and Remote Sensing (DRSRS) currently under the Ministry of Environment and Natural Resources. The Ministry of Reclamation and Development of Arid, Semi-Arid Areas and Wastelands (MRDASAW) was created in 1989 to resolve the problems arising from the fragmented approach and resultant conflicting sectoral objectives in ASAL development (RoK/UNEP, 2002).

Several other institutions followed thereafter before the ratification of the convention to combat desertification (CCD) by Kenya in 1994, and currently there are many institutions and NGOs that are concerned with extension services, research and training. However, despite all the efforts, the activities have fallen short of desired expectations because of among other reasons, sectoral approach, uncoordinated funding, inadequate policies, and inadequate involvement of the local communities (RoK/UNEP, 2002). The main challenge in developing rangelands in the country, however, appear to be how to increase availability and access to information and technology for the development and management of natural

resources. The other major limitation is inadequate government policy for developing drylands.

2.4 THE ANALYTICAL FRAMEWORK FOR LAND DEGRADATION IN BARINGO DISTRICT

In the current study, land degradation is perceived as a product of a complex variety of forces, relationships, interactions and combinations of factors that constitute an ecosystem. Rangeland ecosystems are characterized by rainfall scarcity and variability in space and time that produce seasonality in forage production. These areas exhibit spatial variations in climate, soil and topography resulting in ecological heterogeneity. The latter and seasonal oscillations are the main determinants of the pastoral land-use pattern, and therefore survival strategies that characterise these ecosystems. As noted by several authors (Nyariki *et al.*, 2005; Nyariki and Ngugi, 2002; Campbell, 1999; Herlocker, 1999; Niamir, 1990; Oba and Lusigi, 1987; Sandford, 1983), to ensure their survival in such precarious environments, pastoralists have certain coping strategies that constitute their lifestyle, and adaptive schemes for mitigating the effects of droughts. The seasonal manoeuvres are deliberate and constitute sustainable traditional range management. Pastoralists strike a balance between land-use and grazing resources, therefore ensuring range resilience. Pastoral livestock production system is subject to interdependence, interaction and the dynamisms among the components of range ecosystem. It is considered as an open system in constant interaction with the entire ecosystem, each one modifying the other and being modified in turn. The disruption of this human-land symbiosis results in ecological imbalance, that render pastoralists vulnerable to otherwise 'normal' disturbances, with serious repercussions on pastoral households.

The current study is cognisant of the concept of bi-directionality of some of the socio-ecological processes of land degradation, and that intensifying land-use in ASALs may not universally cause land degradation and impoverishment of the pastoralists. Recent research into natural resources rehabilitation based on in-depth case studies in Kenya has highlighted situations where population growth and agricultural intensification have been accompanied by improved rather than deteriorating soil and water resources (Tiffen *et al.*, 1994). However, Boyd and Slaymaker (2000) in case studies conducted in the semi-arid areas of

Burkina Faso, Nigeria, Senegal, Uganda and Tanzania, contend that the decision to invest substantially in land rehabilitation is merely dependent on the importance of agriculture in rural livelihoods, combined with shortage of agricultural land and/or the potential of the rehabilitation to increase yields. (Kumar, 1994; Rufin, 1992).

The Pressure-State-Impact-Response (PSIR) analytical framework used by the Organization for Economic Co-operation and Development (OECD, 1994) in the analysis of environmental indicators formed the foundation for the model adopted in the current study. A modified PSIR model, the Pressure-Activity-State-Impact-Response (PASIR) analytical framework was used by Anantha *et al.* (2000) to analyse the land tenure, land-use, environmental degradation and conflict resolution in Narok District of Kenya. The PASIR analytical framework was found to be relevant to the current study and was adopted with some modifications to suit the local situation and to incorporate certain pertinent components. In order to analyse the land-use, land degradation and poverty nexus, it was critical to identify the starting point or factors that set in motion the pressure points, which in turn create other processes. Therefore, the driving forces component was introduced into the model. For the purpose of identifying and differentiating the various ecological and socio-economic factors that play a significant role in the nexus, the model retained the socio-economic activity component of the PASIR framework. The socio-economic states and impacts were also added in order to capture changes and impacts not only in the ecological system but also in the economic and social system. The resultant Driving force-Pressure-Activity-State-Impact-Response (DPASIR) analytical framework captures factors responsible for various socio-economic and ecological changes, their drivers and feedback loops.

Figure 2.0 presents a DPASIR analytical model for the study area. It shows how the various components in the framework operate in a dynamic environment characterised by cause-effect relationships and associated feedback loops. The processes of land degradation in the Njemps Flats of Baringo are believed to have originated from restricted herd mobility dating back to early 19th century. Mobility is one of the most critical aspects of traditional pastoral production in Africa. In the presence of mobility, the intensity of land-use was both spatially and temporally distributed and the problem of overgrazing any particular piece of land rarely occurred. The driving forces which have had the greatest impact on pastoralists in Baringo,

as well as the rest of Kenya, have been the past land reforms and associated transformations. Both the pre- and post-independence land reform schemes aimed at sedentarizing the nomadic pastoralists in Kenya are blamed for the breakdown of the pastoralists' adaptive strategies (Campbell, 1999; Evangelou, 1984; Rutten, 1992).

The earlier negative paradigms about pastoralism in Africa formed the basis for the past and even the present pastoral interventions. The main old paradigm included the 1926 Herkovits theory of the 'East African Cattle Complex'; Garret Hardin's concept of the 'Tragedy of the commons' and the allied theory of the 'Prisoner's dilemma' (Sandford, 1983; Bonfiglioli and Watson, 1992), which depicted African pastoralists as economically irrational producers, and destructive to the environment, and viewed nomadism as an inefficient land-use (Galaty, 1980). Pastoral transformations, therefore, started with land reforms with the ultimate goal of transforming a purely subsistence system into a market economy. The advent of colonial rule in Kenya was associated with the implementation of a number of policies by the British. One such policy was the establishment of the colonial government and the definition of specific areas for African (native reserves) and European occupation, which had the effect of confining a growing population into a restricted area, thereby resulting in stock numbers well above the land's carrying capacity (Otieno and Rowntree, 1986). One of the measures undertaken in the native reserves of Baringo was the security from major tribal conflicts, which resulted in the movements of the Tugen from the hills into the Njemps Flats, and the Il Chamus into areas that were originally unoccupied because of the fear of the Maasai raids. In the case of the Pokot, security against the Turkana raids assisted in the build up of larger stock numbers.

Figure 2.4: A Driving force-Pressure-Activity-State-Impact-Response (DPAStIR) Model

Another measure imposed by the colonial administration on the native land units was quarantine restrictions to protect the stock on adjacent European farms from the frequent outbreaks of rinderpest, pleuropneumonia and foot and mouth disease. All stock movements outside the quarantine area were banned, as were sales. These restrictions resulted in a serious build up of stock numbers and consequent overgrazing. Other consequences of reservation of the native land units were loss of herd mobility due to exclusion from the highland grazing areas during critical periods; and loss of access to key watering areas.

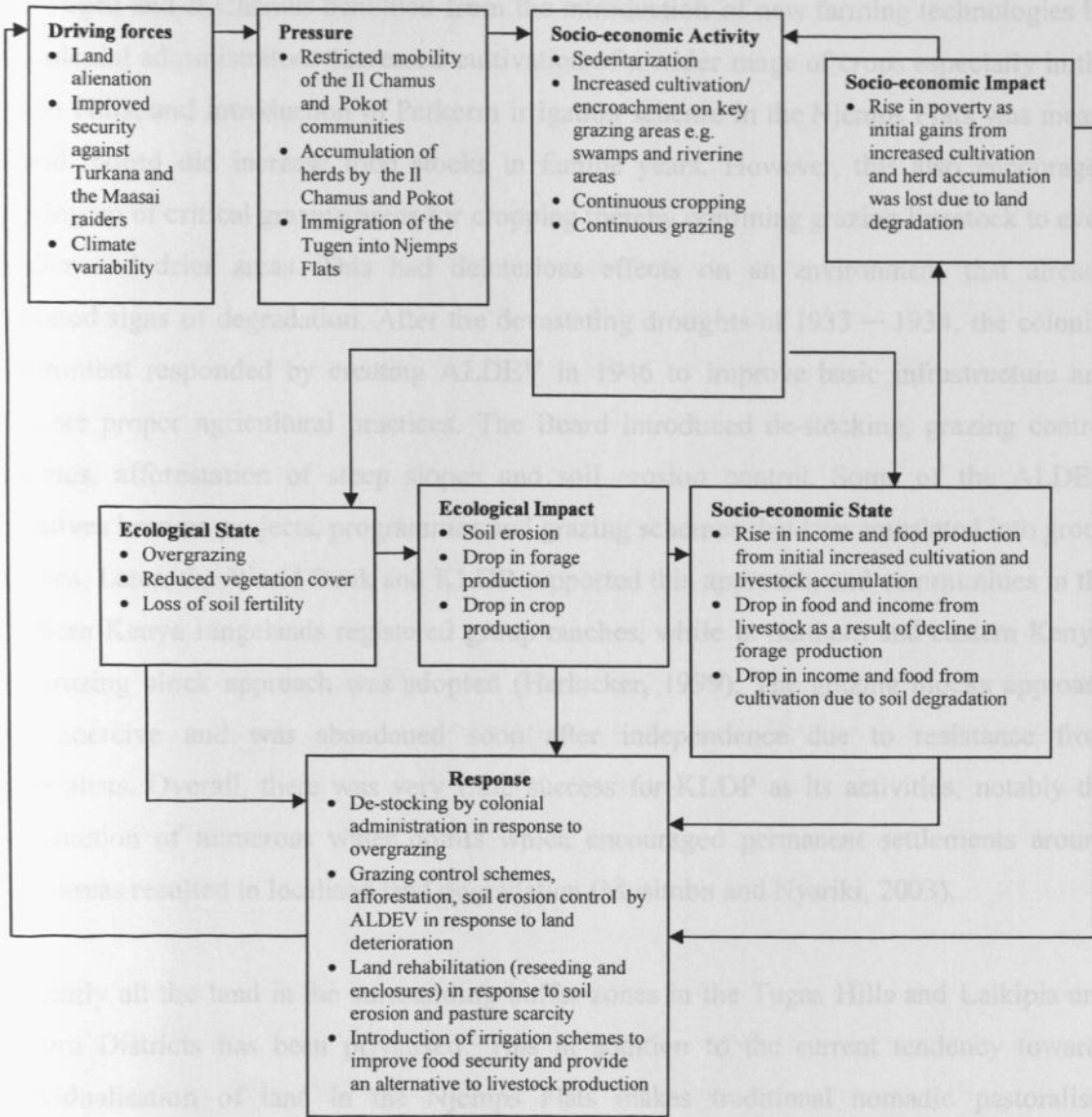


Figure 2.0: A Driving force-Pressure-Activity-State-Impact-Response (DPASIR) Model for the Njemps Flats

Whereas the sequestration of key grazing areas by the European settlers affected them negatively, the Pokot, Tugen and Il Chamus initially benefited from the improved security, when the Maasai and the Turkana were removed from the areas adjacent to their native reserves. They responded by increasing their herds, and benefited in the short run from the increased production. The rise in productivity was, however, short-lived as the accumulated herds combined with restricted mobility began to cause environmental degradation. The three ethnic communities began to suffer from high mortality rates among their livestock as forage became scarce in the Njemps Flats due to overgrazing by their own stock.

The Tugen and Il Chamus benefited from the introduction of new farming technologies by the colonial administrators. Increased cultivation of a wider range of crops especially in the Tugen Hills, and introduction of Perkerra irrigation scheme in the Njemps Flats was meant to and indeed did increase food stocks in famine years. However, this also encouraged opening up of critical grazing areas for cropping thereby confining grazing livestock to even smaller and drier areas. This had deleterious effects on an environment that already indicated signs of degradation. After the devastating droughts of 1933 – 1934, the colonial government responded by creating ALDEV in 1946 to improve basic infrastructure and promote proper agricultural practices. The Board introduced de-stocking, grazing control schemes, afforestation of steep slopes and soil erosion control. Some of the ALDEV initiatives became projects, programmes and grazing schemes that later translated into group ranches. Later, the World Bank and KLDP supported this approach, and communities in the southern Kenya rangelands registered group ranches, while in northern and eastern Kenya, the grazing block approach was adopted (Herlocker, 1999). The grazing blocks approach was coercive and was abandoned soon after independence due to resistance from pastoralists. Overall, there was very little success for KLDP as its activities, notably the introduction of numerous water points which encouraged permanent settlements around these areas resulted in localised land degradation (Musimba and Nyariki, 2003).

Currently all the land in the surrounding buffer zones in the Tugen Hills and Laikipia and Nakuru Districts has been privatised. This in addition to the current tendency towards individualisation of land in the Njemps Flats makes traditional nomadic pastoralism difficult. The implication is that these pastoralists continued to pursue economic activities, which they had been practising for generations, and which were suited to a communal rather than a private land tenure system. Neither re-appropriation of land from the Laikipia ranchers nor reversal of land tenure in the surrounding areas back to communal ownership seems practically tenable. This, therefore, leaves the options of modification of the pastoral production system and promotion of alternative livelihoods alongside environmental conservation strategies as the most realistic approaches towards regenerative livelihoods in the Njemps Flats.

2.5 LAND DEGRADATION IN THE SEMI-ARID LOWLANDS OF BARINGO DISTRICT

An increasing trend of pastoralists shifting to sedentary life is common in eastern Africa. Although land has not been adjudicated in the semi-arid lowlands of Baringo, the pastoralists like their counterparts in southern (Campbell, 1999) and northern (Oba and Lusigi, 1987) Kenya, are increasingly settling around the trading centres. This is evident in Marigat and Kampi ya Samaki in the Njemps Flats. Onyando *et al.* (2005) indicate that about 500 families live in Kampi ya Samaki, and the centre has grown specifically because of the fishing activities in Lake Baringo. Generally, as Chabari (1994), Herlocker (1999) and Coppock (1994) note, the majority of those who live near these centres are poor pastoralists and are increasingly dependent on the sale of milk and milk products.

Several authors (Campbell, 1999; Umar, 1997; Evangelou, 1984; Oba and Lusigi, 1987; Krugmann, 1999) point out that sequestration of the traditional grazing land for other purposes and sedentarization are among the worst occurrences that happened to African pastoralists and their environments. "Policy failures", what Ekbom and Bojo (1999) describe as "policy makers' actions or failures to act", have been adversely linked to the current state of affairs in most Kenyan rangelands, including the Njemps Flats. Land policies dating back to colonial era, are particularly blamed for restraining pastoral mobility, therefore inducing land degradation as a result of overgrazing. Pratt and Gywnne (1977), however, attributed the land degradation in the semi-arid lowlands of Baringo to overgrazing, droughts and invasion of locusts in January 1895: "...its succession of locusts invasions, on top of rinderpest and a number of drought years which must be held largely responsible for the dramatic decline of Baringo District".

According to Meyeroff (1991), the Njemps Flats is under increasing pressure from a growing population of pastoralists who have had to abandon their semi-nomadic practices for more sedentary ways, and from subsistence farmers (particulaly the Tugens) forced out of higher rainfall areas onto more marginal lands. Most of these groups are 'societies in transition' and the breakdown of traditional social structures, especially land-use and management systems, has further increased the pressure on already over utilized natural resources (Meyeroff, 1991). Crawley (2001, 1999) observe that much of the land is severely

degraded, and yet the impoverished pastoralists still have to rely on it for their livelihoods. One may want to argue that changes in lifestyle have occurred faster than the capacity and opportunities to cope with them. This scenario represents a lost balance between pastoral livelihoods and natural resources, driven by policy actions. Although the current status of rangelands of Baringo has been widely linked to overgrazing, it is important not to overlook the exogenous driving forces, social and economic linkages. This is because there is likely to be more than one driving factors in the process of land degradation. The population pressure, change in land-use and land tenure insecurity could be other likely factors driving land degradation in Baringo District.

Crawley (2001) indicated that reseeding the range by Rehabilitation of Arid Environments Trust (RAE) had shown positive results, and that the project had demonstrated to the pastoralists' the need to conserve land resources. However, she notes that this would only be sustainable if the land is adjudicated and ownership rights defined, and can only be tenable given alternative livelihoods that suit the new property rights. To make such decisions, however, the analysis of the drivers of the current situation, the past and present status as well as the totality of the range ecosystem is imperative. Unfortunately, as noted by Oba (1992), there are few instances where development plans have relied on historical analysis to deal with issues in pastoral areas. This explains in part why failures continue to characterize pastoral development projects.

The recent studies in the Lake Baringo basin have concentrated on the deteriorating condition of the lake, which has been described by many researchers as being in a state of environmental collapse. As noted by Crawley (2001), since the 1980s, "the lake has been turning into a swamp". Crawley indicates that one hundred years ago, Lake Baringo was described as "a glittering lake with clear fresh water". In the early 1980s the recorded depth was 8.9 m, while the recent measurements show that it is now only 2 m deep (Onyando *et al.*, 2005; Odada and Olago, 2004). The size of the lake decreased from 148 to 124 km² between 1973 and 2000, a decrease of 16% (Johansson and Svensson, 2002). This has been attributed to the general degradation of the surrounding land.

Overgrazing in the surrounding lowlands and logging in the highlands are believed to be the cause of severe soil erosion. When the rain comes, it floods the bare land, washing the rich topsoil away and leaving gullies behind. The topsoil ends up in the lake, which is becoming increasingly salty as five million cubic metres of sediment is deposited into it each year (Onyando *et al.*, 2005; Odada and Olago, 2004). Due to droughts and poor management, large areas of the forests which form the catchment have been destroyed, and now six of the seven rivers that flow into the lake, have become seasonal. The general biodiversity in the area is also reported to be in the decline. Given the reason that Lake Baringo is one the important stop-over sites for birds migrating between Europe and Africa, its deterioration, therefore, has consequences for global biodiversity. Both the number and the diversity of birds inhabiting the area around the lake have been declining.

It is evident from the foregoing review that the condition of the land and the lake are closely linked. However, with such attention going to the environmental issues, the societal implications of the process of land degradation is often overlooked, with the possibility that the situation continues to worsen. With livestock still the mainstay of their economy, the livelihoods of many pastoralist groups are threatened in this area, and positive environmental and social changes are needed to improve unproductive drylands and the sustainable livelihoods of the communities. That is why the theme: "Promoting alternative livelihoods to combat desertification" adopted during Kenya's 2002 Desertification Day observed in Baringo District (RoK/UNDP, 2004), was appropriate. However, such propositions are unlikely to succeed in absence of in-depth understanding of the dynamics of both the social and ecological components of the ecosystem.

CHAPTER THREE

3.0 THE STUDY AREA AND METHODOLOGY

3.1 STUDY AREA

3.1.1 Location and geo-physical characteristics

This study was conducted in the semi-arid rangelands of Baringo District, Kenya. The district covers 10,949 km² in Rift Valley province of Kenya. The semi-arid rangelands of Baringo cover the northeastern and southeastern parts of the district. According to the Range Management Handbook (Herlocker *et al.*, 1994), Baringo District is divided into 11 range units (areas which are roughly similar in terms of altitude, precipitation, soils and vegetation) ranging between 1,000 km² and 115 km² in size. The current study was carried out in the Njemps Flats (305 km²) range unit (Figure 3.0), which falls within agro-climatic zone IV and V, and is located between latitude 00° 30'N and longitude 36° 00'E. The Njemps Flats is classified as Lower Midland (LM) Livestock-Millet Zone, which is best suited for livestock production (RoK, 2002; Herlocker *et al.*, 1994). This area covers the lowlands between Tugen Hills and the eastern Laikipia highlands that stretch northwards from Lake Bogoria to Kapedo (Figure 3.1).

3.1.2 Climate

Rainfall of the study area is bimodal in distribution, low, erratic and unreliable both in space and time (Kipkorir, 2002; Herlocker, 1999; Pratt and Gywnne, 1977). Droughts have been common in the area notably the 1966, 1973 – 1974, 1984 – 1985, 1992 – 1994, and 1999 – 2000 (Johansson and Svensson, 2002). The spatial rainfall distribution in the Lake Baringo catchment and its temperature pattern is easily correlated with the topography. High potential agricultural land is found to the west and southwestern side, where altitudes reach a high of 2,700 m, and the average yearly rainfall ranges from 1200 to 1500 mm. In contrast, the large lowland areas of the district are semi-arid lands with average altitudes of 900 m and average annual rainfall ranging between 300 and 700 mm (RoK, 2002; Meyerhoff 1991; de Groot *et al.*, 1992).

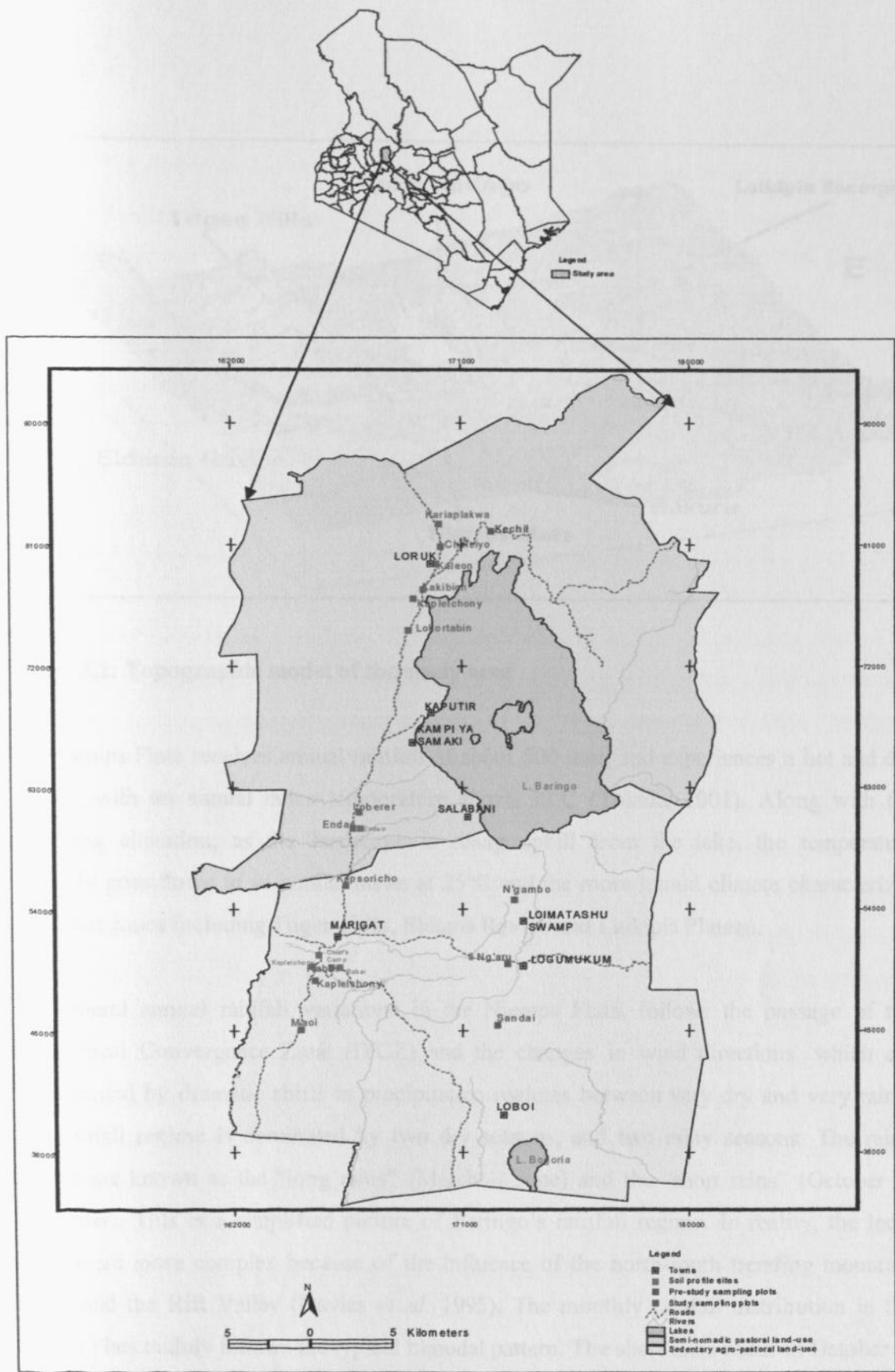


Figure 3.0: The study area (Njemp Flats)

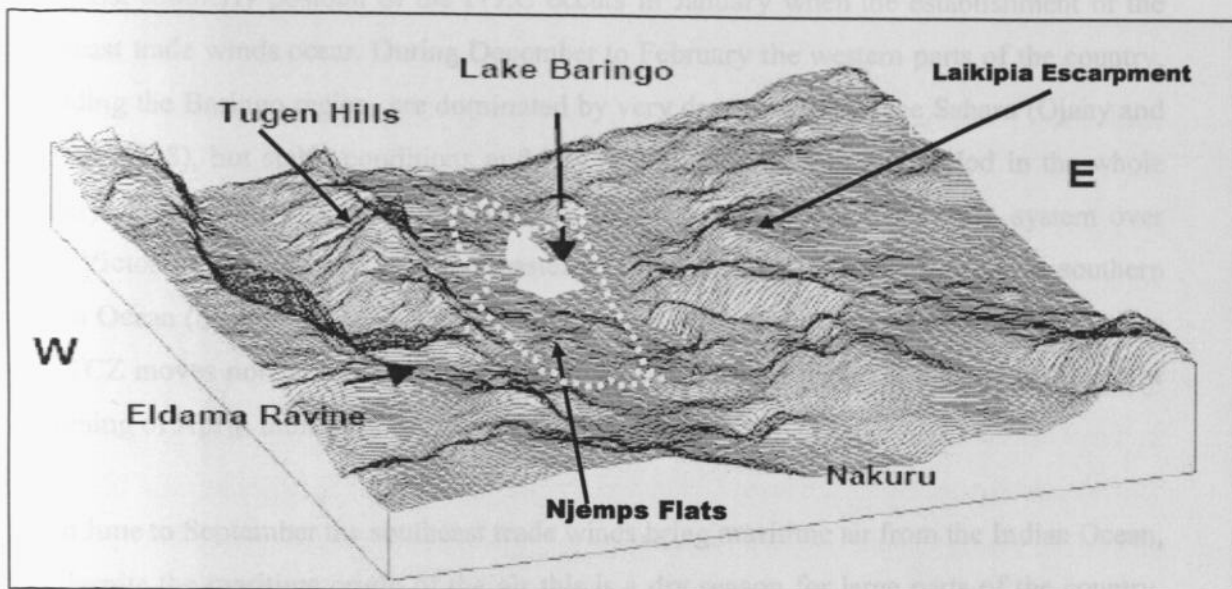


Figure 3.1: Topographic model of the study area

The Njemps Flats receives annual rainfall of about 500 mm, and experiences a hot and dry climate, with an annual mean temperature above 30⁰C (Tokida, 2001). Along with the increasing elevation, as the landscape is rising uphill from the lake, the temperature gradually goes down to an annual mean at 25⁰C and the more humid climate characterizes the higher zones including Tugen Hills, Eldama Ravine and Laikipia Plateau.

The general annual rainfall variations in the Njemps Flats, follows the passage of the Intertropical Convergence Zone (ITCZ) and the changes in wind directions, which are accompanied by dramatic shifts in precipitation regimes between very dry and very rainy. The rainfall regime is dominated by two dry seasons, and two rainy seasons. The rainy seasons are known as the “long rains” (March — June) and the “short rains” (October — November). This is a simplified picture of Baringo’s rainfall regime. In reality, the local patterns are more complex because of the influence of the north-south trending mountain ranges and the Rift Valley (Davies *et al.* 1995). The monthly rainfall distribution in the Njemps Flats mainly follows the typical bimodal pattern. The short rains occur in October — November and the long ones in April — August. But the long rains consist of two major peaks, one in April — May and one in July — August.

The most southerly position of the ITCZ occurs in January when the establishment of the northeast trade winds occur. During December to February the western parts of the country, including the Baringo region, are dominated by very dry winds from the Sahara (Ojany and Ogendo 1988), but stable conditions and low rainfall characterize this period in the whole country. From March to June the northeast flow weakens and low-pressure system over Lake Victoria gives rise to convergent easterly flow. This brings moist air from the southern Indian Ocean (Sutherland *et al.* 1991) producing the first rains of the year (the long rains) as the ITCZ moves northward. The ITCZ envelopes the Baringo region at the end of March or beginning of April, indicating the start of the wet season.

From June to September the southeast trade winds bring maritime air from the Indian Ocean, but despite the maritime origin of the air this is a dry season for large parts of the country. But in Baringo District rainfall continues and intensifies in July — August once again. This second peak is caused by high, naturally unstable, winds known as the “Congo airstream” penetrating from the southwest through Equatorial Africa (Sutherland *et al.* 1991; Davies *et al.* 1995). The “Congo airstream” can also amplify the interactions between convective thunderstorms, associated with breezes initiated by the pressure of Lake Victoria, and westerlies to cause this peak (Camberlin 1996). From September to November the ITCZ retreats, and as the south trade disappears it is replaced by strengthened easterlies carrying moisture from the ocean (Ojany and Ogendo 1988). The convergence creates the second rainy season in October and November, known as the “short rains” in Baringo as well as in the whole country.

The temperature in the study area is much more stable than the precipitation and has none of the extremes characterizing the rainfall distribution. Temperatures, however, vary and follow the annual rainfall pattern with relatively cold duration from June to October. December to March are the hottest months. In the semi-arid lowlands and up along the slopes the daily mean temperature varies from around 15° to 35°C (Tokida, 2001).

3.1.3 Vegetation

The main vegetation classes in the Njempes Flats include Acacia woodland (80%), permanent swamp and seasonally flooded grassland (15%) and shrub grassland (5%) (Herlocker *et al.*, 1994). The vegetation of the study area is dominated by *Acacia* and ephemeral herbaceous species. The perennial grasses and herbaceous cover is very scanty, particularly during the dry seasons and drought. In the lowlands, the vegetation is predominantly *Acacia reficiens* and *A. mellifera* bushland with some colonization of *A. nubica*. Semi-deciduous woodland dominates riverine areas and northern part of the Njempes Flats. Tall *A. tortilis* and *A. xanthophloea* trees are common along the riparian zones and flatter areas. Another woody species common in the study area is *Prosopis juliflora*, which is an exotic species introduced in the early 1980s through the Fuelwood Afforestation Extension Project (Marangu *et al.*, 2008; Kariuki 1993, Lenachuru 2003). *Prosopis juliflora* is very invasive and has since spread to other parts of the region and is a problem mainly in Marigat and Ng'ambo where it has formed dense thickets thereby inhibiting undergrowth. The invasion of *P. juliflora*, however, seems higher in areas where no previous vegetation existed and in areas with high water accessibility.

3.1.4 Soils and water resources

The soils in the Njempes Flats are generally shallow silt loam to clay loam, with low organic matter. Soils of clay loam are generally formed on mostly old (Pliocene) volcanic rocks (Johansson and Svensson, 2002). They are relatively shallow and infertile and often very stony in steep areas. The southeastern parts of the lake are very flat and have relatively fertile soils of coarser loam and clay. The area immediately west of Lake Baringo is one of the most severely degraded semi-arid areas in Kenya (Sutherland *et al.*, 1991) and occasional floods take place, carrying soils as well as gravel to Lake Baringo. Soils here are associated with sedimentary lake deposits and alluviums (Johansson and Svensson, 2002). The sources of water in the study area are rivers, Perkerra, Molo and Endao (seasonal) which drain into Lake Baringo. Other water sources include Lake Bogoria, which unlike Baringo is a salty and Lobo, Sandai, and Ng'ambo swamps.

3.1.5 Land-use

The main land-use practice in the study area is livestock production. Sedentary agro-pastoralism is the main land-use on the west, south and eastern part of the Njemps Flats, while semi-nomadic pastoralism dominates on the northernwest and northern parts of the study area (de Groot *et al*, 1992; Meyeroff, 1991). Livestock production provides 75% of the district's total income, with 70% of the district's population deriving its livelihood from livestock production. Although pastoralism is the main source of livelihood in the Njemps Flats, low livestock productivity due to range degradation and frequent droughts has led to an increasing number of households engaging in some farming. Maize that is the main crop is the most productive. However, the crop is more susceptible to drought than sorghum and millet, which were main crops in the past before the colonisation (Johansson and Svensson, 2002).

The Njemps Flats is one of the most affected areas in the district by the government policy actions of the early 20th century, which included introduction of commercial ranches in the neighbouring highlands, mobility restrictions, and introduction of irrigation schemes. These development interventions are believed to have shaped the current land-use pattern, and the processes of land degradation in the study area (Otieno and Rowntree, 1986). The Njemps flats is classified as being in a severe risk of irreversible degradation, and one in which only opportunistic use by livestock during high rainfall periods is recommended (Herlocker *et al.*, 1994).

3.1.6 The people

The semi-arid lowlands of Baringo District is inhabited by three principal ethnic groups namely the Pokot (35%), Tugen (53%) and Njemps or Il Chamus (12%) (Sutherland *et al.*, 1992). The Tugen living to the west of Lake Baringo are agro-pastoralists, cultivating crops and keeping herds of cattle, sheep and goats. They are more involved in entrepreneurial activities and the cash economy than the Pokot and Il Chamus. The Il Chamus who are related to the Maasai, are sedentary agro-pastoralists, and live to the southeast and southwest around the lake. Although they practice some agriculture, they are heavily dependent on their livestock, primarily cattle and sheep for livelihoods. The Il Chamus who

were originally hunters and gatherers transformed into agro-pastoralists, practicing irrigated agriculture southwest of Lake Baringo during the 19th century, and were referred to as 'agricultural Maasai' (de Groot *et al.*, 1992). The Pokot who like the Tugen belong to the Kalenjin ethnic group occupy the flatter region to the north and north east of the lake. They are nomadic to semi-nomadic pastoralists, herding large herds of cattle, sheep, goats and camels (Meyerhoff, 1991). Land is communally held under common property regime in the Njemps Flats. However, land privatisation has been going on around some trading centres occupied by the agro-pastoral communities.

3.2 METHODOLOGY

3.2.1 Site selection for ecological data collection

Initial reconnaissance survey of the study area was done prior to commencement of the actual study. The overall purpose of the survey was to gain some basic understanding of the area for selection of sampling sites and to introduce the study to the communities residing in the area. Although land is communally owned in the study area, a good rapport with the local communities was an important prerequisite for soil and vegetation sampling in private enclosures. The pre-study familiarisation with both the physical and socio-cultural landscape was also crucial in formulation of the study approach and methods. The reconnaissance survey and pre-study geospatial analyses were used to stratify the study area into two sites based on the land-use systems. This was done in order to enable assessment of the effects of land-use on the selected vegetation and soil attributes and determination of the relationship between land-use, land degradation and poverty in the study area. A current geographic information systems (GIS) data layers and maps derived from satellite images were acquired to aid the demarcation of sampling points to meet the set objectives. The image maps were used in combination with ground observations to identify study sites.

3.2.2 The semi-nomadic pastoral land-use system (SNL) site

This site included Kipsaraman and part of Nginyang Division, and is located to the northwest of Lake Baringo. Although also inhabited by some Tugen, it is mainly a territory of the Pokot who practice a milk-based subsistence economy characterised by nomadic to semi-nomadic herding (de Groot *et al.*, 1992; Meyeroff, 1991). The traditional strategies and practices, including flexible and mobile responses to highly variable and often stressful environment, still comprise a significant element of the pastoral production system in this area (Herlocker, 1999). The elders exercise control over rangeland use by deciding which areas to be opened for dry season grazing and when to open and close them. Their herds are usually split into two units, the satellite or nomadic herds (*sorok* in Pokot) and home-based (locally known as *lepon*), the latter which are left at home during the grazing movements (Wasonga *et al.*, 2003). The pilot survey revealed that herd mobility in the area has been made possible due to communal land rights, sparse settlement and negligible croplands in the area.

3.2.3 The sedentary agro-pastoral land-use system (SAL) site

Sedentary agro-pastoralism is practiced mainly in Marigat Division, which is located to the southern part of Lake Baringo. This is a territory of both the Tugen and Il Chamus communities who practise both sedentary pastoralism and crop cultivation (Meyeroff, 1991). This area is considered to have undergone a lot of transformation in terms of land-use pattern and general livelihood strategies. The arrival of the European settlers in the early 20th century and subsequent establishment of commercial ranches in the neighbouring districts of Laikipia and Nakuru, and introduction of Perkerra irrigation scheme led to restricted mobility of the Il Chamus and immigration of the Tugen into what was originally Il Chamus territory. The population density of Marigat Division increased from 4.4 persons/km² in 1948 to 44 persons/ km² in 1999. The total population was estimated at 54,000 of which the Tugen numbered about 24,000, Il Chamus 22,000 and 8,000 comprised the Pokot and Turkana refugees (Tokida, 2001). Small scale irrigated agriculture has been going on along River Molo, Perkerra, Endao and around Sandai, Lobo and N'gambo swamps, converting key grazing ranges into croplands. Marigat trading centre has since grown into a large urban

centre attracting settlements in the neighbourhood. Although land adjudication has not been done in the area, there is a strong tendency towards individualisation of land (de Groot *et al*, 1992). These transformations have contributed to shrinkage of the grazing resource base and a number of socio-ecological changes in the area (Tokida, 2001).

3.2.4 Experimental layout

An existing Marigat – Loruk road was used to lay a belt transect, cutting each of the two pre-determined sites (SNL and SAL) into two halves, within which vegetation and soil sampling were conducted. The main criterion was to ensure maximum coverage of the Njemps Flats ecosystem taking into account sampling effort, accessibility, security and the required data. Covering the full length of the study area was to ensure a good representative sample for the perceived gradient of land-use pressure. Six enclosures, with at least 20 years history of controlled grazing were selected within the transect in each land-use site. The enclosures varied in size, the smallest being 1.5 acres and the largest 4 acres. The enclosure system involves fencing the degraded areas using thorny branches to exclude grazing animals and other human activities. The enclosures are then either left to regenerate naturally (Plate 3.0) or reseeded with grass (Plate 3.1), and later used as pasture reserves. The unseeded enclosures were used in this study. Each enclosure was paired with an adjacent open plot to allow comparison of soil and vegetation attributes. The paired plots were located at $1 \leq 4$ km, $5 \leq 8$ km and $9 \leq 12$ km radiating towards the south and north directions from the centre of each of the two land-use sites. The next step after identifying the sampling plots involved seeking permission from owners of the identified enclosures.

3.1: An enclosure reseeded with *Cenchrus ciliaris* (background) and adjacent bare ground (foreground) in Lemaick, Njemps Flats



Plate 3.0: An enclosure of naturally regenerated pasture dominated by *Digitaria gayana* and *Eriochloa meyerianum* (background) and adjacent open bare ground (foreground) in Maoi, Njemps Flats



Plate 3.1: An enclosure reseeded with *Cenchrus ciliaris* (background) and adjacent open bare ground (foreground) in Lamalok, Njemps Flats

In the semi-nomadic pastoral land-use system, the sampling points were located at Kariaplakwa, Cheleiyo, Kaleon, Kiplelchony, Kakibich and Lokortabim. Sampling plots in sedentary agro-pastoral land-use system were located at Maoi, Kapchepliel, Rabai, Kapsoricho, Endao and Loberer. A total of twelve pairs of open and enclosed plots were sampled during the study period. Sampling was done at the peak and end of every season, and repeated to capture two wet and two dry seasons during the 2005 –2006 study period. Actual and more detailed sampling procedures and sample sizes are provided under respective chapters.

3.2.5 Procedure for socio-economic data collection

Different methods were used to collect socio-economic data. These included individual interviews using structured questionnaire, key informant interviews, focus group discussions (FGDs), guided transect walks and observations. The identification and training of enumerators from the local community was carried out before the actual fieldwork was undertaken. This was necessary given the language barrier and to provide assistance to speed up the process of data collection. The enumerators were trained for three days to ensure that they did not deviate from the required protocol, thereby reducing bias in the sample data collected. The questionnaire was pre-tested on ten households before it was administered on the main sample. After the initial field experiences and questionnaire-testing exercise, the questionnaire was revised to make it more relevant and effective in gathering the required information.

Due to the inherent difficulties in accessing most parts of the study area, chief of them rough terrain and scattered homesteads, simple random sampling data collection technique proved difficult. Stratified random sampling procedure was therefore used to collect the socio-economic data. The goal of a stratified sampling is to achieve desired representation from various sub-groups in the population (Mugenda and Mugenda, 1999). The method involves dividing the population into two or more sub-populations using given criteria, and then a simple random sample is taken from each sub-population. The reasons for sampling populations in this manner include the desire i) to make statements about each of the subpopulations separately and ii) to increase the precision of the estimates over the entire population. If stratification is used to eliminate some of the variations from the sampling

error, the method must have greater precision than the simple random sampling. In the current study, the two sites representing sedentary agro-pastoral and semi-nomadic pastoral land-use systems were considered as separate strata that exhibit two distinct food economies. A “food economy” is defined by Seaman *et al*, (2000) as all the households in a geographical area where most households obtain their food and cash income by roughly the same combination of means. Detailed methods used in the study are given under relevant chapters in the thesis.

- de Wit, R.H. and I. Scoones, 1993. Rethinking range ecology: implications for rangeland management in Africa. In: de Wit, R.H., I. Scoones and C. Kerven (Eds.) *Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas*. GDI, IIED and Commonwealth Secretariat, London.
- de Wit, R.H. and I. Scoones, 1992. *Rethinking range ecology: implications for rangeland management in Africa*. International Institute for Environment and development (IIED) Issues paper no. 35.
- de Wit, R.H., 1991. Can livestock production be sustained in the Hantveld of Botswana? *Pastoralism*, XI-3: 243 – 245.
- de Wit, R.H., 1989. Explanation and policy in land degradation and rehabilitation for developing countries. *Land Degradation and Rehabilitation*, 1: 23 – 37.
- de Wit, R.H. and C.J. Watson, 1992. *Pastoralists at crossroads: Survival and Development Issues in African Pastoralism*. UNICEF/UNSD project for Nomadic Pastoralists in Africa. UNICEF/UNSD.
- de Wit, R.H. and T. Slaymaker, 2006. Re-examining the ‘more people less erosion’ hypotheses: Special case or wider trend? Overseas Development Institute, *Natural Perspectives* No. 63.
- de Wit, R.H., P. 1996. Interseasonal Variations of June-September Rainfall and Upper-Air Circulation over Kenya. *Theoretical and Applied Climatology*, 54: 107 – 115.
- de Wit, R.H., D.P. Lurie, T. Smucker and E.E. Wangui, 2003. Root cause of land-use change in the Lonkhot area, Kiambu District. *ILRI Working paper* No. 19. International Livestock Research Institute (ILRI), Nairobi, Kenya.
- de Wit, R.H., 1999. Response to drought among farmers and herders in southern Kajiado district, Kenya: A comparison of the 1972 – 1976 and 1994 – 1995. *Journal of Human Ecology*, 27 (7), 377 – 416.

3.3 REFERENCES

- Anantha, K.D., G. Ikiara, M. Manundu, W. Nyangena and R. Sinange. 2000. Land tenure, land use, Environmental degradation and conflict resolution: a PASIR analysis for the Narok District, Kenya. Working paper number 33, International Institute for Environment and Development (IIED), London, and Institute for Environmental Studies, Amsterdam.
- Behnke, R.H. and I. Scoones. 1993. Rethinking range ecology: implications for rangeland management in Africa. In: Behnke, R.H., I. Scoones and C. Kerven (Eds.). *Range Ecology at Disequilibrium. New Models of Natural Variability and Pastoral Adaptations in African Savannas*. ODI, IIED and Commonwealth Secretariat, London.
- Behnke, R.H. and I. Scoones. 1992. *Rethinking range ecology: implications for rangeland management in Africa*. International Institute for Environment and development (IIED) *Issues paper* no. 33.
- Biot, Y, 1991. Can livestock production be sustained in the Hardveld of Botswana? *Pedologie*, XL-3: 243 – 255.
- Blaikie, P. 1989. Explanation and policy in land degradation and rehabilitation for developing countries. *Land Degradation and Rehabilitation*, 1: 23 – 37.
- Bonfiglioli, A.M. and C.J. Watson. 1992. *Pastoralists at crossroads: Survival and Development Issues in African Pastoralism*. UNICEF/UNSO project for Nomadic Pastoralists in Africa. UNICEF/UNSO.
- Boyd, C. and T.Slaymaker. 2000. Re-examining the “more people less erosion” hypothesis: Special case or wider trend? Overseas Development Institute, *Natural Perspectives* No. 63,
- Camberlin, P. 1996, Interseasonal Variations of June-September Rainfall and Upper-Air Circulation over Kenya, *Theoretical and Applied Climatology*, 54: 107 – 115.
- Campbell, D., D.P. Lusch, T. Smucker and E.E. Wangui. 2003. Root cause of land-use change in the loitoktok area, Kajiado District. LUCID *Working paper* No. 19. International Livestock Research Institute (ILRI), Nairobi, Kenya.
- Campbell, D.J. 1999. Response to drought among farmers and herders in southern Kajiado district, Kenya: A comparison of the 1972 – 1976 and 1994 – 1995. *Journal of Human Ecology*, 27 (3), 377 – 416.

- Chabari, F. 1994. Livestock Marketing, In: Herlocker, D.J. Shaabani and S. Wilkes (eds), *Range Management Handbook of Kenya 2* (6) (Baringo District). Ministry of Agriculture, Livestock Development and Marketing/GTZ, Nairobi.
- Chen, S. and M. Ravallion (Eds.). 2008. "The developing world is poorer than we thought, but no less successful". World Bank. <http://www.wds.worldbank.org/external/default>
- Choudhury, K. and L. Jansen (Eds.). 1999. Land cover and land use terminology for integrated resources planning and management. FAO Land and Water Development Division.
- Coppock, D.L. (Ed.). 1994. The Borana Plateau of southern Ethiopia: Synthesis of pastoral research, development and change, 1980 — 91. International Livestock Center for Africa (ILCA) *Systems Study* No. 5.
- Crawley, M. 1999. Combating desertification in Kenya. International Development Research Center (IDRC), Ottawa, Canada.
- Crawley, M. 2001. Rehabilitating the Baringo Drylands of Kenya. Rehabilitation of Arid Environments (RAE) and IDRC, Ottawa, Canada.
- Dahlberg, A. 1994. *Contesting views and changing paradigms: The land degradation debate in Southern Africa*. Nordiska Afrikainstitutet, Uppsala, Sweden.
- Davies T.D., C.E. Vincent and A.K.C. Beresford, 1995. July — August Rainfall in West-central Kenya. *Journal of Climatology*, 5: 17 — 33.
- de Groot, P., A. Field-Juma and D.O. Hall. 1992. *Reclaiming the land: Revegetation in semi-arid Kenya*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- de Leeuw, P.N. and J.C. Tothill. 1990. The concept of rangeland carrying capacity in Sub-Saharan Africa-myth or reality. ODI Pastoral Development *Network Paper* No. 29b.
- Dietz, T. 1987. Pastoralism in dire straits. Survival strategies and external interventions in a semi-arid region at Kenya / Uganda border: West Pokot, 1900 — 1986. *Nederlanse Geografische Studies* 49. *Ecological Bulletins* No. 24.
- Ekaya, W.N., B.F. Makau, D.M. Nyariki and J.M. Gathuma. 2005. *ASAL natural resources management information and awareness*. A report of Arid Lands Resources Management Project. Office of the President, Government of Kenya.
- Ekbom, A. and J. Bojo. 1999. Poverty and Environment: Evidence of links and integration into the country assistance strategy process. Environment Group Africa Region, The World Bank *Discussion Paper* No. 4.

- Ellis, E. 2007. Land-use and land-cover change. In: Cutler J. Cleveland (Eds.) *Encyclopedia of Earth*. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). http://www.eoearth.org/article/Land-use_and_land-cover_change
- Evangelou, P. 1984. *Livestock development in Kenya's Maasailand*. Westview Press.
- Fouad, I. 1993. A Reassessment of the Human Dimension of Desertification. *Geojournal*, 31 (1): 5 – 10.
- Galaty, J. 1980. The Maasai Group-Ranch: Politics and development in African pastoral Society. In: Salzman P.(Ed.). *When Nomads settle*. Bergin, Paeger.
- Gintzburger, G.A. 1986. Annual Medicago species for the mediterranean semi-arid and arid rangelands. In: Joss, P.J., P.W. Lynch and O.B. Williams (eds),: *Rangelands: A resource under siege. Proceedings of the second International Rangeland Congress*. Cambridge University Press.
- Grainger, A. 1990. *The threatening desert: Controlling desertification*. Earthscan Publications, London.
- Herlocker D. 1999. *Rangeland resources in East Africa: Their ecology and development*. GTZ, Nairobi.
- Herlocker, D., S.B. Shaabani and S. Wilkes. 1994. *Range Management HandBook of Kenya*, Ministry of Agriculture, Livestock Development and Marketing, Range Management Division, republic of Kenya.
- Höhnel von, 1894. *Discovery of Lakes Rudolf and Stefanie* (Vol. II). Longman, London.
- ICARDA/ICRISAT. 2002. Desertification, Drought, Poverty, and Agriculture. *A pre-proposal for a CGIAR Challenge Programme*.
- IFAD. 2002. *Assessment of rural poverty: Eastern and Southern Africa*. International Fund for agricultural Development (IFAD), Rome, Italy.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *AR4 Synthesis Report CWT 2-bis Meeting*. 5 – 6 May, Royal Princess Hotel, Bangkok.
- IPCC. 2001. Climate Change: Impacts, Adaptations and Vulnerability. Intergovernmental Panel on Climate Change (IPCC) third Third Assessment reportReport. www.grida.no/
- W.C. 1948. *Conquest of the Land through Seven thousand Years*. U.S. Department of Agriculture (USDA), Soil Conservation Service.

- ISO. 1996. Requirements for characterisation of excavated soil and other soil materials for re-use. CD 15176 ISO/TC 190/SC7/soil and site assessment/WG1/N2. rev.3.
- Johansson, J. and J. Svensson. 2002. Land degradation in semi-arid catchment of Lake Baringo, Kenya. A minor field study of physical with socio-economic aspect. Earth Science Centre, Department of Physical Geography, Göteborg University.
- Jones, K.B., A.C. Neale, T.G.Wade, J.D.Wickham, C.L.Cross, C.M. Edmonds, T.R.Loveland, M.S. Nash, K.H. Riitters and E.R.Smith. 2001. The consequences of landscape change on ecological resources: An assessment of the United States Mid-Atlantic region, 1973 – 1993. *Ecosystem Health*, 7 (4): 229 – 242.
- Kariuki P.M. 1993. A social forestry project in Baringo, Kenya: A critical analysis. M.Sc. thesis, Moi University, Kenya.
- Keya, G.A. 1998. Impact of land use patterns and climate on the vegetation ecology of arid and semi-arid nomadic pastoral ecosystems of northern Kenya. PhD thesis, University of Trier, Germany.
- Kiage, L. M., K. B Liu, N.D. Walker, N. Lam, and O.K. Huh. 2007. Recent land-cover/use change associated with land degradation in the Lake Baringo catchment, Kenya, East Africa : evidence from Landsat TM and ETM+, *International Journal of Remote Sensing*, 28 (19): 1 – 25.
- Kipkorir, E.C. 2002. Analysis of rainfall climate on the Njemps Flats, Baringo District, Kenya. *Journal of Arid Environments*, 50: 445 – 458.
- Kiriro, P. 2003. Food Aid: Cure or Curse- the controversy. The case of Kenya. *Paper presented at the policies against hunger II international workshop*. September 2 – 4, 2003. Berlin, Germany.
- Kristjanson, P. M. Radeny, D. Nkedianye, R. Kruska, R. Reid, H. Gichohi, F. Atieno and R.Sanford. 2002. *Valuing alternative land-use options in the Kitengela wildlife dispersal area of Kenya*. ILRI, Nairobi, Kenya.
- Krugmann, H. 1996. Towards Improved Indicators to Measure Desertification and Monitor the Implementation of the Desertification Convention. <http://www.idrc.ca/books/focus/794/krugmann.html>.
- Lenachuru C. I. 2003. Impacts of *Prosopis* species in Baringo District. *Proceedings of Proceedings of a workshop on integrated management of Prosopis species in Kenya*,
- Lowdermilk, W.C. 1948. *Conquest of the Land through Seven thousand Years*. U. S. Department of Agriculture (USDA), Soil Conservation Service.

- Lusigi, W.J. 1986. The Integrated Project on Arid (IPAL) Kenya. In: Joss, P.J., P.W. Lynch and O.B. Williams (eds): *Rangelands: A resource under siege. Proceedings of the second International Rangeland Congress*. Cambridge University Press, *in arid and*
- Mabutt, J.A. 1986. Desertification indicators. *Climate Change*, 9: 113 – 122.
- Maher, C. 1937. *Soil erosion and land utilization in the Kamasia, Njemps, and East Suk reserves*. Colony and Protectorate of Kenya, Nairobi. *Journal of Human Ecology*,
- Mainquet, M. 1991. *Desertification: Natural Background and human mismanagement*. Springer Verlag, Berlin. *anga, V.O., Issa, I., Kyagaba, E. and Luganja, M. (2005):*
- Maitima, J., R.S. Reid, L.N. Gachimbi, A. Majule, H. Lyaruu, D. Pomeroy, S. Mugatha, S. Mathai and S. Mugisha. 2004. The linkages between land-use change, land degradation and biodiversity across East Africa. *LUCID Working Paper Series No. 42*. *Developing countries*. In: Joss, P.J., P.W. Lynch and O.B. Williams (eds):
- Mango, N., J. Cheng'ole, G. Kariuki and W. Ongadi. 2004. Social Aspects of Dynamic Poverty Traps: Cases from Vihiga, Baringo and Marsabit Districts, Kenya. BASIS CRSP research report. *actors in land use conflicts, land administration and food*
- Marangu, D.K., J.N. Kimani, F. Msafiri and H.P. Roimen. 2008. *Mapping of prosopis species in Baringo District*. Department of Resources Survey and Remote Sensing (DRSRS) Technical Report No. 173. DRSRS. Ministry of Environment and Natural Resources, Republic of Kenya. *www.dl.org.uk/pdn/papers*.
- Meyerhoff, E. 1991. *Taking Stock: Changing Livelihoods in a Agropastoral Community*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- Migot-Adholla, S.E. and Little, P.D. 1981. Evolution of policy towards the development of pastoral areas in Kenya, Pp.144 – 156. In: *The future of the pastoral peoples. Proceedings of the conference held in Nairobi, Kenya, 4 – 8 August 1980*.
- Millennium Ecosystem Assessment (MA). 2003. *Ecosystems and Well-being. A Framework for Assessment*. Island Press. *Kenya. Water Resources Management, 19: 133 – 143.*
- Mugenda, O.M. and A.B. Mugenda. 1999. *Research Methods: Quantitative and Qualitative approaches*. ACTS Press, Nairobi, Kenya. *Institute of British Geographers, Reading*
- Musimba, N.K. R. and D.M. Nyariki. 2003. Development of and policy on the Range and Pastoral industry with special reference to Kenya. *Anthropologist*, 5(4): 261– 267. *at*
- Mwasi, B. 2004. Landscape change dynamics in a semi-arid part of Baringo District, Kenya. PhD thesis, University of Amsterdam, the Netherlands.

- Nelson, R. 1988. Dryland Management: The desertification problem. Environment Department The World Bank *Working Paper No. 8*, Washington DC.
- Niamir, M. 1990. *Herders decision-making in natural resources management in arid and semi-arid Africa*. FAO, Rome.
- Nyariki, D.M. and R.K. Ngugi. 2002. A review of African pastoralists production system: Approaches to their understanding and Development. *Journal of Human Ecology*, 13(3): 137 – 250.
- Nyariki, D.M., Kitalyi, A., Wasonga, V.O., Isae, I., Kyagaba, E. and Lugenja, M. (2005). Indigenous techniques for assessing and monitoring range resources in East Africa. World Agroforestry Centre (ICRAF) *Ocassional paper No.2*,
- O'Brien, T. 1986. Land ownership-feed ownership, responsibility in range management in developing countries. In: Joss, P.J., P.W. Lynch and O.B. Williams (eds),: *Rangelands: A resource under siege. Proceedings of the second International Rangeland Congress*. Cambridge University Press.
- Oba, G. 1992. Ecological factors in land use conflicts, land administration and food insecurity in Turkana, Kenya. Overseas Development Institute (ODI) *Network paper No.33a*.
- Oba, G. and W. Lusigi. 1987. An overview of drought strategies and land use in African pastoral systems. Paper 23a, www.odi.org.uk/pdn/papers.
- Odada E. O. and D.O. Olago. 2004. *The East African Great Lakes: Limnology, Palaeolimnology and Biodiversity*. Kluwer Academic Publishers. www.wkap.nl/prod/b/1
- OECD. 1994. *Environmental indicators*, OECD Core Set, Paris.
- Ojany F.F. and Ogendo R.B. 1988. *Kenya: A study in Physical and Human Geography*. Longman Publishers, UK.
- Onyando, J.O, P. Kisoyan and M.C. Chemelil. 2005, Estimation of potential soil erosion for river Perkerra catchment in Kenya. *Water Resources Management*, 19: 133 – 143.
- Otieno, A.K. and K.M. Rowntree. 1986. A comparative study of land degradation in Machakos and Baringo District, Kenya. Institute of British Geographers, Reading, England.
- Paré, S. 2008. Land Use Dynamics, Tree Diversity and Local Perception of Dry Forest Decline in Southern Burkina Faso, West Africa. PhD thesis, Swedish University of Agricultural Sciences.

- Pattie, D. 2009. Land-use change-drivers, impacts and responses. *Proceedings of the 7th International Conference on Human Dimensions of Global Environmental Change*. 26 – 30 April, 2009, World Conference Centre, Bonn.
- Pratt, D.J., and M.D. Gwynne. 1977. *Rangeland Management and Ecology in East Africa*. Robert E.Krieger Publishing Co. Humington, New York. U.S.A
- Republic of Kenya (RoK), 1974. *Baringo District Development Plan 1974 – 1978*. Office of the Vice-President and Ministry of Planning and National Development, Nairobi.
- RoK. 1997. Baringo District Development Plan, Office of the Vice-President and Ministry of planning and National Development, Nairobi, Kenya.
- RoK. 2002a. Baringo District Development Plan, Office of the Vice-President and Ministry of planning and National Development, Nairobi, Kenya.
- RoK. 2000. The 1999 Population and Housing Census. Counting our People for Development. Central Bureau of Statistics, Ministry of Finance and Planning. Volume I and II, Nairobi, Kenya.
- RoK. 2002b. *National Action Programme. A framework for combating desertification in Kenya*. Ministry of Environment and Natural resources, Government of Kenya.
- RoK. 2005. *Geographic dimensions of well-being in Kenya. Who and where are the poor? A constituency level*, Vol II. Central Bureau of Statistics, Ministry of Planning and National Development, Government of Kenya.
- RoK/UNDP. *Ten years Anniversary of the World Day to Combat Desertification*. 2004. WDCD, UNDP, Nairobi.
- RoK/UNEP. 1997. *National Land Degradation Assessment and Mapping*. UNEP, Nairobi, Kenya.
- RoK/UNEP. 2002. National Action Programme: A Framework for combating desertification in Kenya, In the context of the United Nations Convention to Combat Desertification. National Environment Secretariat, Nairobi, Kenya.
- Rutten, M.M.E.M. 1992. *Selling wealth to buy poverty*. Verlag breitenbach publishers. Saarbrucken, Germany.
- Safriel, U.N. 2007. The Assessment of Global Trends in Land Degradation. In: Sivakumar, M.V.K. and N. Ndiangu' (Eds.). *Climate and Land Degradation*. Springer-Verlag Berlin Heidelberg.
- Sandford, S. 1983. *Management of pastoral development in the third world*. John Wiley and Sons, Chichester.

- Seaman, J., P. Clarke, T. Boudrea and J. Holt (Eds.). 2000. *The Household Economy Approach*. Save the Children *development Manual* No. 6. Save the Children, London.
- Sivakumar, M.V.K. and N. Ndiangu'i. 2007. *Climate and Land Degradation*. Springer-Verlag Berlin Heidelberg.
- Skovlin, J.M. 1986. Long-term trends from selected range sites throughout Kenya. In: Joss, P.J., P.W. Lynch and O.B. Williams (Eds). *Rangelands: A resource under siege. Proceedings of the second International Rangeland Congress*. Cambridge University Press.
- Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales, and C. de Haan. 2006 (Eds.). *Livestock's long shadow*. FAO, Rome.
- Stenfeld, H, H.A. Mooney, L.E. Neville, P. Gerber and R. Reid. 2008. *Livestock in a changing landscape*. Policy Brief No. 6. UNESCO-SCOPE_UNEP, Paris.
- Sutherland, R.A., R.B. Bryan and D.O. Wijendes. 1991. Analysis of the monthly and annual rainfall climate in a semi-arid environment, Kenya. *Journal of Arid Environments*, 20: 257 — 275.
- Tarras-Wahlberg H., D. Harper and N. Tarras-Wahlberg. 2003. A first limnological description of Lake Kichiritith, Kenya: a possible reference site for the freshwater lakes of the Gregory Rift Valley. *South African Journal of Science*, 99: 9 — 10.
- Thomas, D. 1998. Desertification and the Convention to Combat Desertification: Issues and links to poverty, natural resources and policies. SCID, Department of Geography, University of Sheffield.
- Thomas, G.W. 1986. Livestock production in sub-Saharan Africa: Pastoralists caught in fragile environment. In: Joss, P.J., P.W. Lynch and O.B. Williams (Eds). *Rangelands: A resource under siege. Proceedings of the second International Rangeland Congress*. Cambridge University Press.
- Tiffen, M. , M. Mortimore and F. Gichuki. 1994. *More people less erosion: Environmental recovery in Kenya*. John Wiley, London.
- Tokida, K. 2001, *The Study on the integrated Rural Development Project in the Baringo Semi Arid Land Area*, Master Plan, Japan International Cooperation Agency (JICA), Ministry of Agriculture and Rural Development (MOARD).
- Toulmin, C. 1993. Combating desertification: Setting the agenda for a global convention. IIED *Dryland Networks Paper, Issue Paper*, No 42.

- Turner, B.L., W.C Clark, R.W. Kates, J.F Richards, J.T.Mathews, W.B. Meyers (Eds). 1990. *The Earth as Transformed by Human Actions*. Cambridge University Press, Cambridge, UK.
- Umar, A. 1997. Resource Utilization, conflict and insecurity in pastoral areas of Kenya. Kenya Pastoral Forum. www.payson.Tulane.edu/conflict.
- UNCCD. 2003a. *An introduction of United Nations Convention to Combat Desertification*. United Nations.<http://www.unccd.int/publicinfo>.
- UNCCD. 2003b. Causes, general extent and physical consequences of land degradation in arid, semi-arid and dry sub-humid areas. <http://www.unccd.int/publicinfo>.
- UNEP. 2008. *Africa Atlas of our changing environment*. UNEP. www.na.unep.net/AfricaAtlas.
- UNEP/GEF. 2005. *Protecting the environment from land degradation*. UNEP's Action in the Framework of the Global Environment Facility. UNEP, Nairobi.
- United Nations Convention on Environment and Development (UNCED). 1992. Agenda 21: programme for action for sustainable development. United Nations. New York, USA.
- Verstraete, M.M. and B. Pinty. 1991. The potential contribution of satellite remote sensing to the understanding of arid lands process. *Vegetation*, 91: 59 –72.
- Wasonga, V.O., Ngugi, R.K., and Kitalyi, A. (2003). Traditional range condition and trend assessment: Lessons from the Pokot and Il Chamus pastoralists of Kenya. *Anthropologist*, 5 (2): 79 – 87.
- World Bank. 1990. *World Development Report*. Oxford University Press. Oxford
- Yassoglou, N.J. 2000. History and development of desertification in the mediterranean and its contemporary reality. In: Enne, G.C. Zanolla and D. Peter (Eds). *Desertification in Europe: mitigation strategies, land-use planning. Proceedings of the advanced study course*. Alghero, Sardinia, Italy 31 May-10 June, 1999. European Union, Brussels. 27 – 44.

CHAPTER FOUR

4.0 SPATIAL AND TEMPORAL RELATIONSHIPS BETWEEN LAND COVER, RAINFALL, HUMAN AND LIVESTOCK POPULATIONS IN THE NJEMPS FLATS

4.1 ABSTRACT

Spatially explicit identification of changes in social and ecological conditions is key to targeting and prioritizing areas for development interventions. GIS-based multi-temporal land-use data provides a historical vehicle for determining and evaluating long-term trends in bio-physical landscapes. Land-use and land cover assessment and mapping are some of the most useful applications of GIS for planning, management and development. This study was conducted in the Njemps Flats to determine the longitudinal relationship between land cover, land-use, rainfall variability, livestock and human populations over the past four decades. The geo-spatial analysis of the Njemps Flats landscape shows a close link between the declining herbaceous cover and rising human and livestock populations. The difference in vegetation structure between the two land-use systems is evident with the sedentary agro-pastoral land-use system showing an increase in closed woodland as opposed to increase in bare ground with scattered shrubs under the semi-nomadic pastoral land-use system. The expansion of the area under closed woodland is partly attributed to the invasion of the study area by *Prosopis juliflora*, an alien species introduced in the 1980s. While the mean annual rainfall showed high variability and a slight increase between 1966 and 2008, the total number of rain-days declined over the same period.

KEY WORDS: Geo-spatial analysis; land cover; land-use; rainfall trends; demographic Trends; Njemps Flats.

4.2 INTRODUCTION

In the past few decades, land-use and land cover in Kenya, like in the other parts of the world, have undergone remarkable changes. These changes are associated with growing human population, socio-political and economic changes that have resulted in increased exploitation of natural resources and changes in land-use and land cover. According to FAO (2006), rising human population and global climate change are among the key factors that have contributed towards the downward trends in the drylands of the world. UNEP (2008) points at expansion of agriculture as one of the main factors behind the general change in land cover in many parts of East Africa. In their report on land-use change analysis in East Africa, Maitima *et al.* (2004) indicated that the changes are fuelled by a growing demand for agricultural products that are necessary to improve food security and generate income, not only for the rural, but also for large-scale investors in commercial farming sector. In a study conducted in Afar and Tigray

regions of Ethiopia, Alemu *et al.* (2000) attributed the changing land-use mainly to settlement and cultivation of the semi-arid range areas.

Explicit identification of changes in social and ecological conditions is key to targeting and prioritizing areas for development interventions. A critical limitation to this point in the past was the development of methods to conduct such studies. However, currently the use of GIS technology can break old myths, add rigor to on-going analysis, and discover novel trends (Robbins, 2003). The application of computer systems and information technology in handling geographical and spatial data has become a necessity. The application of GIS facilitates new avenues of exploratory spatial data analysis that were previously not feasible and also enables the integration of data collected by different media, thereby substantially increasing the communication capabilities of those involved in resource management (Rainis *et al.*, 2003). GIS-based multi-temporal land-use data provides a historical vehicle for determining and evaluating long-term trends in bio-physical landscapes. Land-use and land cover assessment and mapping are some of the most useful applications of GIS for planning, management and development (Yang *et al.*, 2007).

Although land-use changes have been reported in all ecosystems of the world, their effects have been felt more in arid and semi-arid rangelands, especially in areas where traditional grazing lands have been converted into settlements and croplands. A number of studies have been conducted in the rangelands of Kenya to assess the land-use and land cover changes all pointing at massive changes of the arid and semi-arid landscapes. Maitima *et al.* (2004) and Campbell *et al.* (2003) reported land-use changes and associated land degradation mostly associated with expansion of arable lands at the expense of grazing lands in semi-arid areas of Loitokitok Division, Kajiado District and in Mbeere District, Kenya. Similar trends have been reported in the Mara Ecosystem by Serneels and Lambin (2001a and 2001b) in their study on the impact of land-use changes on the wildebeest migration in the northern part of the Serengeti-Mara ecosystem. They concluded that land-use change is a major driver of the habitat modification and can have important implications on the distribution of wildlife species and the entire ecological system.

In their study to evaluate the alternative land-use options in the Kitengela wildlife dispersal area, Kristjanson *et al.* (2002) found that rapidly increasing human population and changing

socio-economic lifestyles, and the associated greater natural resource exploitation are the major drivers of land-use changes in the area. They further argue that land-use policies and rapid changes in people's expectations over the past few decades have resulted in expansion of cultivation, growth in the number of permanent settlements, urbanisation and diversification of land-use activities in the arid and semi-arid rangelands. The numerous findings notwithstanding, this study takes cognisance of the spatial and temporal differences in causes, scale and impacts of social and ecological changes between areas, implying that findings from a given location may not be directly applied in another, and hence the need for more studies at local level for the purpose of constituting appropriate ameliorative actions. As noted by Serneels and Lambin (2001b), these changes are dynamic, diverse, and dependent upon both cultural and natural landscapes.

In Baringo District, Johansson and Svensson (2002) conducted a minor study using 1973, 1984 and 2000 LANDSAT-ETM images to assess the general trends in land degradation in Lake Baringo catchment. Mwasi (2004) in his study in Baringo District focused on landscape change dynamics between 1984 and 1995. Other studies on these aspects included Onyando *et al.*, (2005), Odada and Olago (2004) and Crawley (2001), all pointing at increasing land degradation in the lake Baringo basin and blaming overgrazing and other unsustainable land-uses for the downward trend in the range condition. However, none has been able to explicitly assess the long-term correlation between these causal agents and land degradation. The current study was conducted in the Njemps Flats to determine the longitudinal relationships between land cover, land-use, rainfall variability, livestock and human populations over the last four decades.

4.3 METHODS

4.3.1 Data collection and analysis

4.3.1.1 Land cover

Satellite imagery scenes for the Njemps Flats in Baringo District, Kenya were used for the land cover analysis. The images were obtained from Department of Resource Surveys and Remote Sensing (DRSRS) in Nairobi. LANDSAT-ETM scenes for 1973, 1986, 2000 and Aster image for 2008 (Figure 4.0 and 4.1) were selected for the geo-spatial analysis to identify and delineate vegetation and land cover types, and explore land cover trends for the past four decades. The image dates were arrived at considering availability, quality (cloud cover) and season. All the images selected for the analysis had a cloud cover of $\leq 10\%$ and were those taken during the dry seasons to avoid overestimation of vegetation cover. Initially, a ten-year interval between the image dates, one for each decade was proposed. However, it was not possible to achieve this as some of the preferred images had a cloud cover of more than 10%, while others were either unavailable or taken during the wet seasons. Ground-truthing or field checks were done in 15 randomly selected representative points of various vegetation types to verify those classes obtained during visual interpretation. Each point was visited and its coordinates registered using a hand-held Global Positioning System (GPS). Visual percent vegetation cover of each land cover class was recorded around each point in various directions as far as possible in the entire delineated vegetation to obtain the common species and principal vegetation structure in the entire polygon (area).

1. land cover classes were delineated;

2. Open shrubland (areas covered by bare rock and scattered shrubs);

3. Open woodland (areas covered bare rock and scattered trees);

4. Areas covered by bare soil devoid of vegetation;

5. Flooded water reservoirs;

6. Irrigation fields;

7. Areas covered by swamps;

8. Shrubland (scattered shrubs with herbaceous cover);

9. Woodland (scattered trees with herbaceous cover);

10. Water (areas covered by lakes and rivers)

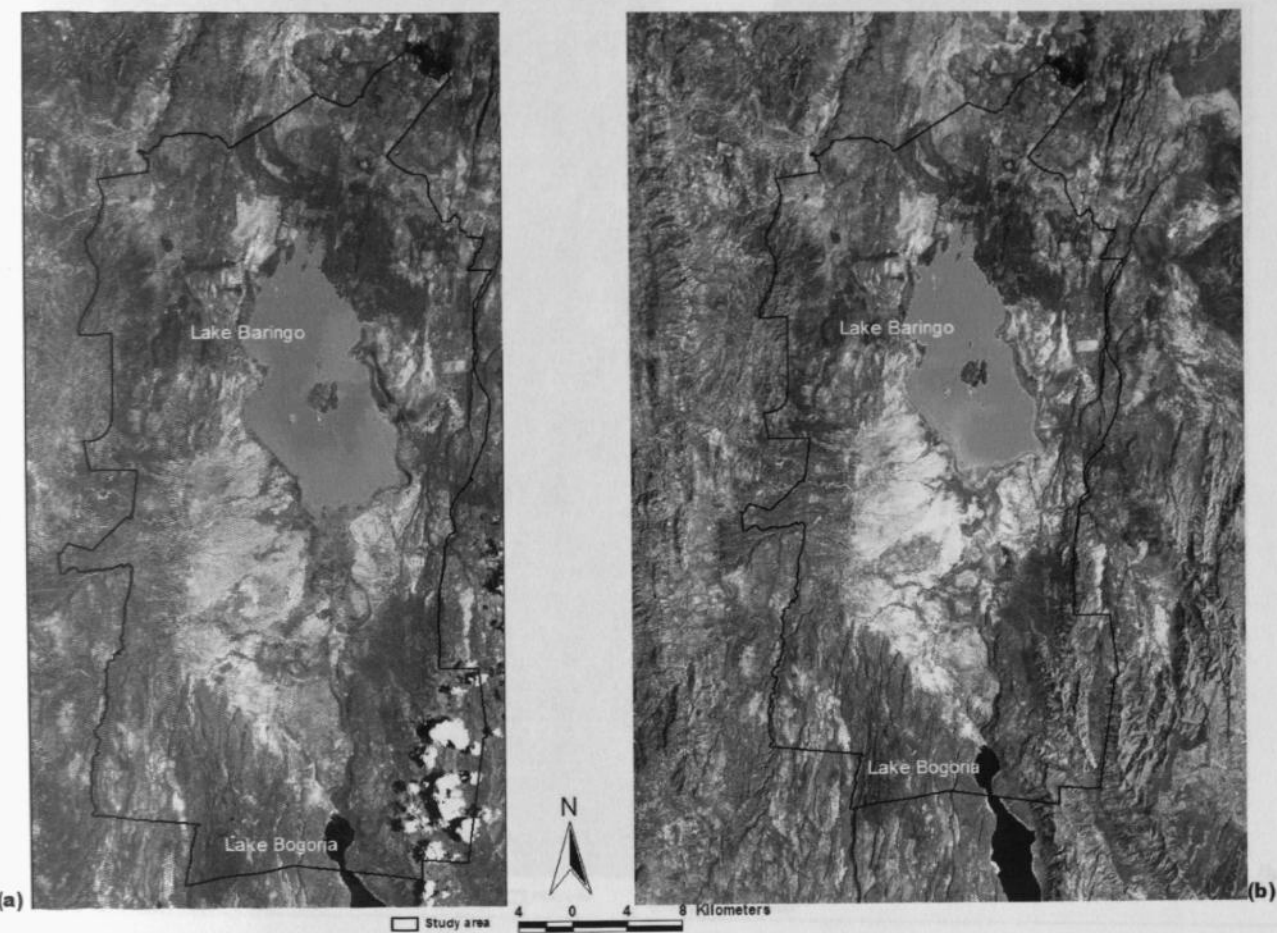


Figure 4.0: Aster image for 2008 (a) and LANDSAT-ETM image for 2000 (b)

A classification indicating land cover and vegetation type based on the vegetation associations and the degree of openness in vegetation provided a physiognomic classification for each map.

The following land cover classes were delineated:

- a) Bare rock/Open shrubland (areas covered by bare rock and scattered shrubs).
- b) Bare rock/Open woodland (areas covered bare rock and scattered trees)
- c) Bare land (areas covered by bare soil devoid of vegetation)
- d) Dam (excavated water reservoirs)
- e) Irrigated agriculture (irrigation fields)
- f) Marshland (areas covered by swamps)
- g) Open shrubland (scattered shrubs with herbaceous cover)
- h) Open woodland (scattered trees with herbaceous cover)
- i) Water body (areas covered by lakes and rivers)

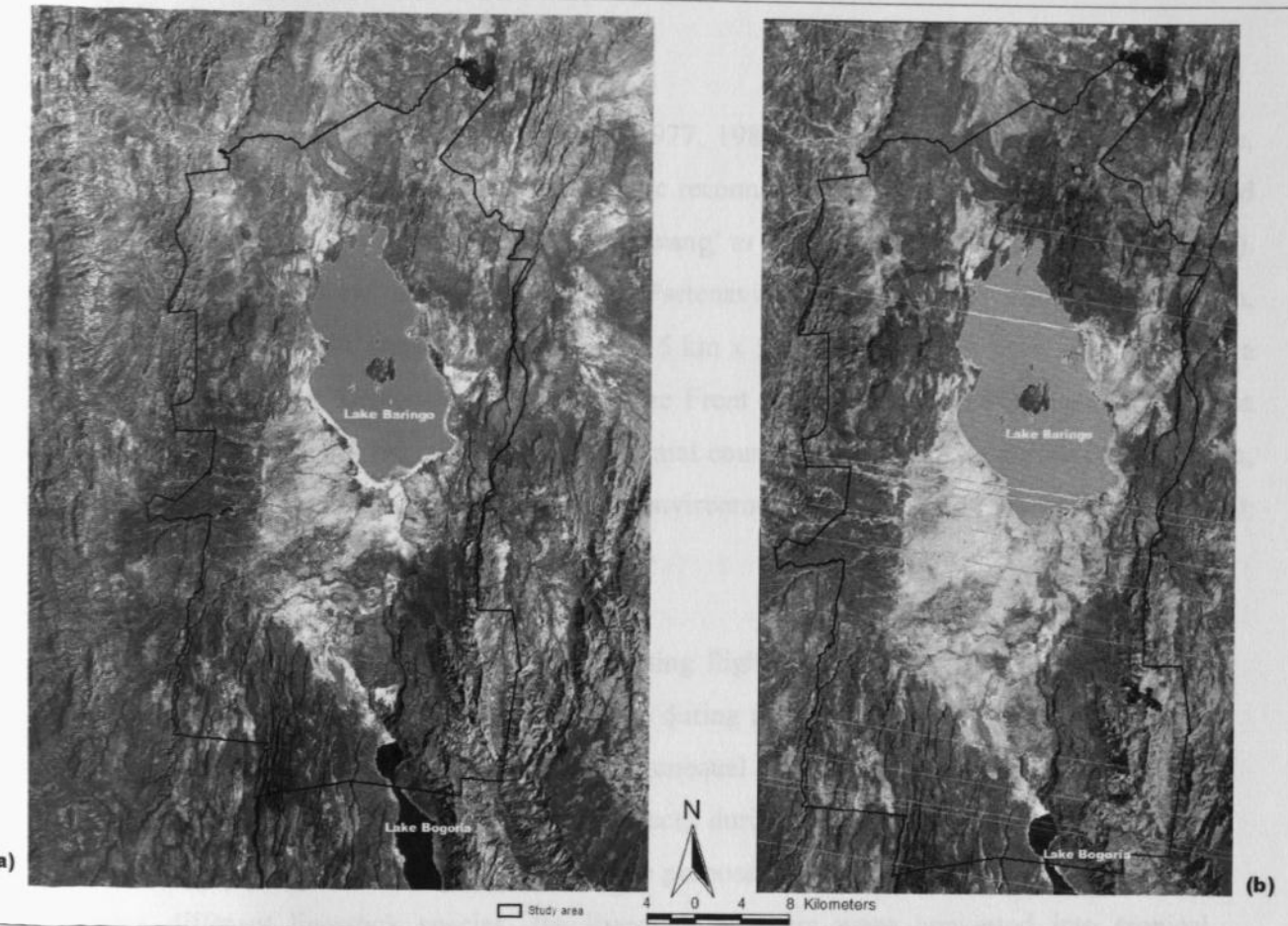


Figure 4.1: LANDSAT-ETM image for 1986 (a) and 1973 (b)

4.3.1.2 Rainfall data

The long-term rainfall data (1966 – 2008) for two weather stations in the study area were obtained from the Kenya Meteorological Department (KMD). The data were collected from Perkerra and Snake Park meteorological stations, located on sites under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems, respectively. These data were collated and analyzed using Genstat statistical package version 9.1 (Lawes Agricultural Trust, 2006) to generate descriptive statistics. The long-term mean annual rainfall, annual variance, the total monthly and annual rain-days were computed for the purpose of obtaining intra-and inter-monthly and annual variations in rainfall during the past four decades.

4.3.1.3 Livestock population

Aerial census livestock population data for 1977, 1986 and 1994, each presenting a decade, were obtained from the DRSRS. The systematic reconnaissance flight (SRF) methodology used in collecting the data is fully described by Ojwang' *et al.* (2006) and Norton-Griffiths (1978). The censuses were done using a high winged Partenavia aircraft equipped with GPS, intercom, and radar altimeters. A sampling resolution of 5 km x 5 km was used. A crew comprising of a pilot, two Rear Seat Observers (RSO) and one Front Seat Observer (FSO) were involved in every flight. The RSO are responsible for animal counts, while the FSO assists in navigation, crew coordination and recording of general environmental parameters (Muriuki *et al.*, 2000; 1998).

A GPS was used as navigation tool for mapping flight line tracking, and geo-referencing geographical locations where counts are made during the survey. The population estimates were calculated using Jolly (II) method of unequal transect length (Jolly 1969). The livestock numbers recorded within the transects during the census were converted into livestock densities (numbers per km²). For the purpose of standardization and comparisons across different livestock species, the livestock numbers were converted into tropical livestock units (TLU). One TLU was taken as an equivalent of a mature live animal weighing 250 kg (KARI/ODA, 1996). A mature cow or bull was, therefore, equal to 1 TLU, a sheep = 0.1 TLU, a goat = 0.1 TLU, a donkey = 0.5 TLU and a camel = 1.25 TLU. A combination of data analysis and mapping procedure was achieved by using ArcView software version 3.3 of the GIS component (Environmental Systems Research Institute (ESRI), 2003). Data interpretation and classification was done using appropriate coding and the distribution maps were compiled, annotated and plotted at desired scale.

4.3.1.4 Human population

The Human population data was obtained from the Kenya National Bureau of Statistics (KNBS) and DRSRS. These data comprised of the censuses of 1979, 1989 and 1999 conducted by the Ministry of Planning and National Development, Republic of Kenya. The data were segregated by sub-locations that fall within the Njemps Flats in Baringo District, Kenya. After computing human densities per sub-location, the data were converted into spatial form and analyzed using

ArcGIS software version 9.0 (ESRI, 2004) to produce population maps for the purpose of determining spatial and temporal trends.

4.4 RESULTS AND DISCUSSIONS

4.4.1 Land cover trends

Figures 4.2, 4.3 and 4.4 present land cover while Figures 4.5 – 4.10 are land cover maps showing the land cover classes as well as spatial and temporal patterns for the Njemps Flats from 1973 – 2008. The results show that scattered shrubs on bare ground occupied the largest area ($74,341.67 \pm 11$ ha) in 1973. This increased to $79,651.59 \pm 11$ ha in 1986 and $81,124.07 \pm 11$ ha in 2000 and 2008. A corresponding decrease in area covered by open shrubs with herbaceous understorey from $29,006.96 \pm 22$ ha in 1973 to $16,072.29 \pm 22$ ha in 2008 is an indication that herbaceous cover is declining in the study area. Open woodland with bare understorey currently covered only 0.25% of the total study area and did not show significant change during the four-decade period. Bare ground areas formed only 1.05% of the total land area of the Njemps Flats in 1973 and 1986 but slightly decreased to 1% in 2000 and 2008. The decline in bare ground in 2008 is consistent with the increase in closed woodland from $15,095 \pm 13$ ha in 1973 to $21,788 \pm 13$ ha in 2008, and indication of bush encroachment in the Njemps Flats. Decline in herbaceous cover as well as conversion of grazing land into closed woodlands are perceived as indicators of land degradation.

Area under irrigated agriculture has been expanding during the last four decades. Irrigation fields occupied only $1,401.78 \pm 63$ ha in 1973 compared to $3,415 \pm 63$ ha in 2008. Marshlands initially increased from $4,743.83 \pm 16$ ha in 1973 to $5,519.17 \pm 16$ ha in 1986 then declined to 2406.17 ± 16 ha in 2000 and slightly increased to $3,441.82 \pm 16$ ha in 2008. The decline in marshlands is attributed to continuous grazing and conversion of swamps into croplands by sedentary pastoralists seeking alternative sources of income and food. Area covered by the lakes and rivers declined steadily from $16,525 \pm 28$ ha in 1973 to $1,506.82 \pm 28$ ha in 1986, $15,094.41 \pm 28$ ha in 2000 and $14,629.55 \pm 28$ ha in 2008.

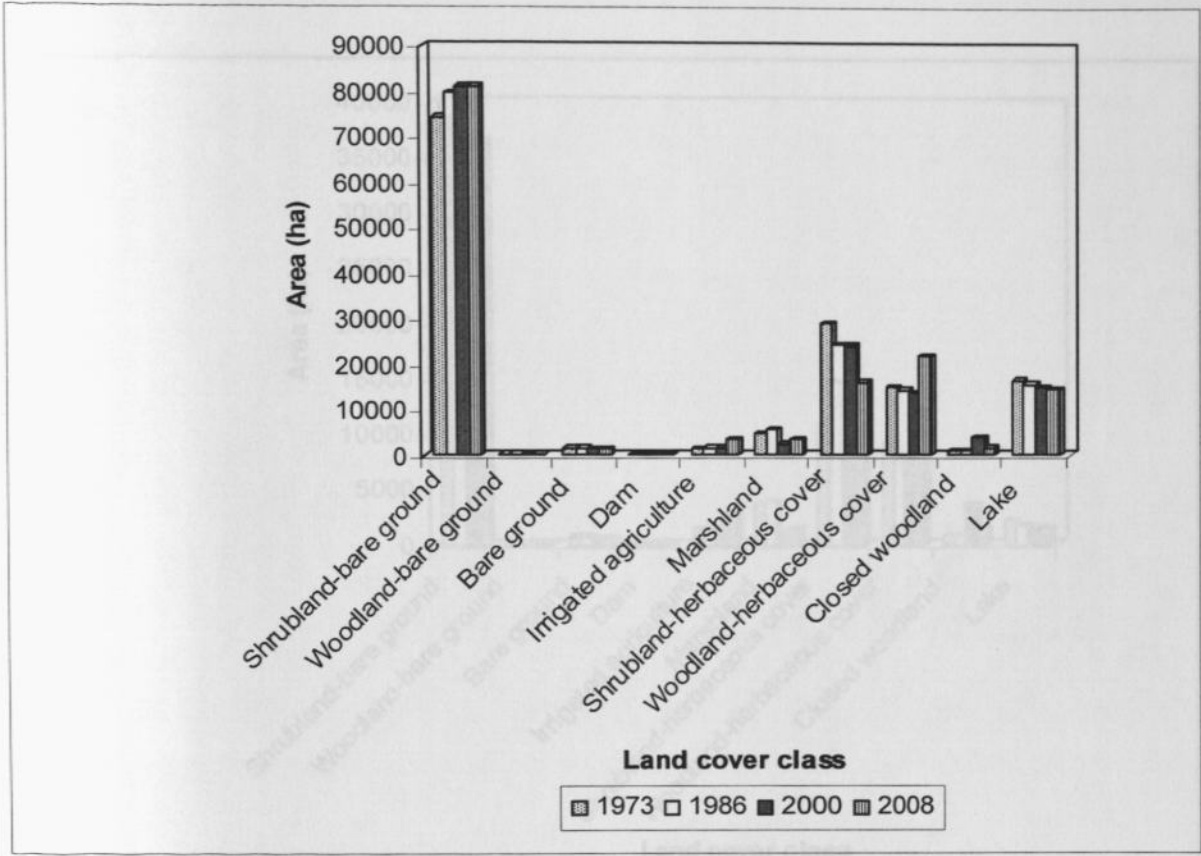


Figure 4.2: Land cover in the Njemps Flats during 1973 – 2008

Whereas bare ground showed a slight decrease in the sedentary agro-pastoral land-use system (741.87 ± 20 ha in 1973 to 672.56 ± 20 ha in 2008), no significant change was observed in the semi-nomadic pastoral land-use system (765.54 ± 00 ha). Closed woodland was found to be increasing faster and consistently higher in the sedentary agro-pastoral land-use system (878.87 ± 66 ha in 1973 to 1591.15 ± 66 ha in 2008) than in the semi-nomadic pastoral land-use system (0 to 1.03 ± 63 ha). Irrigated agriculture more than doubled under sedentary agro-pastoral land-use system from 1401.78 ± 32 ha in 1973 to 2808.30 ± 32 ha in 2008) compared to semi-nomadic pastoral land-use system (0 in 1973 to 607.23 ± 15 ha in 2008).

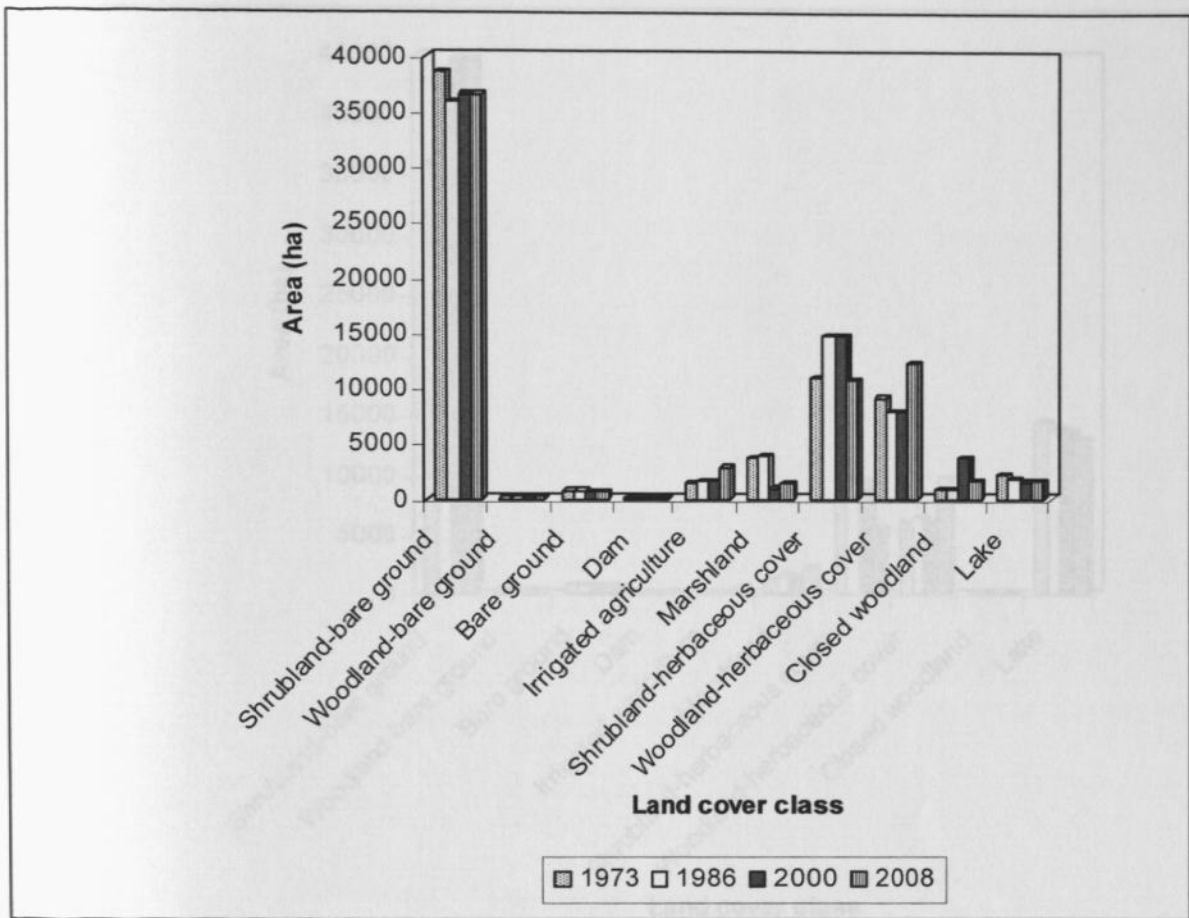


Figure 4.3: Land cover under semi-nomadic pastoral land-use system in the Njemps Flats during 1973 – 2008

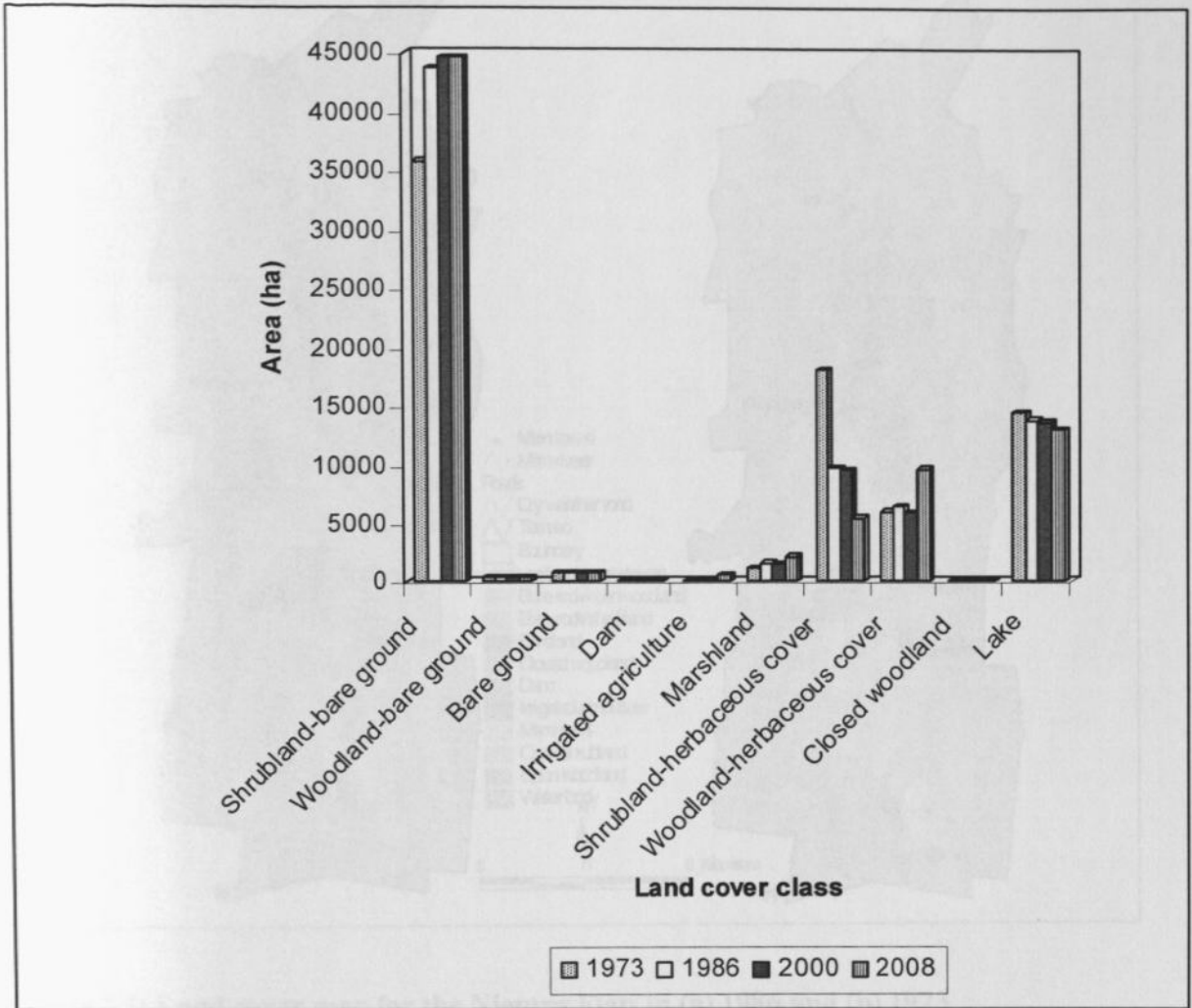


Figure 4.4: Land cover under sedentary agro-pastoral land-use system in the Njemps Flats during 1973 – 2008

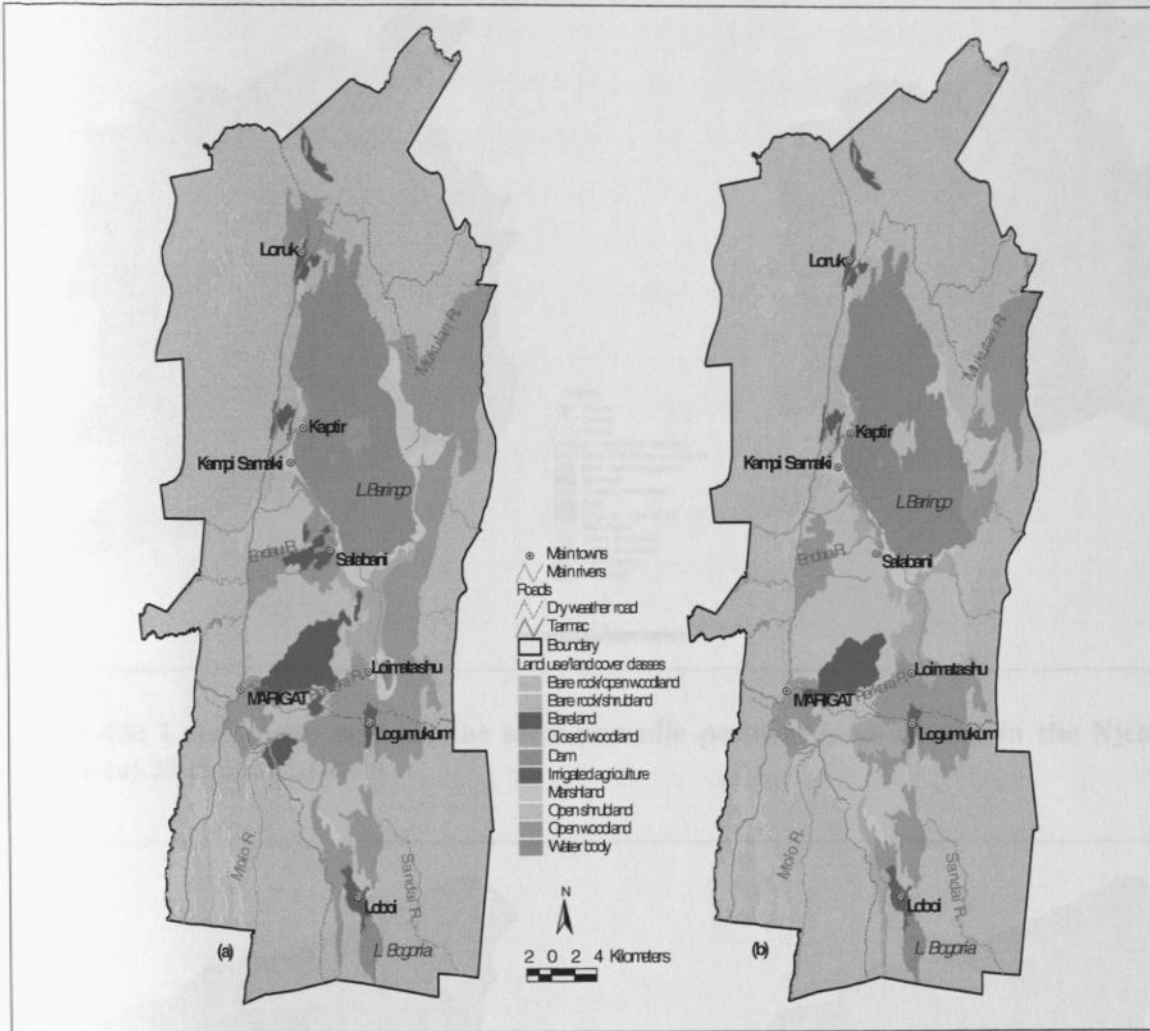


Figure 4.8: Land cover map for the Njemps Flats in (a) 2008 and (b) 2000

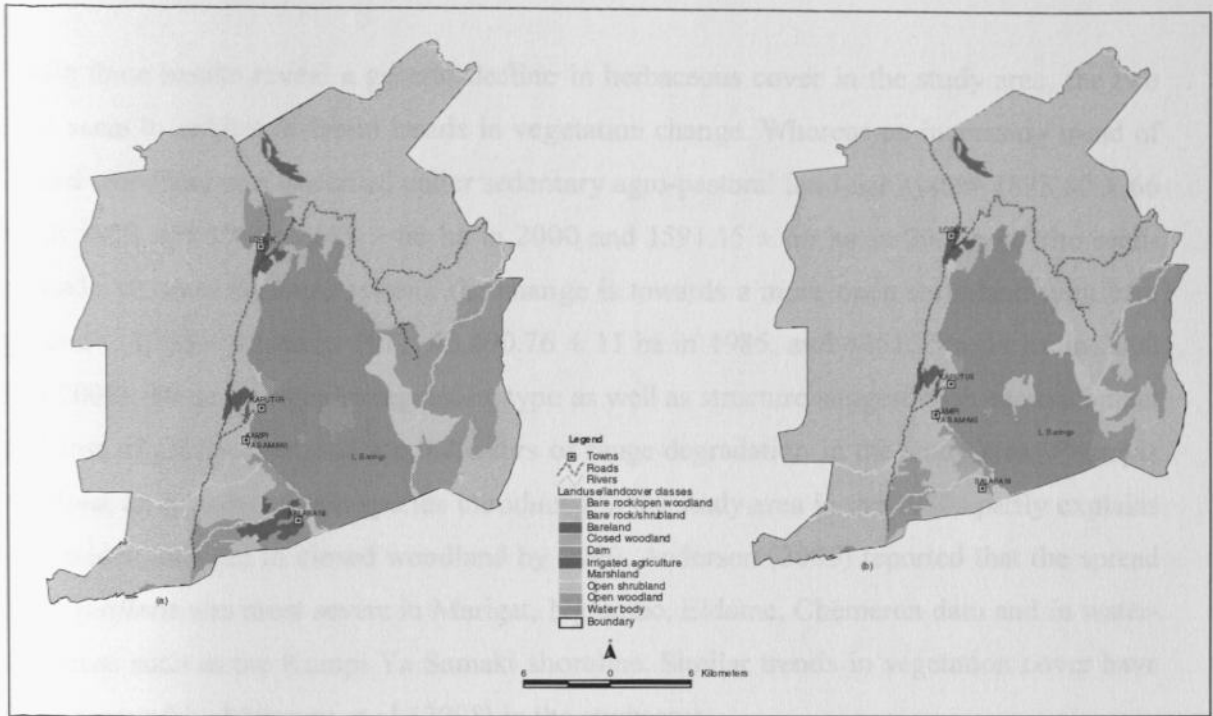


Figure 4.9: Land cover map for the semi-nomadic pastoral land-use site in the Njemps Flats in (a) 2008 and (b) 2000

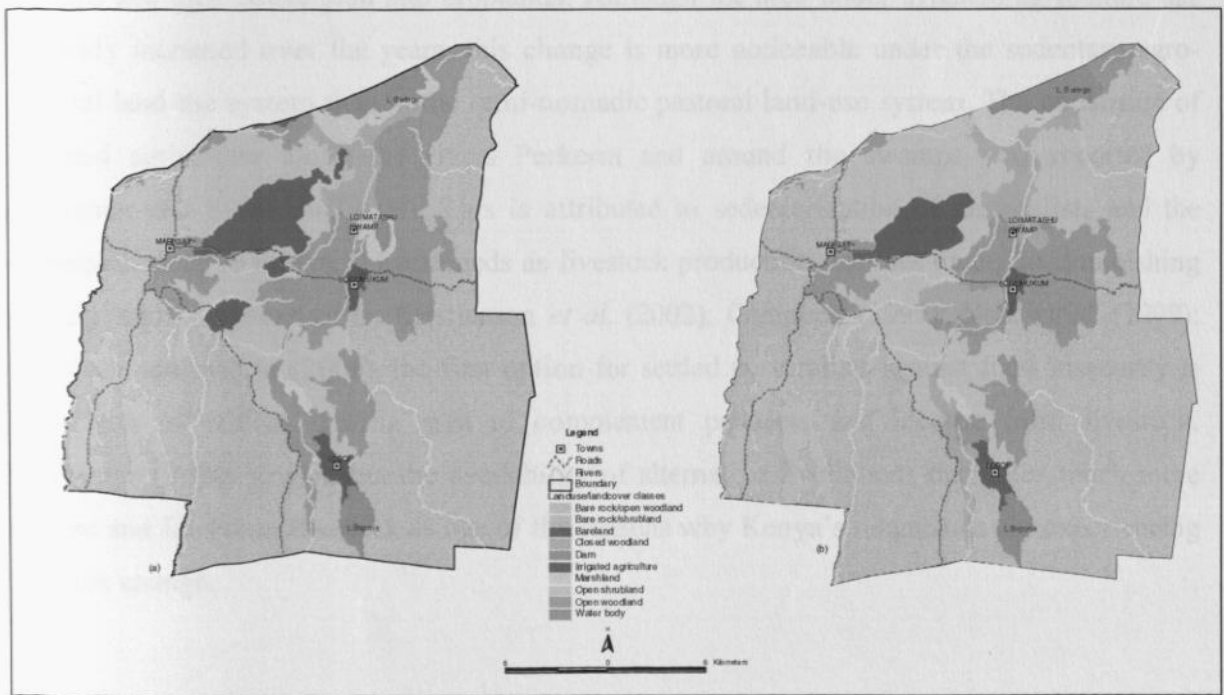


Figure 4.10: Land cover map for the sedentary agro-pastoral land-use site in the Njemps Flats in (a) 2008 and (b) 2000

While these results reveal a general decline in herbaceous cover in the study area, the two sites seem to exhibit different trends in vegetation change. Whereas an increasing trend of closed woodland was observed under sedentary agro-pastoral land-use system (878.87 ± 66 ha in 1973 and 1986, $3,685 \pm 66$ ha in 2000 and 1591.15 ± 66 ha in 2008), in the semi-nomadic pastoral land-use system, the change is towards a more open shrubland with bare ground ($35,763 \pm 11$ ha in 1973, $43,690.76 \pm 11$ ha in 1986, and 4451.75 ± 11 ha in 2000 and 2008). These changes in vegetation type as well as structure suggest bush encroachment and loss of grass cover, and are indicators of range degradation in the study area. *Prosopis juliflora*, an invasive exotic species introduced in the study area in the 1980s partly explains the sudden increase in closed woodland by 2000. Anderson (2005) reported that the spread of *P. juliflora* was most severe in Marigat, Ng'ambo, Eldume, Chemeron dam and in water-fed areas such as the Kampi Ya Samaki shoreline. Similar trends in vegetation cover have been reported by Marangu *et al.* (2008) in the study area.

A decrease in areas classified as marshlands can be attributed to the continuous grazing of swamps and their conversion into croplands. Although the area under irrigated agriculture has generally increased over the years, this change is more noticeable under the sedentary agro-pastoral land-use system than in the semi-nomadic pastoral land-use system. The expansion of irrigated agriculture along the rivers Perkerra and around the swamps was reported by Johansson and Svensson (2002). This is attributed to sedentarization of pastoralists and the subsequent need to diversify livelihoods as livestock production declines owing to diminishing grazing land. As observed by Kristjanson *et al.* (2002); Campbell (1999); Noor *et al.* (1999); and Roth and Fratkin (2005), the first option for settled pastoralists against food insecurity is cultivation of critical grazing area to complement products and income from livestock. Nkedianye (2004) singled out the availability of alternative livelihoods that offer much more income and food than livestock as one of the reasons why Kenya's rangelands are experiencing land-use change.

4.4.2 Rainfall trends

Rainfall data collected at the KARI, Perkerra meteorological station indicate 21 years of annual rainfall below the long-term average of 674 mm. Below average annual rainfall was recorded consistently at this station between 2000 and 2008 (Figure 4.11). This pattern corresponds to the mild droughts experienced at an interval of 3 – 5 years during the last four decades. During 1966 – 2008, the lowest rainfall was recorded in (January 22.2 mm) and December (21.6 mm), while the highest rainfall was recorded in the month of April (100 mm) and July (96.6 mm) (Figure 4.12). These patterns show no variance from the expected rainfall peaks in April and July (Davies *et al.* 1995). Rain-days recorded in Perkerra show a steady decline between 1966 and 2008 but inconsistent with the mean annual amounts. This implies that while rainfall events have been decreasing, in many instances the intensities have increased. This explains in part the increasing soil erosion reported in the study area (de Groot *et al.*, 1992; Meyeroff, 1991; Snelder and Bryan, 1995; Rowntree, 1988).

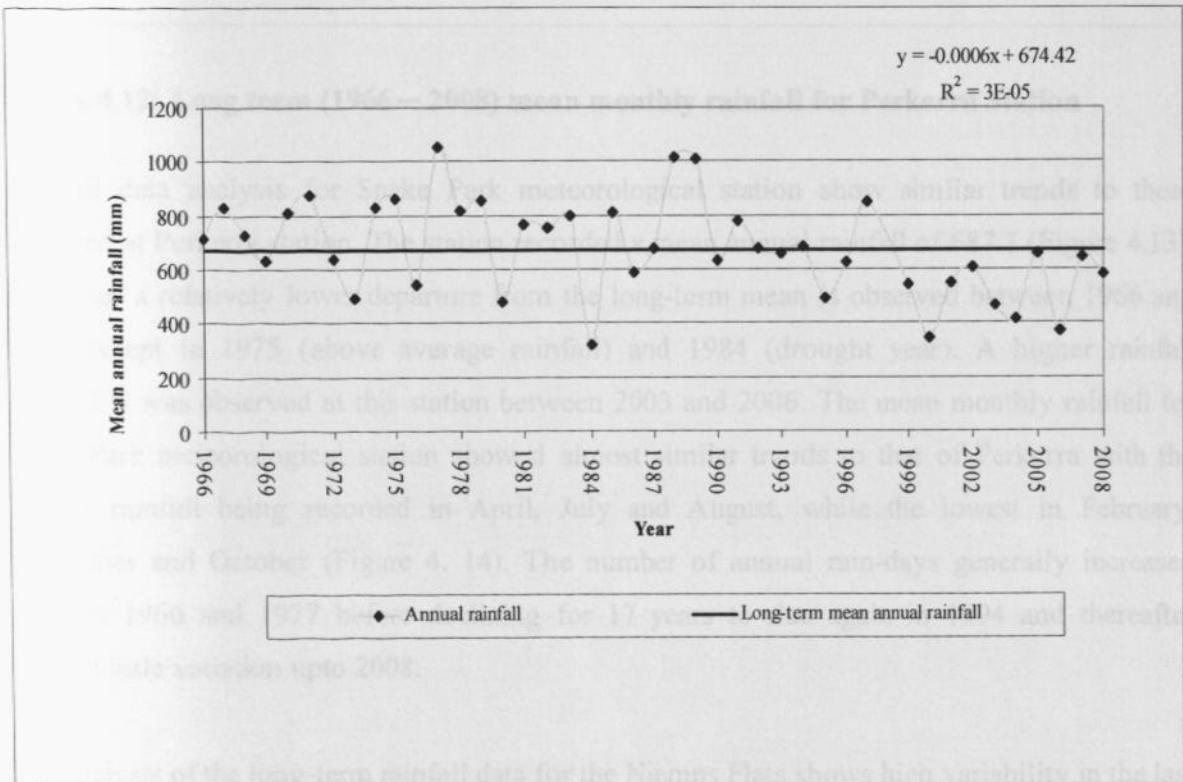


Figure 4.11: Long term (1966 – 2008) mean annual rainfall for Perkerra Station in the Njemps Flats

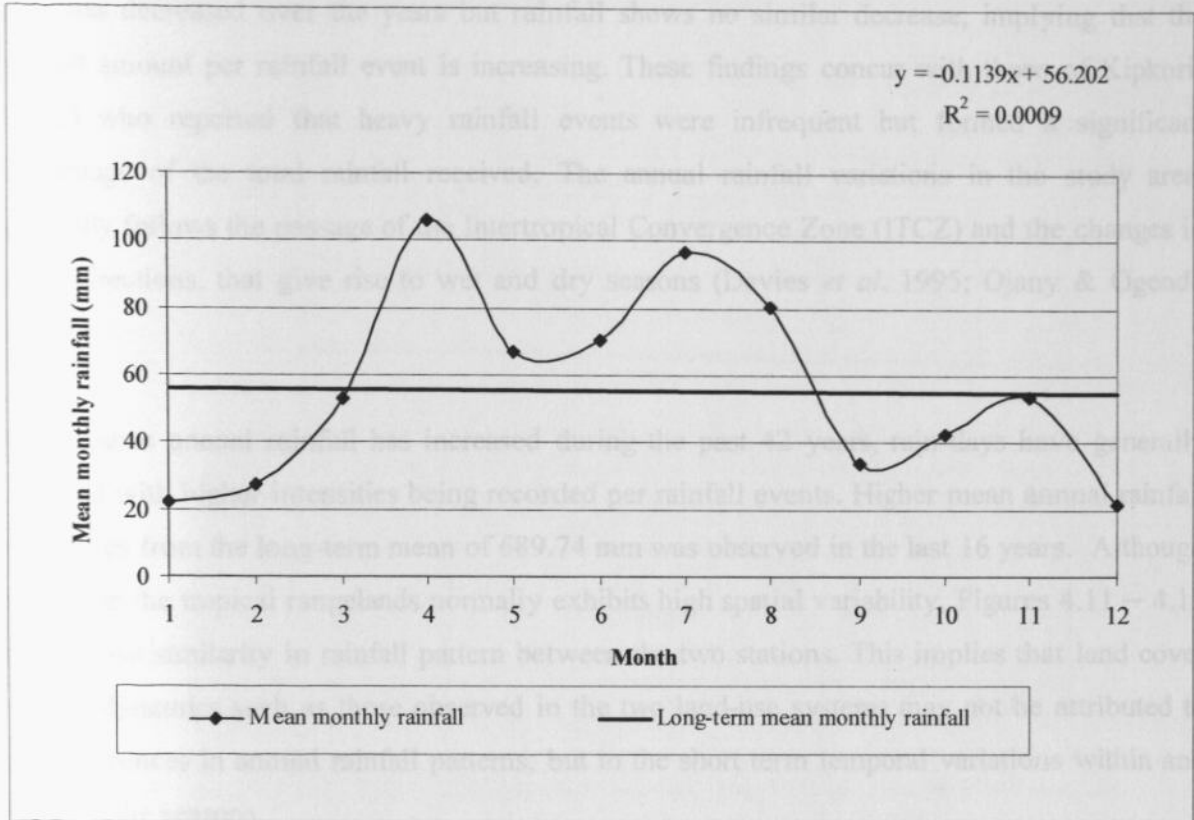


Figure 4.12: Long term (1966 – 2008) mean monthly rainfall for Perkerra Station

Rainfall data analysis for Snake Park meteorological station show similar trends to those observed at Perkerra station. The station recorded a mean annual rainfall of 687.3 (Figure 4.13). However, a relatively lower departure from the long-term mean is observed between 1966 and 2002 except in 1975 (above average rainfall) and 1984 (drought year). A higher rainfall variability was observed at this station between 2003 and 2006. The mean monthly rainfall for snake Park meteorological station showed almost similar trends to that of Perkerra with the highest rainfall being recorded in April, July and August, while the lowest in February, September and October (Figure 4. 14). The number of annual rain-days generally increased between 1966 and 1977 before declining for 17 years to rise again in 1994 and thereafter showed little variation upto 2008.

The analysis of the long-term rainfall data for the Njemps Flats shows high variability in the last three decades, the minimum annual rainfall being 177 ± 42 mm and the highest, $1,512 \pm 42$ mm. The monthly means have been equally variable with minimum being 22.9 ± 8.3 mm and maximum of 101.8 ± 8.3 mm, and a standard deviation of 28.6. Annually, the number of rain-

days has decreased over the years but rainfall shows no similar decrease, implying that the rainfall amount per rainfall event is increasing. These findings concur with those of Kipkorir (2002) who reported that heavy rainfall events were infrequent but formed a significant percentage of the total rainfall received. The annual rainfall variations in the study area, generally follows the passage of the Intertropical Convergence Zone (ITCZ) and the changes in wind directions, that give rise to wet and dry seasons (Davies *et al.* 1995; Ojany & Ogendo 1988).

While mean annual rainfall has increased during the past 42 years, rain-days have generally declined with higher intensities being recorded per rainfall events. Higher mean annual rainfall departures from the long-term mean of 689.74 mm was observed in the last 16 years. Although rainfall in the tropical rangelands normally exhibits high spatial variability, Figures 4.11 – 4.15 show close similarity in rainfall pattern between the two stations. This implies that land cover change dynamics such as those observed in the two land-use systems may not be attributed to the differences in annual rainfall patterns, but to the short term temporal variations within and between the seasons.

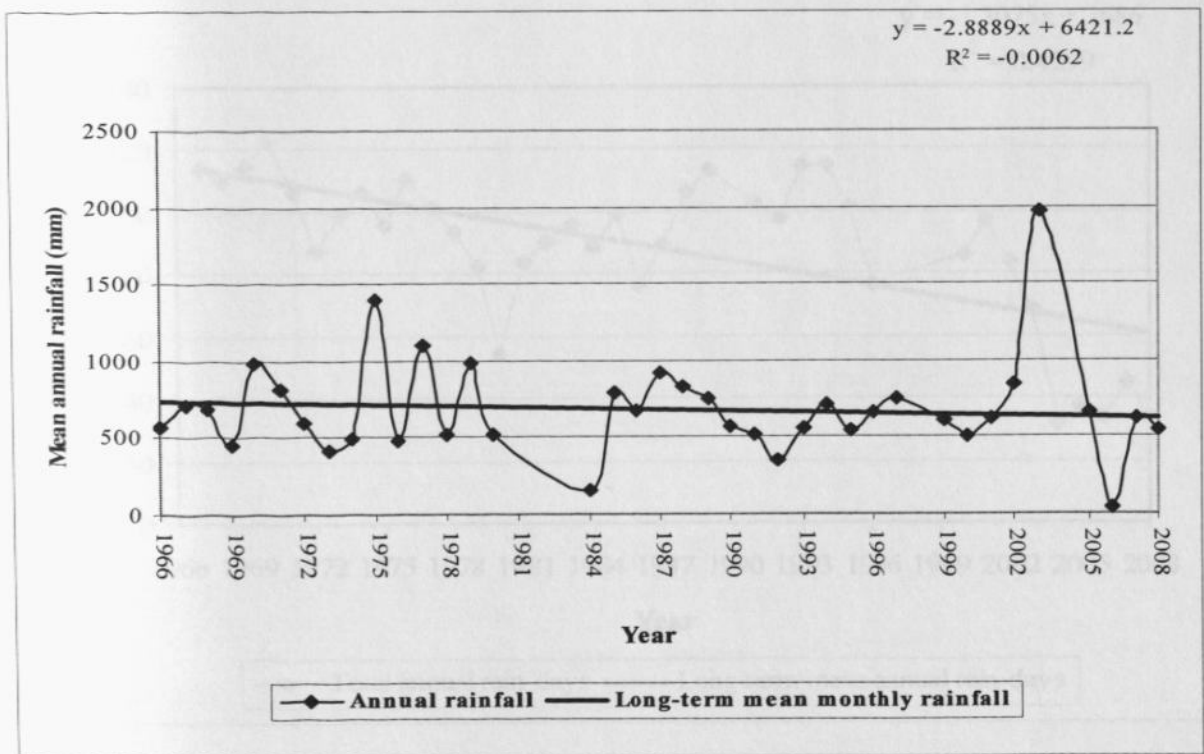


Figure 4.13: Long term (1966 – 2008) mean annual rainfall for Snake Park Station

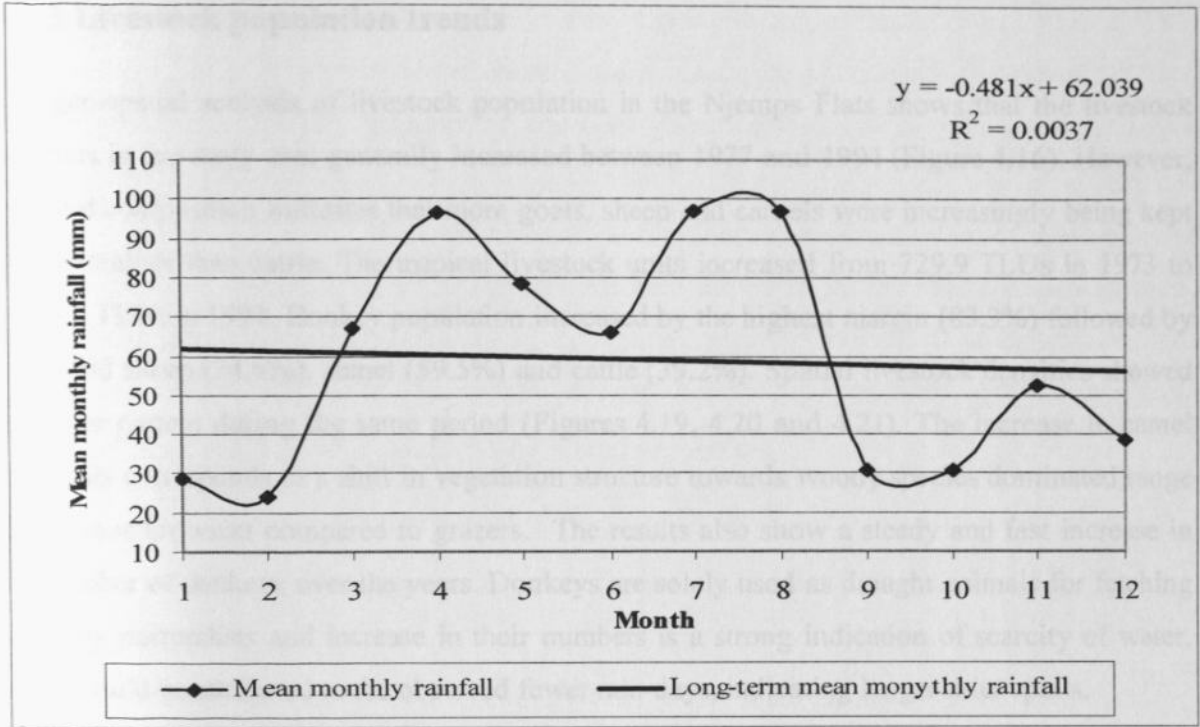


Figure 4.14: Long term (1966 – 2008) mean monthly rainfall for Snake Park Station

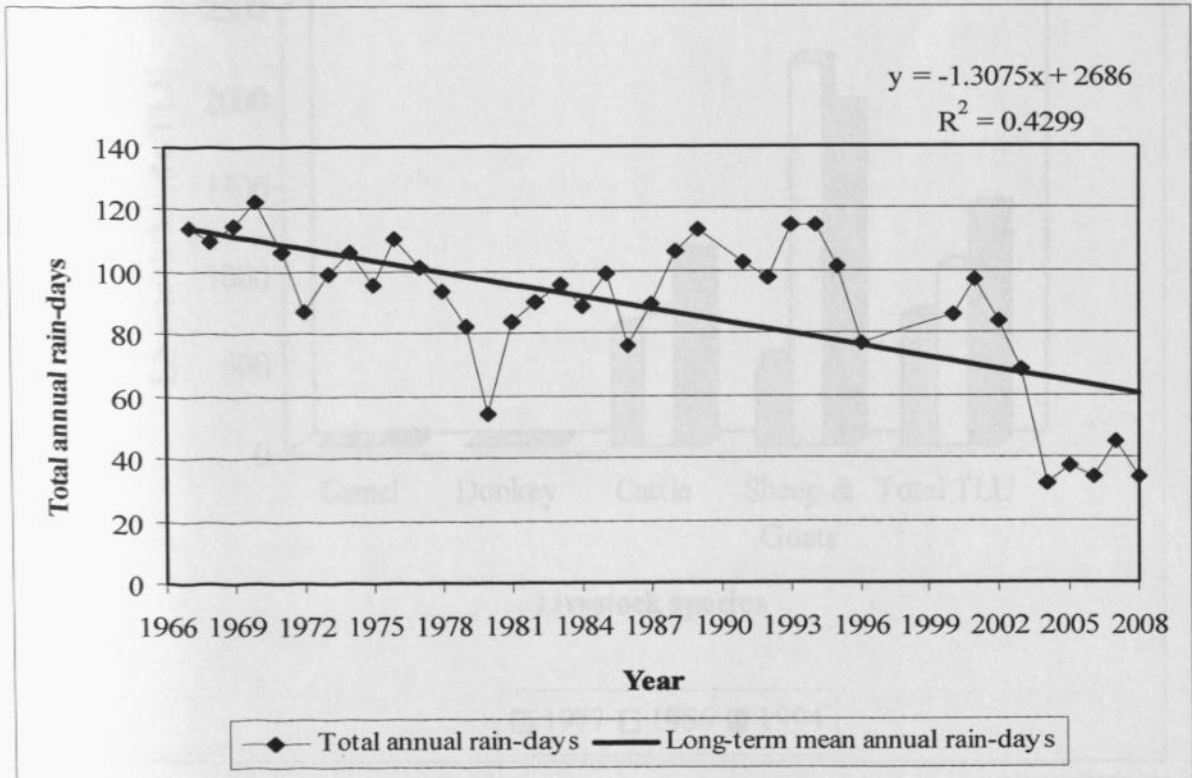


Figure 4.15: Long term (1966 – 2008) total annual rain-days in the Njempes Flats

4.4.3 Livestock population trends

The geo-spatial analysis of livestock population in the Njemps Flats shows that the livestock numbers in the study area generally increased between 1977 and 1994 (Figure 4.16). However, the herd composition indicates that more goats, sheep and camels were increasingly being kept by pastoralists than cattle. The tropical livestock units increased from 729.9 TLUs in 1973 to 1,334.5 TLUs in 1994. Donkey population increased by the highest margin (83.3%) followed by goats and sheep (74.6%), camel (59.5%) and cattle (39.2%). Spatial livestock densities showed a similar pattern during the same period (Figures 4.19, 4.20 and 4.21). The increase in camel and goats corresponds to a shift in vegetation structure towards woody species dominated range that favour browsers compared to grazers. The results also show a steady and fast increase in the number of donkeys over the years. Donkeys are solely used as draught animals for fetching water by pastoralists and increase in their numbers is a strong indication of scarcity of water, which could be attributed to the observed fewer rain-days, indicating longer drier spells.

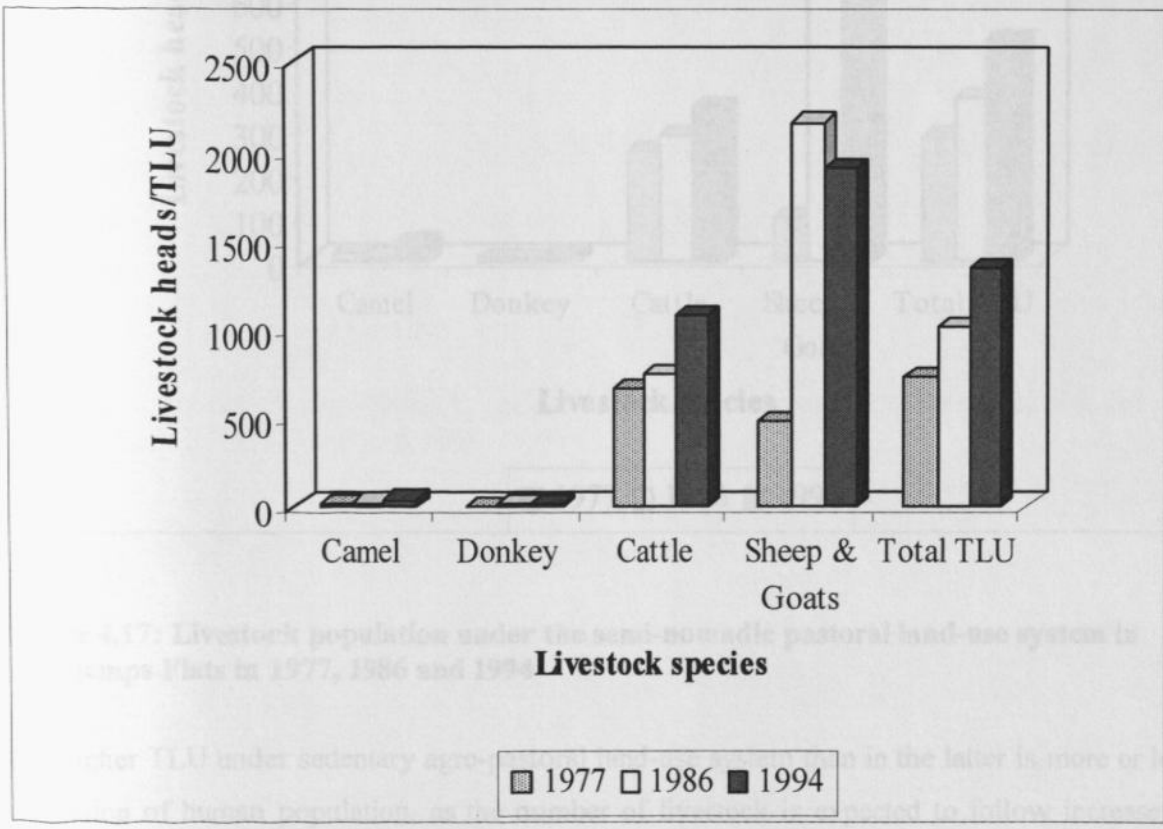


Figure 4.16: Livestock population in the Njemps Flats in 1977, 1986 and 1994

Comparing the two land-use systems, livestock population under the sedentary agro-pastoral land-use system was almost twice that in the semi-nomadic land-use system between 1977 and 1994 (Table 4.17 and 4.18). Whereas the trends in other livestock species are similar in the two land-use types, no camel and donkey was observed under sedentary agro-pastoral land-use system in 1977 and 1994. This is, however, attributable to cultural differences among the communities that inhabit the Njemps Flats—almost all the camel in the study area belong to the Pokot community and are therefore found in the semi-nomadic pastoral land-use system. The results also show higher cattle, sheep and goats population in the sedentary agro-pastoral land-use system than under semi-nomadic pastoral land-use system.

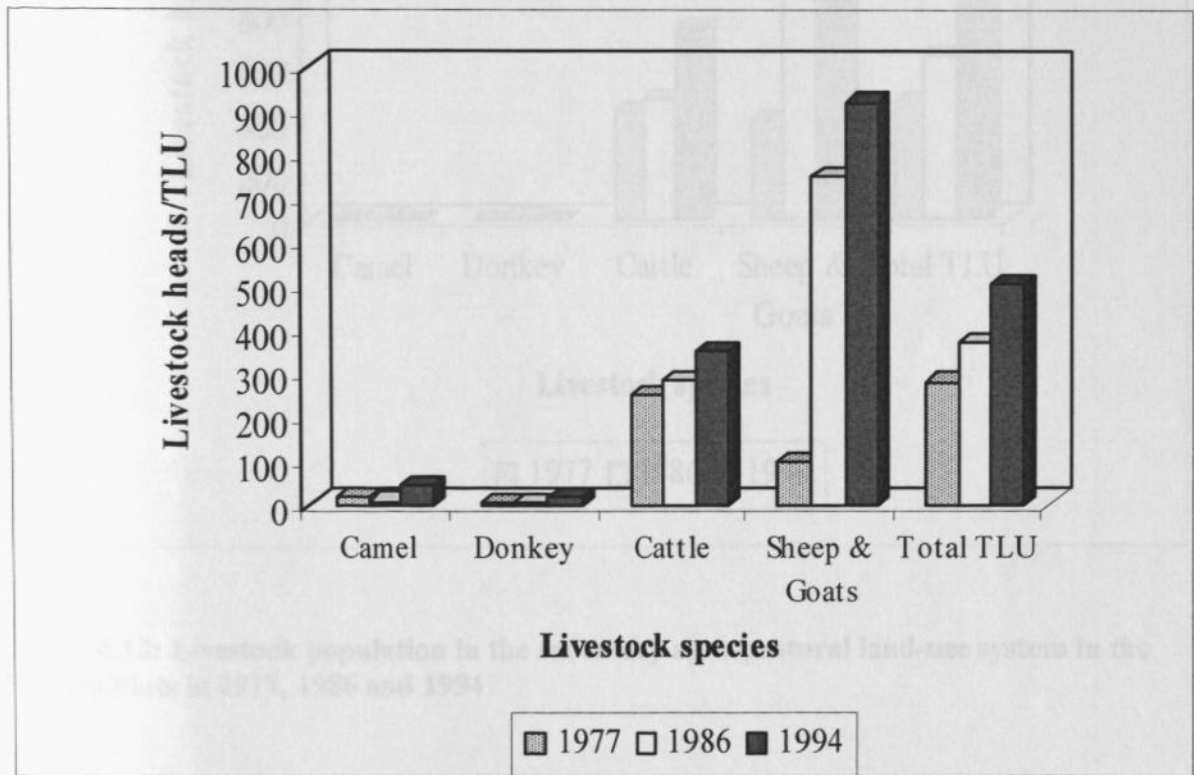


Figure 4.17: Livestock population under the semi-nomadic pastoral land-use system in the Njemps Flats in 1977, 1986 and 1994

The higher TLU under sedentary agro-pastoral land-use system than in the latter is more or less a function of human population, as the number of livestock is expected to follow increase in human population. Similar results have been reported in the southern rangelands of Kajiado, Kristjanson *et al.* (2002) found that livestock population in the Kitengela wildlife dispersal area

has been rising despite a setback due to drought between 1990 and 1996. Such trends have a myriad of associated implications on the environment. They reported an increase in wildlife-human conflict as one of the problems arising from the increase in livestock population in Kitengela area.

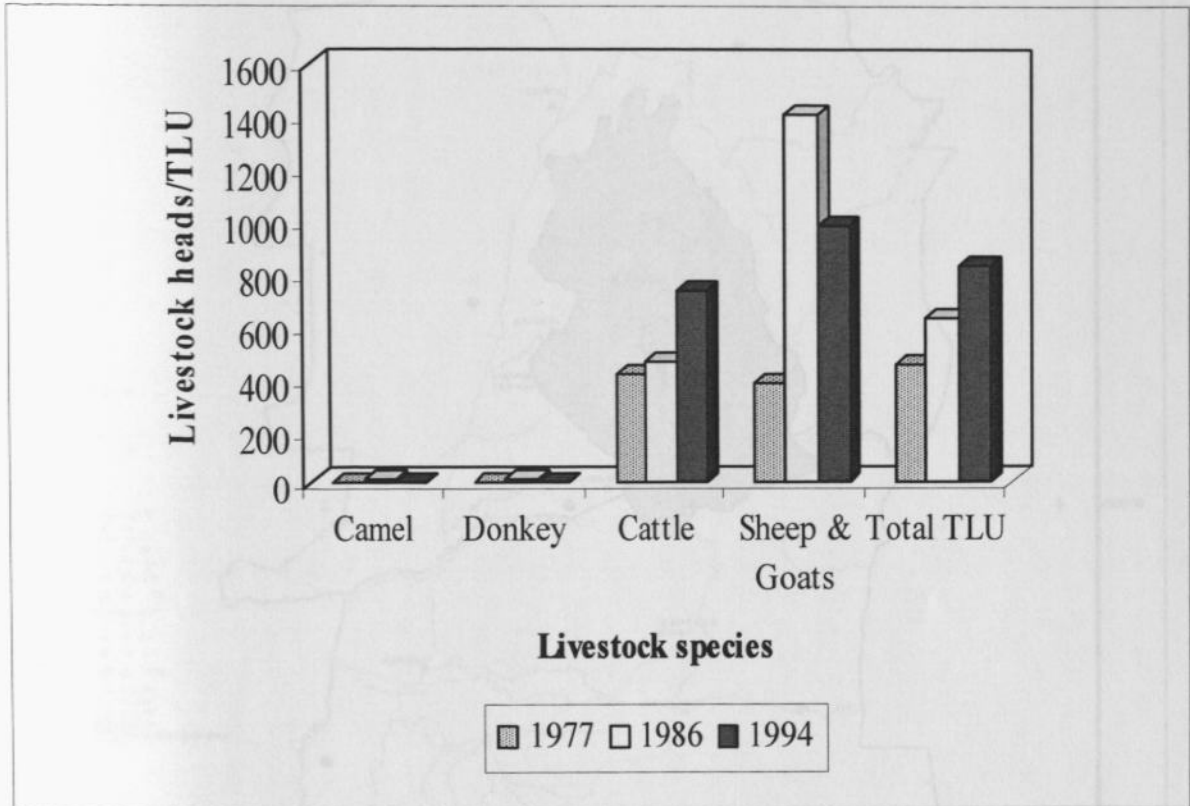


Figure 4.18: Livestock population in the sedentary agro-pastoral land-use system in the Njemps Flats in 1977, 1986 and 1994

4.19: Livestock density (TLU/km²) in the Njemps Flats in 1977

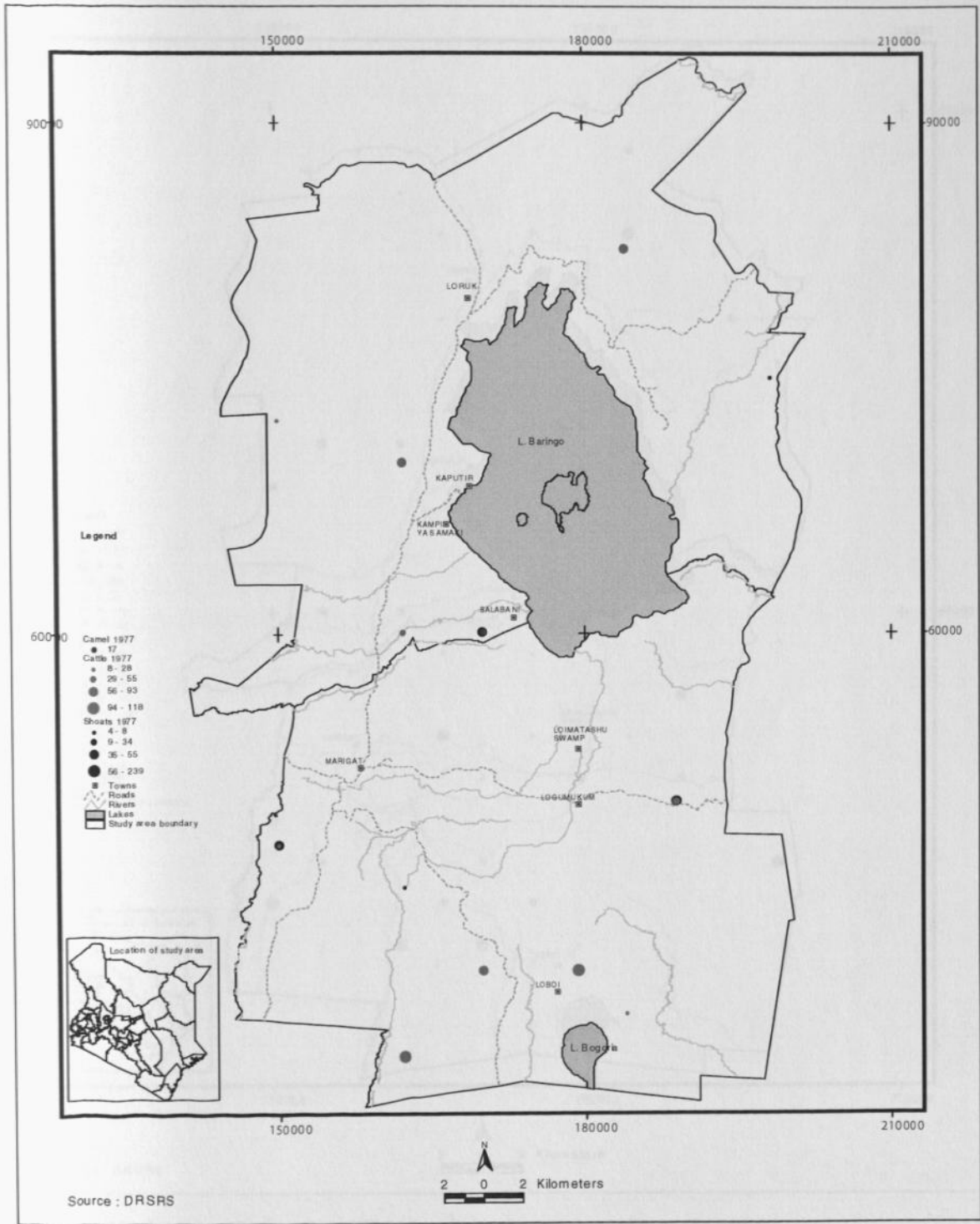


Figure 4.19: Livestock density (TLU/km²) in the Njemps Flats in 1977

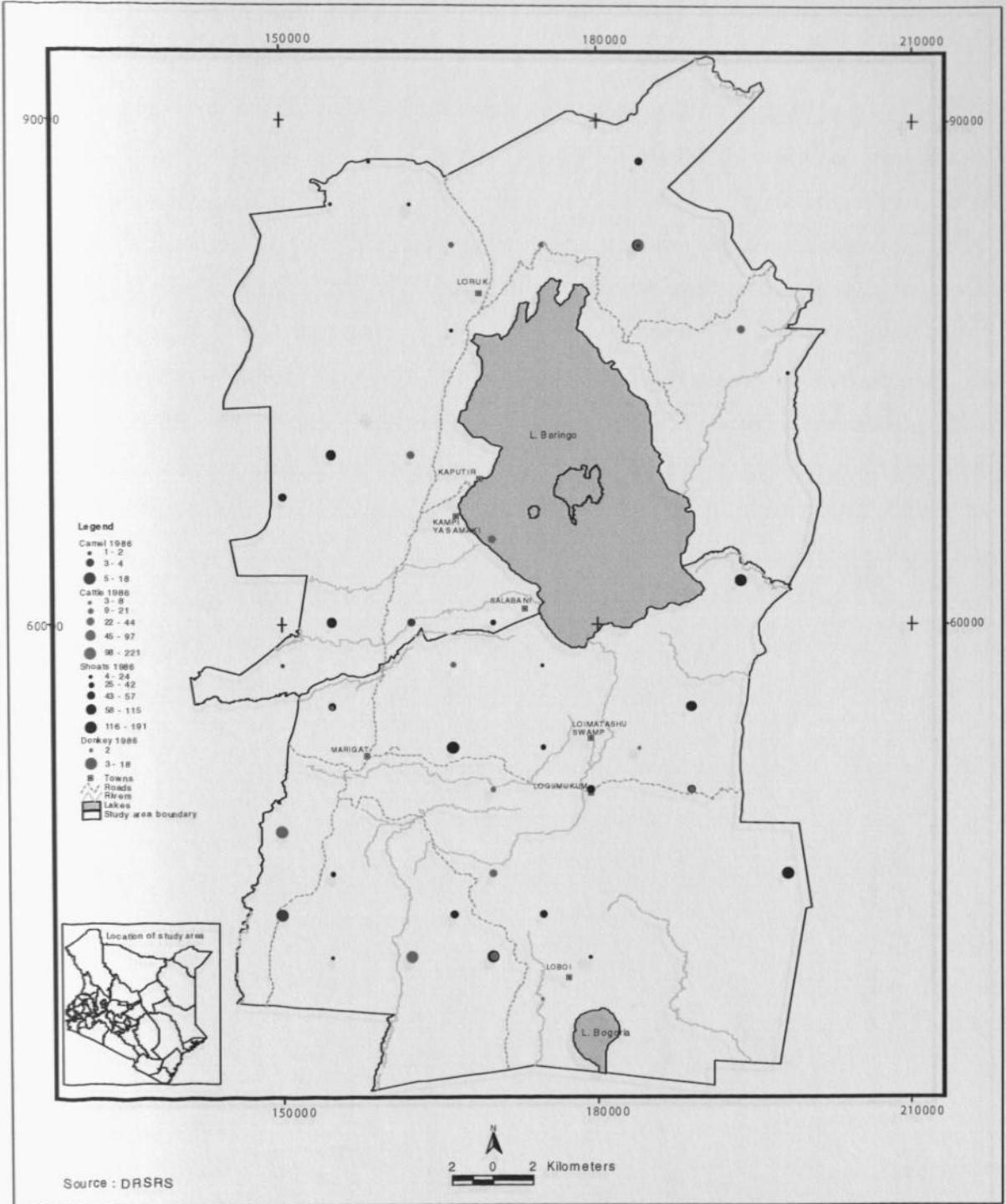


Figure 4.20: Livestock density (TLU/km²) in the Njemps Flats in 1986

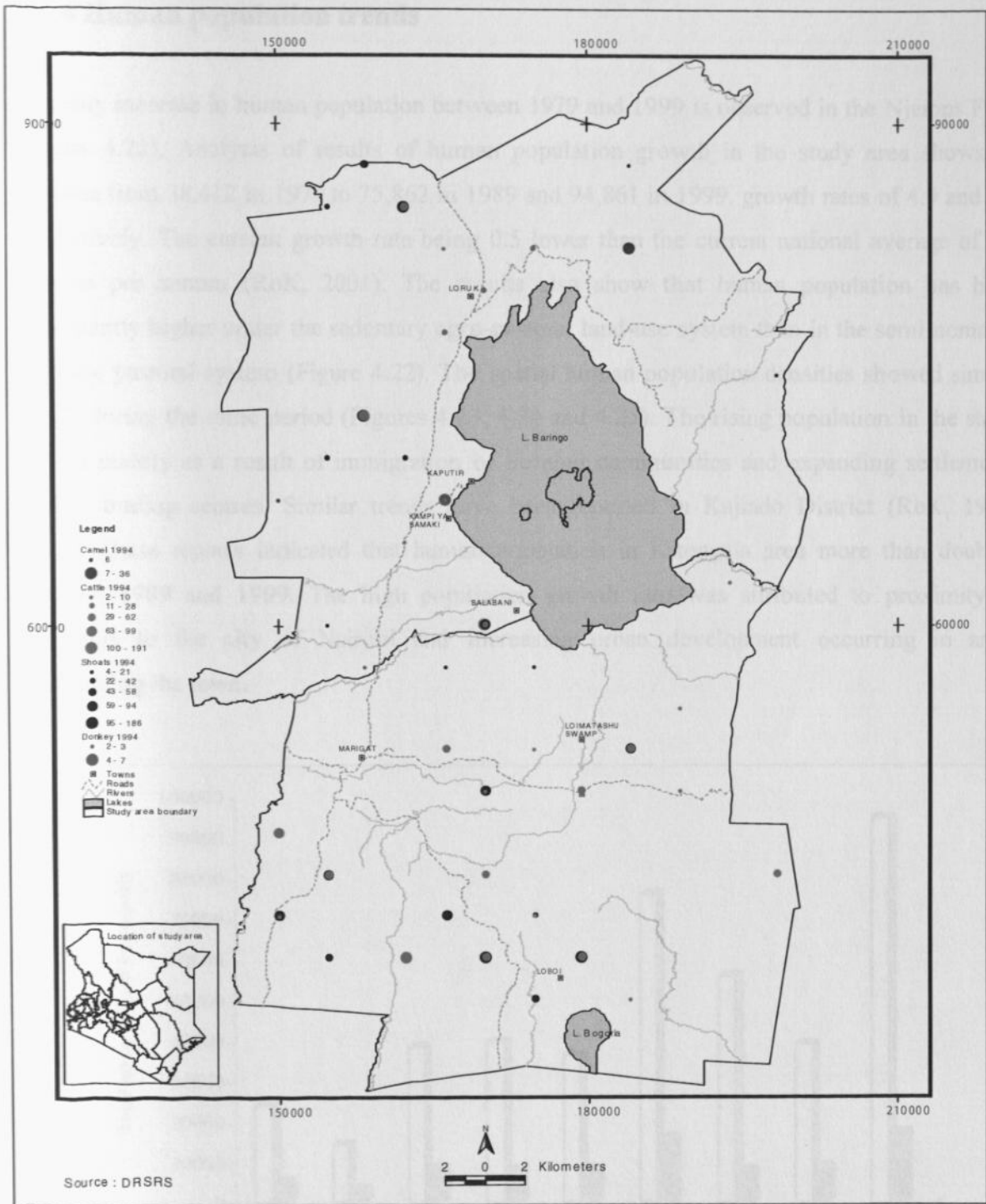


Figure 4.21: Livestock density (TLU/km²) in the Njempis Flats in 1994

4.4.4 Human population trends

A steady increase in human population between 1979 and 1999 is observed in the Njemps Flats (Figure 4.22). Analysis of results of human population growth in the study area shows an increase from 38,412 in 1979 to 75,862 in 1989 and 94,861 in 1999, growth rates of 4.9 and 2.0 respectively. The current growth rate being 0.5 lower than the current national average of 2.5 persons per annum (RoK, 2001). The results also show that human population has been consistently higher under the sedentary agro-pastoral land-use system than in the semi-nomadic land-use pastoral system (Figure 4.22). The spatial human population densities showed similar trends during the same period (Figures 4.23, 4.24 and 4.25). The rising population in the study area is mainly as a result of immigration of farming communities and expanding settlements around trading centres. Similar trends have been reported in Kajiado District (RoK, 1994; 2001). These reports indicated that human population in Kitengela area more than doubled between 1989 and 1999. The high population growth rate was attributed to proximity of Kitengela to the city of Nairobi and increasing urban development occurring in areas surrounding the town.

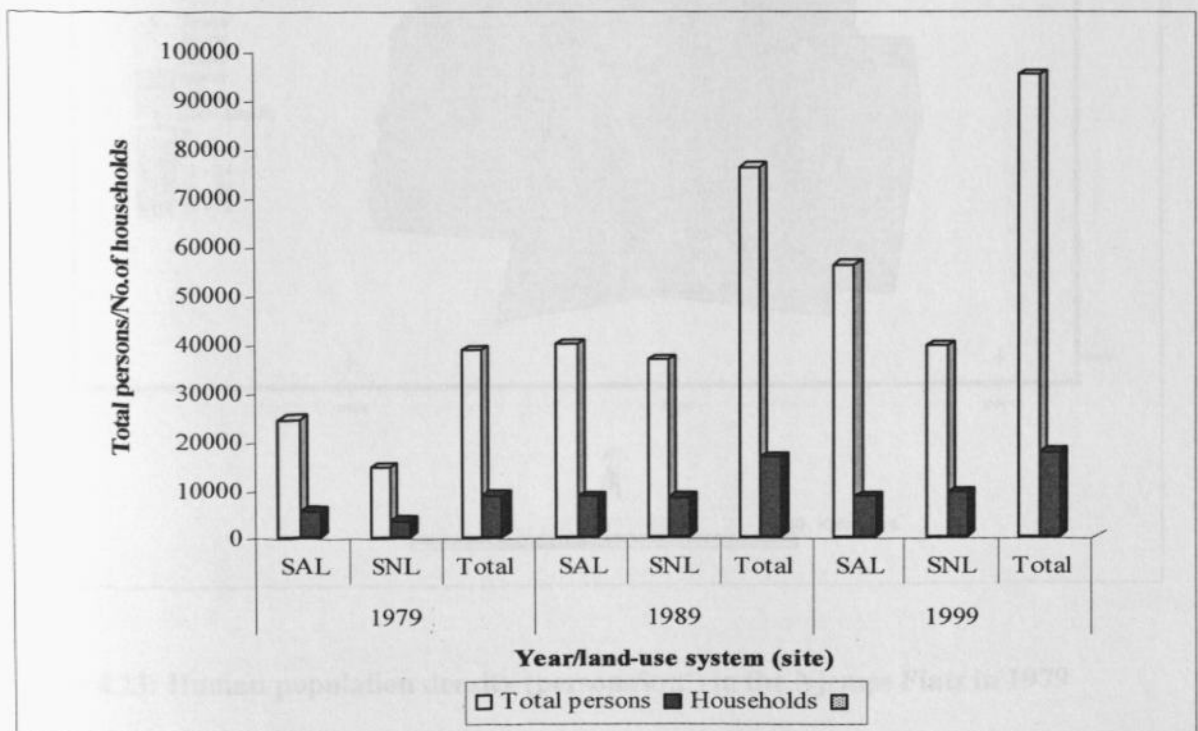


Figure 4.22: Human population and number of households in the Njemps Flats in 1979, 1989 and 1999



Figure 4.23: Human population density (persons/km²) in the Njemp Flats in 1979

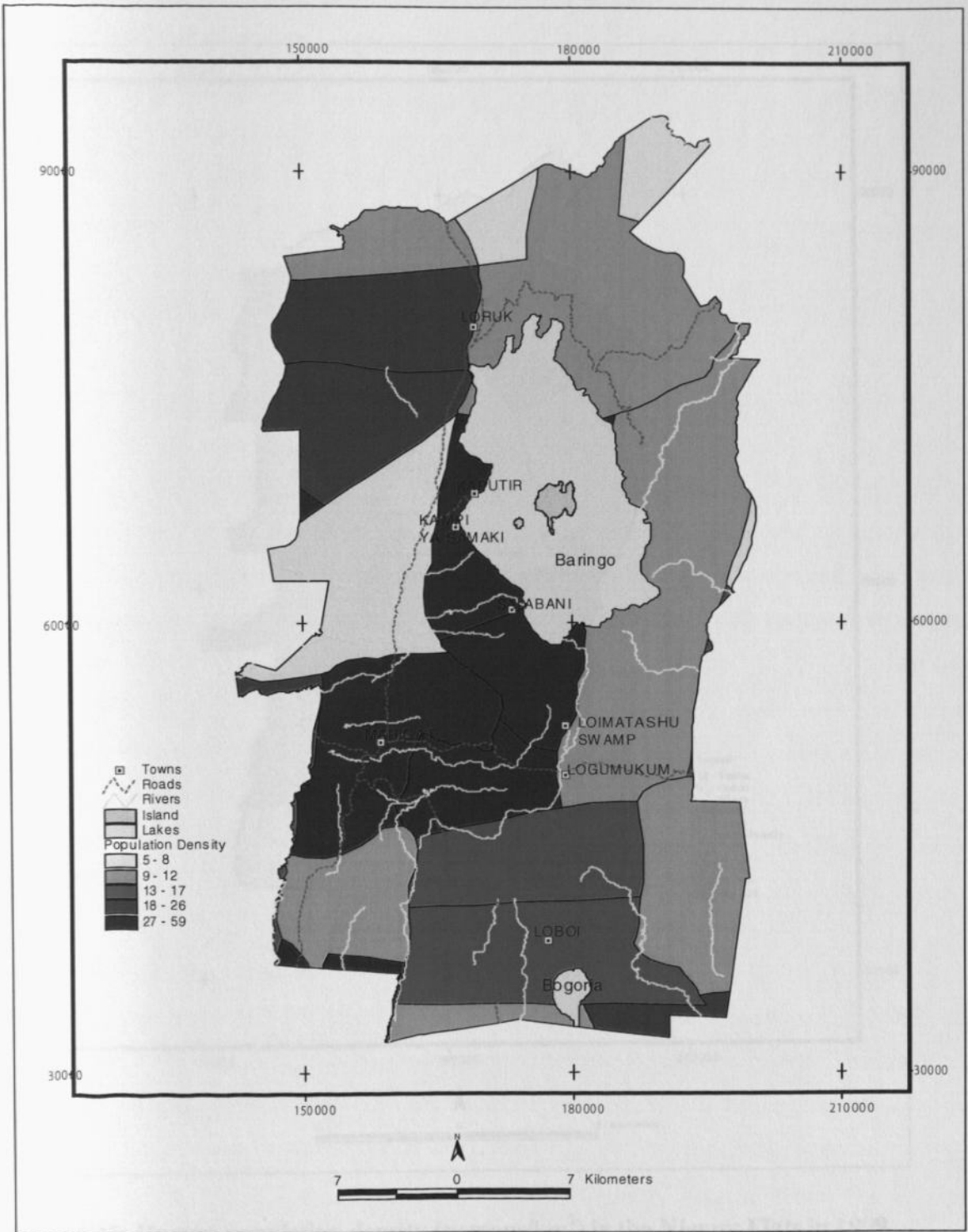


Figure 4.24: Human population density (persons/km²) in the Njemp Flats in 1989

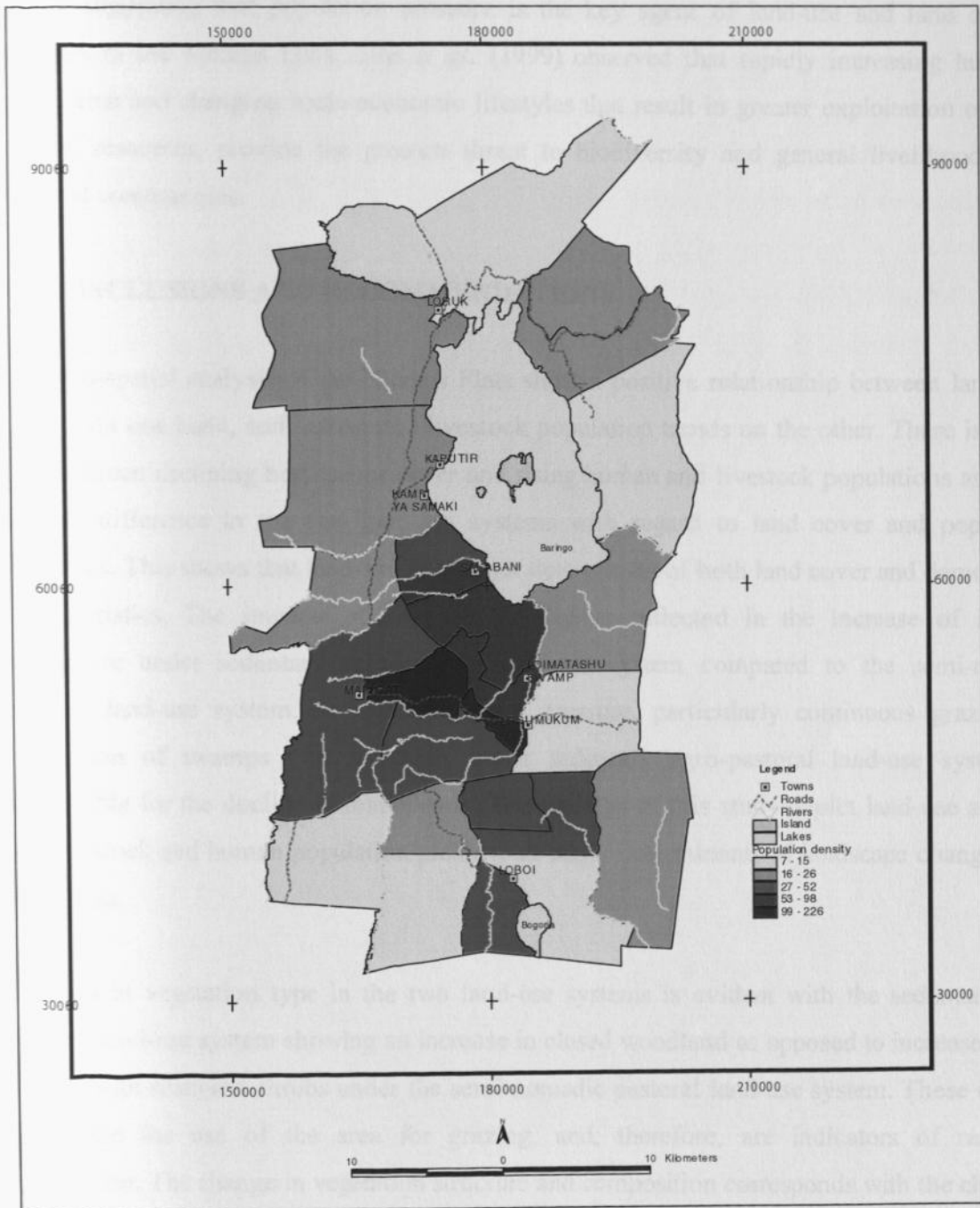


Figure 4.25: Human population density (persons/km²) in the Njemp Flats in 1999

The trend in human population is linearly and positively related to that of livestock and land cover, suggesting that population pressure is the key agent of land-use and land cover changes in the Njemps Flats. Ellis *et al.* (1999) observed that rapidly increasing human population and changing socio-economic lifestyles that result in greater exploitation of the natural resources, provide the greatest threat to biodiversity and general livelihoods of pastoral communities.

4.5 CONCLUSIONS AND RECOMMENDATIONS

The geo-spatial analysis of the Njemps Flats show a positive relationship between land cover change on one hand, and human and livestock population trends on the other. There is a close link between declining herbaceous cover and rising human and livestock populations as well as distinct difference in the two land-use systems with regard to land cover and populations dynamics. This shows that land-use as a major determinant of both land cover and demographic characteristics. The impacts of land-use are further reflected in the increase of irrigated agriculture under sedentary agro-pastoral land-use system compared to the semi-nomadic pastoral land-use system. A higher land-use pressure, particularly continuous grazing and conversion of swamps into croplands under sedentary agro-pastoral land-use system are responsible for the decline in marshlands. The findings of this study depict land-use activities and livestock and human population pressure as major determinants of landscape change in the study area.

Changes in vegetation type in the two land-use systems is evident with the sedentary agro-pastoral land-use system showing an increase in closed woodland as opposed to increase in bare ground with scattered shrubs under the semi-nomadic pastoral land-use system. These changes undermine the use of the area for grazing, and, therefore, are indicators of rangeland degradation. The change in vegetation structure and composition corresponds with the change in herd structure in the study area. The results also show an upward surge in human and livestock populations, the growth rate being higher under sedentary agro-pastoral land-use system than in the semi-nomadic pastoral land-use system. Rainfall in the study area exhibits high variability around both the monthly and annual long-term means, and slight increase in mean annual rainfall despite declining rain-days. This implies an increasing intensity of rainfall events and explains, in part, the increasing soil erosion observed in the study area in the past four decades.

Even though land-use and population pressure appear to be the major determinants of shifts in land cover type and vegetation structure in the Njemps Flats, the role of rainfall variability in exacerbating the negative impacts of land-use activities can not be ignored. Whereas efforts towards reversing the current trends in climatic anomalies associated with climate change require long term strategies, reduction of land-use pressure on the rangelands can be achieved through promotion of viable alternative livelihoods. Diversification of pastoral livelihoods provides the most immediate step towards reducing overdependence on livestock and improvement of livelihood security of pastoral households. However, this should be exercised concurrently with land conservation measures to control range degradation and ensure sustainable natural resource base.

- area, Kajiado District. LUCID Working paper No. 19, International Livestock Research Institute (ILRI), Nairobi, Kenya.
10. O. J. 1999. Response to drought among farmers and herders in southern Kajiado District, Kenya: A comparison of the 1972 – 1976 and 1994 – 1995. *Journal of Human Ecology*, 27 (3): 377 – 416.
11. M. 2001. Rehabilitating the Baringo Drylands of Kenya. Rehabilitation of Arid Environments (RAPE) and IDRC, Ottawa, Canada.
12. J. D., C.E. Vincent and A.K.C. Beresford. 1995. July-August Rainfall in West-Central Kenya. *Journal of Climatology*, 5: 17 – 33.
13. A. P., A. Field-Juma and D.O. Hall. 1992. *Reclaiming the land: Revegetation in arid and semi-arid Kenya*. African Centre for Technology Studies (ACTS) Press, Nairobi and Human Users Network, Harare.
14. B. Reid, P. Thornton and R. Kruska. 1999. Population growth and land-use change among pastoral people: Local processes and continental patterns. In: David E. and F. David (Eds.), *Proceedings of the Sixth International Rangeland Congress*, Townsville, Queensland 19 – 23 July, 1999.
15. Environmental Systems Research Institute (ESRI). 2003. ArcView Version 3.3. New York State, Redlands, CA, USA.
16. Environmental Systems Research Institute (ESRI). 2004. ArcGIS Version 9.0. 280 New York Street, Redlands, CA, USA.
17. 2006. Properties and management of drylands. FAO Land and Water Digital Media Series no. 24. Rome, Italy.

4. 6 REFERENCES

- Alemu, D. T., D.M. Nyariki and K.O. Farah. 2000. Impact of land-use system and socio-economic roles of vegetation in semi-arid Africa: The case of the Afar and Tigray of Ethiopia. *Journal of Social Science*, 4 (3): 199 – 206.
- Andersson, S. 2005. Spread of the introduced tree species *Prosopis juliflora* (Sw.) DC in the Lake Baringo area, Kenya. A minor field study. Institutionen för skoglig vegetationsekologi SLU 901 83 UMEÅ.
- Campbell, D., D.P. Lusch, T. Smucker and E.E. Wangui. 2003. Root cause of land-use change in the loitoktok area, Kajiado District. LUCID *Working paper* No. 19. International Livestock Research Institute (ILRI), Nairobi, Kenya.
- Campbell, D.J. 1999. Response to drought among farmers and herders in southern Kajiado district, Kenya: A comparison of the 1972 – 1976 and 1994 – 1995. *Journal of Human Ecology*, 27 (3): 377 – 416.
- Crawley, M. 2001. Rehabilitating the Baringo Drylands of Kenya. Rehabilitation of Arid Environments (RAE) and IDRC, Ottawa, Canada.
- Davies T.D., C.E. Vincent and A.K.C. Beresford. 1995. July-August Rainfall in West-Central Kenya. *Journal of Climatology*, 5: 17 – 33.
- de Groot, P., A. Field-Juma and D.O. Hall. 1992. *Reclaiming the land: Revegetation in semi-arid Kenya*. African Centre for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- Ellis, J. R. Reid, P. Thornton and R. Kruska. 1999. Population growth and land-use change among pastoral people: Local processes and continental patterns. In: David E. and F. David (Eds.), *Proceedings of the Sixth International Rangeland Congress*, Townsville, Queensland 19 – 23 July, 1999.
- Environmental Systems Research Institute (ESRI). 2003. ArcView Version 3.3. New York Street, Redlands, CA, USA.
- Environmental Systems Research Institute (ESRI). 2004. ArcGIS Version 9.0, 380 New York Street, Redlands, CA, USA.
- FAO. 2006. Properties and management of drylands. FAO Land and Water *Digital Media Series* No. 31. Rome, Italy.

- Johansson, J. and J. Svensson. 2002. Land degradation in semi-arid catchment of Lake Baringo, Kenya. A minor field study of physical with socio-economic aspect. Department of Physical Geography, Gotenberg University.
- Jolly, G.M. 1969. Sampling methods for aerial censuses of wildlife populations. *East African Agricultural Journal*. 34: 46 – 49.
- KARI/ODA. 1996. *Manual of livestock production systems in Kenya*. Livestock socio-economics and epidemiology project. National veterinary research centre, Kikuyu, Kenya.
- Kipkorir, E.C. 2002. Analysis of rainfall climate on the Njemps Flats Baringo District, Kenya. *Journal of Arid Environments*, 50: 445 – 458.
- Kristjanson, P. M. Radeny, D. Nkedianye, R. Kruska, R. Reid, H. Gichohi, F. Atieno and R.Sanford. 2002. *Valuing alternative land-use options in the Kitengela wildlife dispersal area of Kenya*. ILRI, Nairobi, Kenya.
- Lawes Agricultural Trust. 2006. GenStat Release 9.1. Lawes Agricultural Trust (Rothamsted Experimental Station).
- Maitima, J. R.S. Reid, L.N. Gachimbi, A. Majule, H. Lyaruu, D. Pomeroy, S. Mugatha, S. Mathai and S. Mugisha. 2004. The linkages between land-use change, land degradation and biodiversity across East Africa. LUCID *Working Paper Series* No.42.
- Marangu, D.K., J.N. Kimani, F. Msafiri and H.P. Roimen. 2008. *Mapping of prosopis species in Baringo District*. Department of Resources Survey and Remote Sensing (DRSRS) Technical Report No. 173. DRSRS. Ministry of Environment and Natural Resources, Republic of Kenya.
- Muriuki, G., Okita O.B., and Omondi, P. 1998. *Elephant, Buffalo and Key livestock wet season aerial count in the Maasai Mara National Reserve and the adjacent Areas*. Kenya Wildlife Service, Biodiversity Department, Nairobi, Kenya.
- Muriuki, G., Omondi, P. and Sinange, R. 2000. *Elephant, Buffalo, Giraffe, and Key livestock dry season total aerial Count of Maasai Mara and the Adjacent Pastoral areas*. Research and Planning Department, Kenya Wildlife Service, Nairobi, Kenya.
- Mwasi, B. 2004. Landscape change dynamics in a semi-arid part of Baringo District, Kenya. PhD thesis, University of Amsterdam, The Netherlands.
- Meyerhoff, E. 1991. *Taking Stock: Changing Livelihoods in a Agropastoral Community*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.

- Nkedianye, D. K. 2004. Testing the attitudinal impact of a conservation tool outside a protected area: The case of the Kitengela Wildlife Conservation Lease Programme for Nairobi National Park. Masters thesis, University of Nairobi.
- Noor, A.A., K.O. Farah and N.K. Musimba. 1999. Socio-economic impact of small holder irrigation schemes on the pastoral nomads of Garissa District, North-eastern Kenya. The African Pastoral Forum *Working paper series* No. 9. Pastoral Information Network Program, University of Nairobi, Kenya.
- Norton-Griffith. 1978. *Counting animals*. Handbook No. 1, 2nd Edition. African Wildlife Foundation, Nairobi, Kenya.
- Odada E. O. and D.O. Olago. 2004. The East African Great Lakes: Limnology, Palaeolimnology and Biodiversity. Kluwer Academic Publishers. www.wkap.nl/prod/b/1
- Ojany F.F. and R.B. Ogendo. 1988. *Kenya: A study in Physical and Human Geography*. Longman, UK.
- Ojwang', G.O., P.W. Wargute and L.W. Njino. 2006. Trends and Spatial Distribution of Large Herbivores in Kajiado District (1978 – 2000). DRSRS *Technical Report No. 161*. DRSRS. Ministry of Environment and Natural Resources, Republic of Kenya.
- Onyando, J.O, P. Kisoyan and M.C. Chemelil. 2005, Estimation of potential soil erosion for river Perkerra catchment in Kenya. *Water Resources Management*, 19: 133 – 143.
- Rainis, R. H. Juahir and S. M. Zain. 2003. GIS Application in Evaluating Land Use-Land Cover Change and its Impact on Hydrological Regime in Langat River Basin, Malaysia. www.gisdevelopment.net/application/environment/water/ma03039.htm
- Robinnis, P. 2003. Beyond ground truth: GIS and the environmental knowledge of herders, professional foresters, and other traditional communities. *Human Ecology*, 31 (2): 233 – 253.
- ROK. 1994. *Kenya Population and Census, 1989. Volume I*. Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi Kenya.
- ROK. 2001. *Kenya Population and Census, 1999. Volume I*. Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi Kenya.
- Roth, E.A. and E. Fratkin. 2005. The social, health and economic consequences of pastoral sedentarization in Marsabit District, northern Kenya. In: Fratkin, E. and E.A. Roth (Eds.), *As pastoralists settle*. Kluwer Academic Publishers, New York.

- Rowntree, K. M. 1988. Storm rainfall on the Njemps flats, Baringo District, Kenya. *International Journal of Climatology*, 8 (3): 297 – 309.
- Serneels, S. and E. F. Lambin. 2001a. Impact of land-use changes on the wildebeest migration in the northern part of the Serengeti-Mara ecosystem. *Journal of Biogeography*. 28: 391 – 407.
- Snelder D.J. and R.B. Bryan. 1995. The use of rainfall simulation tests to assess the influence of vegetation density on soil loss on degraded rangelands in the Baringo District, Kenya, *Catena*, 25 (4): 105 – 116.
- Serneels, S. and E. F. Lambin. 2001b. Proximate causes of land-use change in Narok District, Kenya: a spatial statistical model. *Agriculture, Ecosystems and Environment*, 85: 65 – 81.
- UNEP. 2008. Africa: *Atlas of our changing environment*. UNEP, Nairobi Kenya. www.Na.unep.net/AfricaAtlas.
- Yang, J., Y. Liu, and S. Wang. 2007. An overview of the methods of GIS-based land-use suitability analysis. *Proceedings of a Conference on Geospatial Information Technology and Applications* held in Nanjing, China in August 2007. SPIE Digital Library.

CHAPTER FIVE

5.0 A LOCAL PERCEPTIONS ANALYSIS OF THE SOCIO-ECOLOGICAL TRENDS IN THE NJEMPS FLATS

5.1 ABSTRACT

The landscape change dynamics in the Kenya's rangelands are driven by the social, economic, political as well as climatic factors. These trends are a cause of concern for integrity of pastoral ecosystems and livelihoods. This calls for a clear understanding of the dynamics with the aim of formulating appropriate policies to ensure sustainable resource use and livelihood security of pastoral households. The spatial and temporal ecological knowledge expressed by those with long familiarity with the ecology has been shown to be superior in quality and resolution than those gathered remotely and modelled digitally. In view of this, the current study adopted a local perceptions approach in assessing the social and ecological change dynamics in the Njemps Flats over a period of four decades. The results reveal a changing vegetation structure, declining diversity and increasing soil erosion that are attributed to the rise in both human and livestock populations, and exacerbated by rainfall anomalies. Despite the decline in rain-days, heavy torrents accompanied by floods have become common in the Njemps Flats in the past 40 years. The results also show a rising trend in diversification of economic activities in response to decline in livestock production. These findings suggest that pastoralism in Baringo is a system in transition, attempting to maintain itself while at the same time trying to adapt progressively to a continuously shrinking resource base.

KEY WORDS: Socio-ecological trends; local knowledge; semi-arid lowlands of Baringo District.

5.2 INTRODUCTION

Technical advances in the recent past have unequivocally shown that the entire world is undergoing rapid ecological changes at local, regional and global scales (UNEP, 2008; Walsh *et al.*, 2004), and that the most obvious and pronounced change is caused by human land-use. In Kenya, rangelands have undergone considerable social and ecological transformations over the years. These changes have been largely attributed to both the pre- and post-independence pastoral development interventions, anthropogenic activities and climatic anomalies. As observed by many authors (Campbell, 1999; Leneman and Reid, 2001; Anantha *et al.*, 2000; Rutten, 1992; Farah, 1996; Mulaku, 2000; Oba, 1992; Oba and Lusigi, 1987; Otieno and Rowntree, 1986), the precursor to Kenya's post-independence approach to pastoral issues, and present-day status of pastoral production systems took form

in the colonial era. The colonial administration witnessed the fundamental transformation and evolution of socio-political relations, land tenure and the traditional institutions of natural resource use and management, which wrought the logic for present day policy towards pastoral development. Up till then, pastoral practices were normally organized and operated under a diversity of social and ecological conditions.

All the factors that undermine pastoralism in Kenya, just like in the rest of Africa, are believed to be responsible to the man-induced process of land degradation. Land degradation in Kenyan rangelands is considered to be a result of unsustainable land-use practices that are extractive rather than regenerative (Ngugi and Nyariki, 2005). The degradation of pastoral areas has led to the erosion of the economic livelihood of the pastoralists (Evangelou, 1984), which is reflected in increased destitution among pastoral households. Some of the main factors blamed for the observed social and ecological trends in the Kenya's rangelands, in addition to recurrent droughts, are those that restrict pastoralists' mobility and weaken traditional institutions. Lambin *et al.* (2003) observed that land conversion to agriculture in East Africa has outpaced the proportional human population growth in the recent past, and that natural vegetation cover has given way not only to cropland but also to native or planted pasture.

Maitima *et al.* (2004) pointed out that the expansion of urban centres from 7% in 1960 to 30% in 2001 is partly responsible for land-use change and range degradation in Kenya. In a study conducted in the semi-arid rangelands of southeast Kajiado District, Kenya, Campbell *et al.* (2003) reported the expansion of agriculture into critical grazing areas as a result of increase in human population. Based on the knowledge and perception of local communities, Alemu *et al.* (2000) reported a reduction in natural vegetation cover and consequent environmental degradation due to the settlement of pastoralists and subsequent crop cultivation of grazing lands in the semi-arid region of Afar, Ethiopia. Among the important factors perceived to cause the ecological deterioration in Afar were clearing of land for cultivation, settlements, road construction, firewood collection, charcoal making, and felling trees and shrubs for various purposes. They also reported that recurrent droughts and overgrazing have had significant impacts on land cover.

Kristjanson *et al.* (2002) while working in Kitengela in Kajiado District of Kenya found that considerable social and ecological changes have occurred in the area over the last 40 years. They reported the increasing privatisation of land, increase in crop cultivation and livelihood diversification. The study also reported a decrease in livestock population between 1990 and 1996 followed by an increasing trend. The wildlife populations in the area showed a steady decline during the same period. These social and ecological dynamics bear similarities across rangelands of Eastern Africa and are a cause of concern for the integrity of pastoral ecosystems and livelihoods. This calls for a clear understanding of the dynamics with the aim of formulating appropriate policies to ensure livelihood security and improved well-being of pastoral households.

The importance of local knowledge in understanding scenarios at local level is increasingly being acknowledged. However, little research is directed at advancing our appreciation of it and utilizing it in informing policy formulation. In particular, the spatial and ecological understanding expressed by those with long familiarity with the ecology have been shown to be superior in quality and resolution those gathered remotely and modelled digitally. Turner and Hiernaux (2002), for example, have demonstrated that maps of livestock activity based on local herder knowledge prove more effective and accurate for management than those rigorously developed through spatial modelling. Similarly, Njoka *et al.* (2004) underscore the importance of investigating change from the people most affected by the change, and who have experienced it over the years. Wasonga *et al.* (2003) reported a sound knowledge and understanding of environment among the pastoralists of northern Kenya and recommended mainstreaming of traditional pastoral knowledge in pastoral development. By incorporating and evaluating local knowledge, researchers come closer to an accurate picture of the overall system and therefore likely to bridge the gap in knowledge between rural communities and experts (Al-Kodmany, 2001).

In addition to understanding the current interplay between components of an ecosystem, planning of successful development interventions requires identification of historical factors which set in motion the current state of affairs. Unfortunately, there are a few instances where development plans have relied on historical analysis to deal with development issues at both local and regional levels (Oba, 1992). Further more, many studies in rangelands are conducted over time periods that are too short to capture the inherent temporal variability of

these systems. This implies that land-use and land cover history is not readily available at local level, a deficit that can, however, be bridged by utilizing the local knowledge systems. Kenya is no exception to this information deficit, which more often than not elicits interventions that only address the symptoms and not causes of problems. The starting point of this study is that land degradation cannot be adequately understood or effectively managed unless our understanding of the social and ecological drivers of this process is improved. As observed by Robbins (2003), only through simultaneous examination of the partialities of all knowledge, lay and expert, can research achieve an in-depth understanding of social and ecological dynamics at the local scale. This study adopts a local perception analysis of the socio-ecological trends to explore the longitudinal relationship between land cover and land-use on one hand, and rainfall variability, human and livestock populations on the other hand. The hypotheses are that the social and ecological change dynamics in the Njemps Flats are interlinked, and that local knowledge and perceptions corroborate the conventional information on the socio-ecological trends.

5.3 METHODS

A combination of methods was used in this study to collect information. A questionnaire was used to obtain specific information on socio-ecological perceptions of the local communities. Discussions with key informants were carried out to verify information from the individual interviews. In addition, focus group discussions (FGDs) were conducted to further clarify responses that appeared unclear, and assess if there was a consensus on general socio-ecological trends as perceived by the respondents. Supporting information was obtained from field observations. The individual and key informant interviews targeted elderly persons over 60 years of age. The group discussions, however, involved all categories of age comprising children, women and men. The variables used to assess the social and ecological trends included soil and vegetation characteristics, climatic and hydrological factors, demographic characteristics, and change dynamics in sources of livelihoods.

5.3.1 Data collection

Stratified random sampling procedure as described by Mugenda and Mugenda (1999) was used to collect data. The two land-use system sites (SAL and SNL) were considered separate strata or sub-groups. The stratification guaranteed the uniformity of the population of sub-groups to safeguard accuracy. Randomization was then done within the two strata. In each stratum, 55 persons were interviewed making a total of 110 respondents. The questionnaire contained questions pertinent to perceptions of the local communities on social and ecological trends observed by the communities over the last four decades. In particular, they included, among others, the changes observed in forage production, vegetation cover and diversity, soil fertility and erosion, climatic and hydrological factors, human and livestock populations, traditional natural resource management strategies, and sources of livelihood. Because all relevant data could not be gathered through the formal questionnaire, informal discussions described by Seaman *et al.*, (2000), involving key informants with considerable knowledge about issues under investigation were conducted.

Two FGDs on socio-ecological perceptions were conducted in each stratum. The FGD is a commonly used qualitative approach to data collection, and its importance in understanding social realities has been recognized by social scientists (Rietbergen-McCracken and Narayan, 1998). In the SNL stratum, the FGDs were conducted in Loruk trading centre and Lokortabim village, while in the SAL stratum, the discussions were carried out in Marigat and Loberer trading centres.

In addition to FGDs, guided field walks were used to make certain observations mentioned in the FGDs, and identify some of the plant species mentioned by the participants. This is a very popular method of capturing local knowledge because it allows the researcher to note important details and quantify the reported information. The exercise involved walking along imaginary transects through the range by the interviewer guided by key informants. The interviewer made observations on anything relevant to the subject being investigated, and asked questions to obtain further clarification from the key informants.

5.3.2 Data analysis

The information gathered during the literature search, FGDs and guided field walks was compiled and organized under various topics addressed during the study. Quantitative data were analysed using statistical package for social sciences (SPSS) to generate statistics which were then used to draw inferences. The qualitative information from the FGDs and key informants was used to help interpret the quantitative data (Seaman *et al.*, 2000).

5.4 RESULTS AND DISCUSSIONS

5.4.1 Livelihood trends

The main sources of livelihood in the study area were found to be livestock and crop production (Table 5.0). Important alternative livelihood options included petty trade (small and medium business enterprises), honey production, formal employment, fishing and charcoal production, in that order. Livestock and crop production were reported to have shown declining trends in the past 40 years and, with exception of fishing, all the alternative livelihoods were reported to be on the increase (Figure 5.0).

Table 5.0: Sources of livelihood in the study area

Activity	Frequency (N=105)	Percentage of respondents
Livestock production	56	53.3
Formal employment	3	2.9
Crop production	31	29.5
Business/petty trade	8	7.6
Honey production	4	3.8
Fishing	2	1.9
Charcoal production	1	1.0

The declining trend in livestock production was mainly attributed to the shrinking grazing land (50.5%), followed by frequent droughts (33.3%) and lack of herding labour (16.2%) (Table 5.2). The latter was attributed to school attendance by children who traditionally provide herding labour. The major reason for declining crop production was given as frequent and severe droughts (60%) and soil degradation (40%). The increasing poverty,

decline in livestock production and shrinking grazing resource base were blamed for the rising charcoal production by the pastoralists.

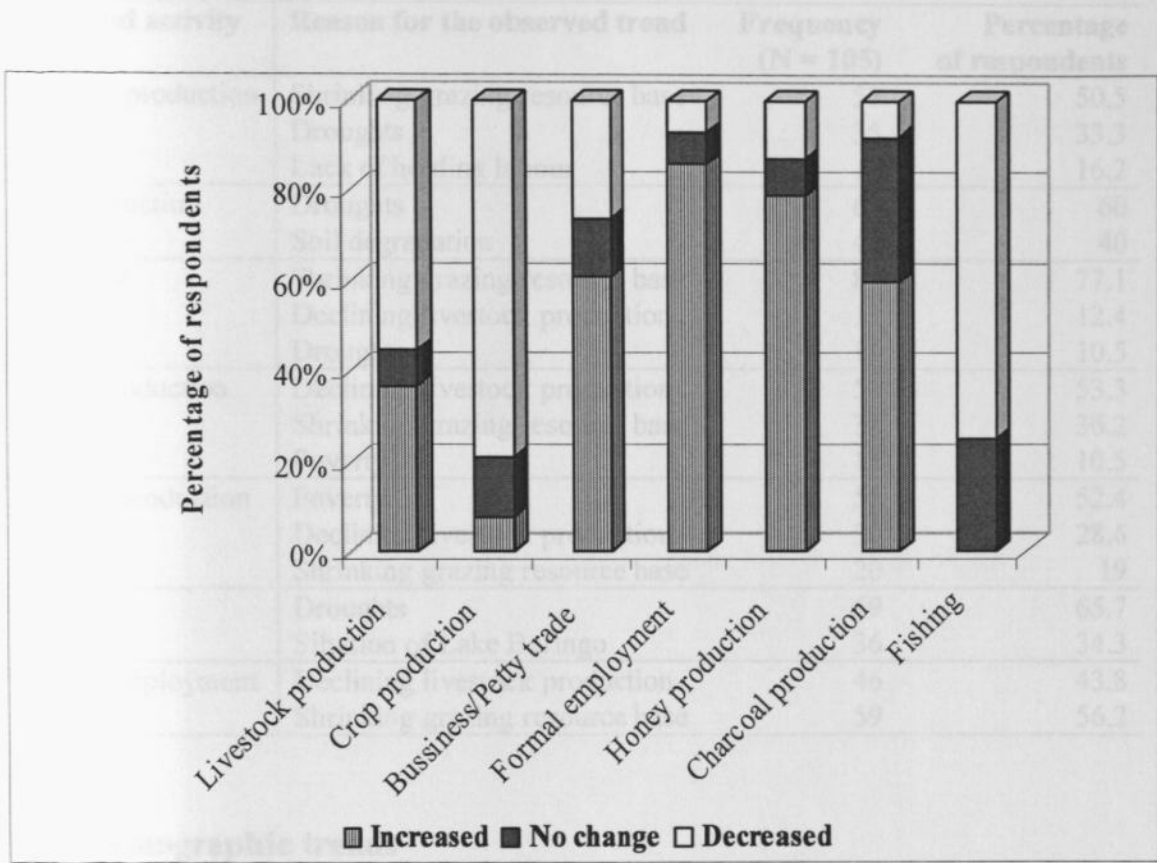


Figure 5.0: Trends of livelihood sources as perceived by local communities

The rising trend of petty trade as an alternative livelihood activity among the pastoralists was attributed to shrinking grazing land (77.1%), declining livestock production (12.4%) and frequent droughts (10.5%). These perceptions corroborate the findings of Warinda (2001) and Kristjanson *et al.* (2002) who reported declining productivity in both livestock and crops accompanied by an increase in diversification of livelihoods in the pastoral areas of Kitengela and Magadi Divisions in Kajiado District. These reports linked the trends to land sub-division, sedentarization and population increase, especially due to immigration of cultivators. A few respondents thought that fishing in Lake Baringo has declined due to siltation and majority of them blamed severe and frequent droughts for the trend. Onyando *et al.* (2005) reported fluctuations in fish production but, associated it with over-fishing and turbidity of the lake.

Table 5.1: Reasons for the observed trends in sources of livelihood

Livelihood activity	Reason for the observed trend	Frequency (N = 105)	Percentage of respondents
Livestock production	Shrinking grazing resource base	53	50.5
	Droughts	35	33.3
	Lack of herding labour	17	16.2
Crop production	Droughts	63	60
	Soil degradation	42	40
Petty trade	Shrinking grazing resource base	81	77.1
	Declining livestock production	13	12.4
	Droughts	11	10.5
Honey production	Declining livestock production	56	53.3
	Shrinking grazing resource base	38	36.2
	Poverty	11	10.5
Charcoal production	Poverty	55	52.4
	Declining livestock production	30	28.6
	Shrinking grazing resource base	20	19
Fishing	Droughts	69	65.7
	Siltation of Lake Baringo	36	34.3
Formal employment	Declining livestock production	46	43.8
	Shrinking grazing resource base	59	56.2

5.4.2 Demographic trends

The results of this study reveal a number of demographic changes in the lowlands of Baringo. Group discussions with elderly persons over 60 years of age showed that the overall human and livestock populations have increased in the last 40 years (Figure 5.1). The household size was, however, perceived to have declined during the same period. According to a report by Tokida (2001), the historical immigration and the natural population growth led to a tenfold increase in the human population in the Njemps Flats between 1948 and 1999, and that the population density increased from 4.4 to 44 persons per km² during the period. According to the 1999 human population census, the population of Baringo District was growing at 2.65% and was expected to rise from 265,241 in 1999 to 336,346 in 2008 (RoK, 2001). A similar trend has been reported in the rangelands of Kajiado District. According to the 1989 Census (RoK, 1990), the human population of Kajiado District was estimated at 258,659, an increase of 98% from 4,799 in 1927. In 1999, the human population of Kajiado rose to 406,054, and it was projected to reach 464,883 in 2002 and 609,349 at the end of 2008. The population density of Kajiado District has

increased over the years from 4 to 7 to 12 to 19 persons per km² in 1979, 1989, 1999, respectively. The increase in human population in Kajiado is attributed to encroachment into high potential ranges of the District by farming communities.

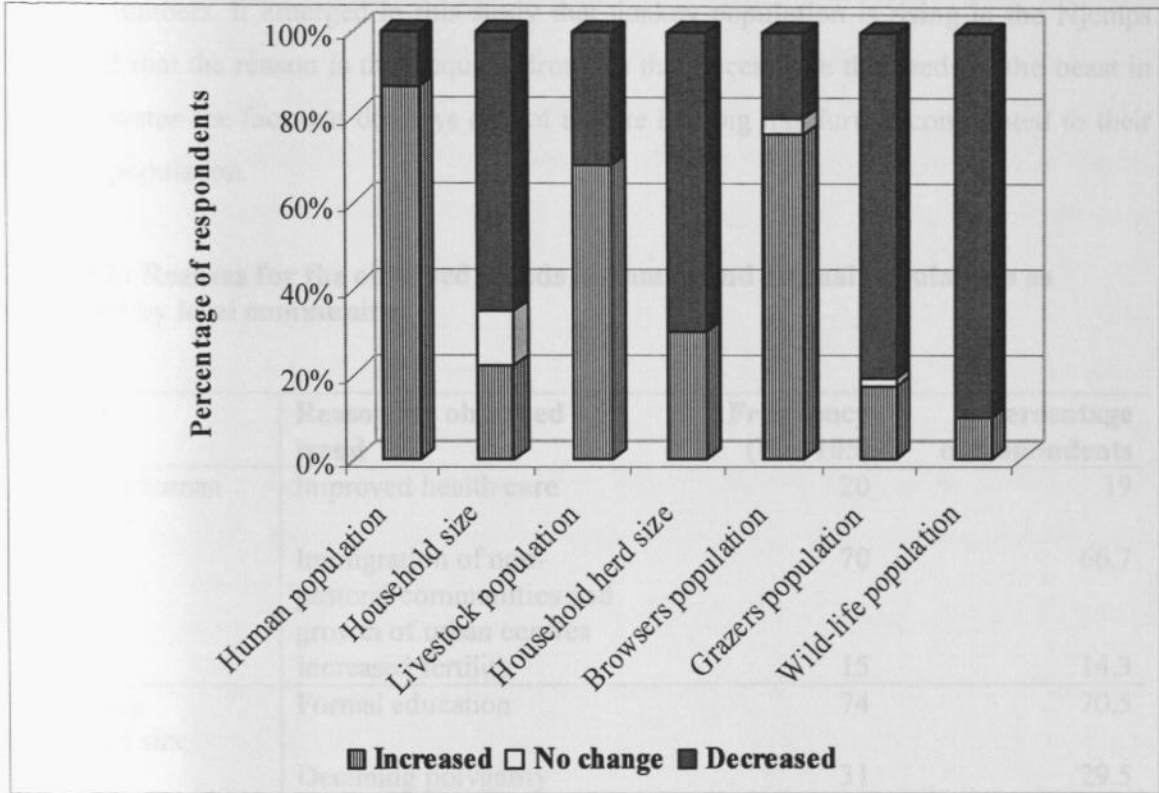


Figure 5.1: Human and animal population trends in the Njemps Flats during the last 40 years as perceived by local communities

Table 5.2 presents the reasons given by the respondents for the observed trends in the current study. The respondents attributed the increase in human population mainly to immigration of non-pastoral communities, growth of urban centres, improved health care and increased fertility. Increase in livestock population was, however, ascribed to both rise in human population and improved veterinary services. The decrease in household size was associated with the decline in polygamy and the increase in formal education. While goat and camel populations have increased in the area, the population of cattle and sheep has declined, a trend related to bush encroachment implying that browsers have become more suited to the environment than grazers. Household herd size was reported to have decreased mainly due to diminishing grazing land, increased poverty and tribal conflicts in that order. School fees and lack of herding labour were other reasons for the dwindling household

stocks. Herding labour was mentioned as a serious problem as most of the children attend school, therefore, making them unavailable for herding. This is made worse when the livestock have to be sold to pay for their school fees. The destruction of the habitat, as pastoralists continue to settle and cultivate, was given as the major reason for decline in wildlife numbers. It emerged in this study that donkey population is rising in the Njempes Flats, and that the reason is the frequent droughts that necessitate the need for the beast in fetching water—the fact that donkeys do not require herding has further contributed to their growing population.

Table 5.2: Reasons for the observed trends in human and animal populations as perceived by local communities

Attribute	Reason for observed trend	Frequency (N = 105)	Percentage of respondents
Increasing human population	Improved health care	20	19
	Immigration of non-pastoral communities and growth of urban centres	70	66.7
	Increased fertility	15	14.3
Decreasing household size	Formal education	74	70.5
	Declining polygamy	31	29.5
Increasing livestock population	Rising human population	67	63.8
	Improved health care	38	36.2
Decreasing household herd size	Diminishing grazing land	53	50.5
	Poverty	26	24.7
	Tribal conflicts	8	7.6
	Sale of livestock to pay school fees	11	10.5
	Lack of herding labour	7	6.7
Decreasing grazers population	Tribal conflicts	10	9.5
	Lack of herding labour	18	17.2
	Bush encroachment	77	73.3
Increasing browsers population	Lack of herding labour	39	37.1
	Bush encroachment	66	62.9
Decreasing wildlife population	Destruction of habitat	100	100

5.4.3 Climatic and hydrological trends

There was a general consensus among the local communities that climatic characteristics of the study area have undergone some changes. Figure 5.2 summarizes the climatic trends as perceived by the local communities. The respondents mentioned decline in rainfall to imply fewer rain-days compared to 40 years ago. They, however, pointed out that despite the decrease in rain-days, heavy torrents accompanied by floods are now more common than before. They also indicated that the rains have become less reliable over the years. While the atmospheric temperature was perceived not to have changed much in the last four decades, they reported stronger winds than before. They blame the winds and floods for the soil erosion observed in the area. More frequent and severe droughts are perceived to be responsible for the reduced water level in Lake Baringo and intermittency of most rivers which were previously permanent. Lake Baringo was reported to have receded for approximately 2 kilometers. The local communities also indicated that River Endao, one of the major sources of water in the area, has changed its course several times in the recent past and has since become seasonal.

Although there were no clear reasons for the changes observed in climatic factors, the local communities alluded to the destruction of the environment but could not quantify how this affected the rainfall regime. What they believed, though, and stated with some degree of certainty, was that 'the climate is changing'. According to Kipkorir (2002), while the annual rain-days have been decreasing in the study area, annual and monthly rainfall has been homogeneous between 1965 and 2000, implying that the rainfall amount per rain-day is increasing. In regard to water bodies, Onyando *et al.* (2005) reported a decrease in the depth of Lake Baringo from 8 m in 1969 to 1.7 m in early 2003. The surface area of the lake has shown a decreasing trend from 219 km² in 1976, 136 km² in 1986, 114 km² in 1995 and 108 km² in 2001 (Onyando *et al.*, 2005). They attributed the shrinking of the lake to mainly siltation, made worse by the frequent droughts. A report by Johansson and Svensson (2002) indicated that a number of streams had dried out and become seasonal. The report also showed fluctuating river discharge amounts for the semi-permanent rivers, Molo and Perkerra during the period 1963 – 1985.

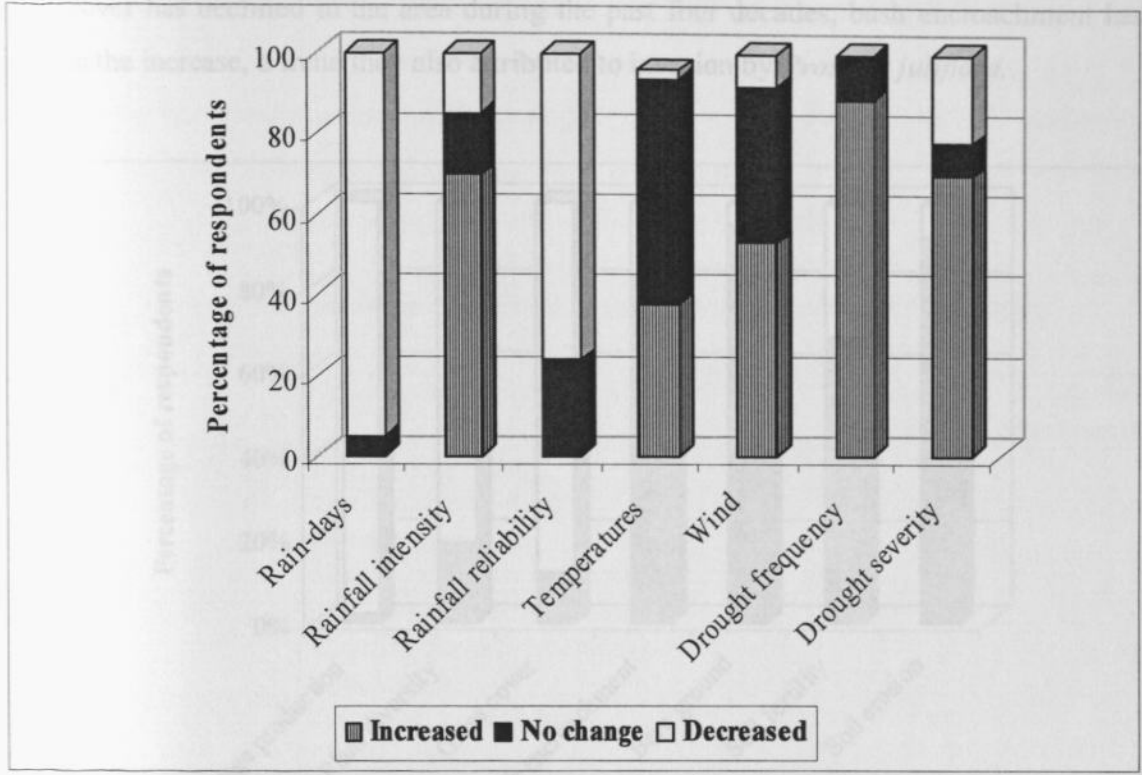


Figure 5.2: Climatic trends during the last 40 years as perceived by local communities

5.4.4 Vegetation and soil change dynamics

Figure 5.3 and Table 5.3 present the perceptions of the respondents on vegetation dynamics and the reasons behind the trends, respectively. The results of the individual interviews and group discussions indicate that the forage production, plant diversity and cover have generally declined. Frequent droughts, decrease in rain-days, overgrazing and human population pressure, in that order, were mentioned as the main causes of decline in forage production. Human population pressure, land clearing for settlement and cultivation and cutting of trees for building and fencing were considered to be the major causes of diminution of plant diversity. The general reduction in vegetation cover was, however, attributed to overgrazing, frequent droughts, human population, land clearing for settlement and cultivation, decline in rain-days and cutting of trees for building and fencing, in that order. The increasing soil erosion was perceived to be as a result of mainly overgrazing and land clearing for settlement and cultivation. The respondents, however, indicated that while

grass cover has declined in the area during the past four decades, bush encroachment has been on the increase, a trend they also attributed to invasion by *Prosopis juliflora*.

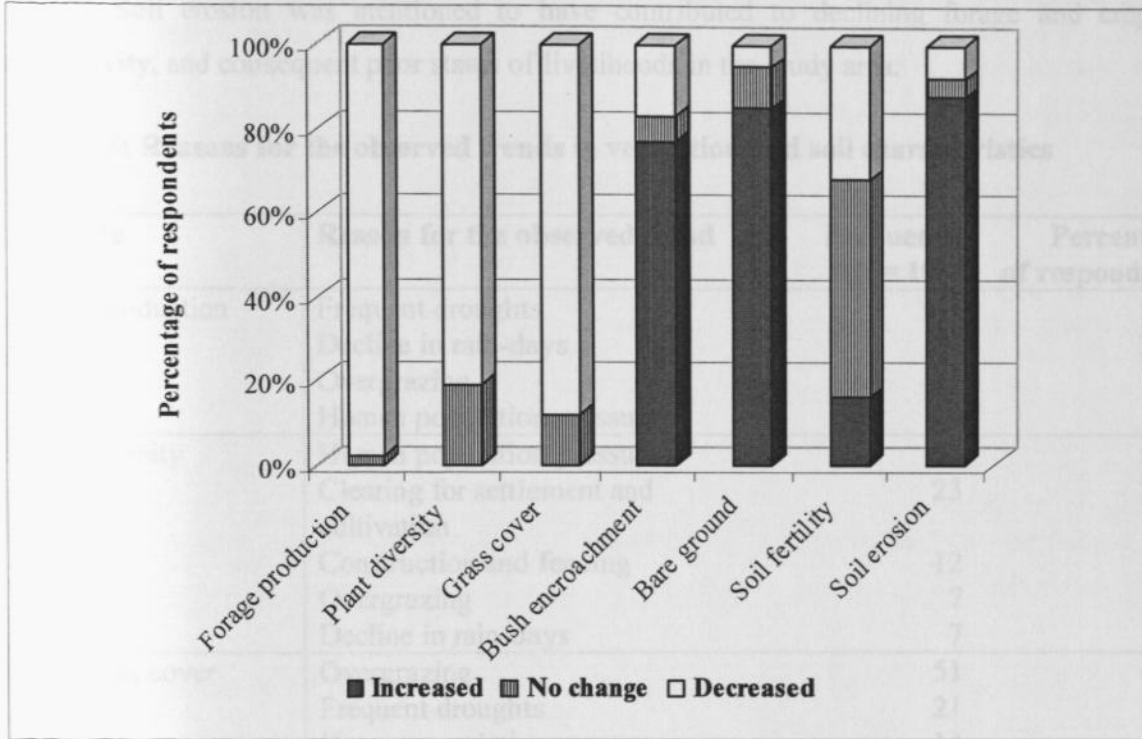


Figure 5.3: Vegetation and soil change trends in the past 40 years as perceived by local communities

Some plant species have decreased in abundance in the last 40 years. Most of the species that have either declined in abundance or disappeared are key perennial forage species such as *Cynodon dactylon*, *Eragrostis superba* and *Heteropogon contortus* and *Aristida mutabilis*, *Acacia nilotica*, *Terminalia brownii*, *Zizyphus pubescens*, *Cordia sinensis*, *Indigofera schimperi*, *Grewia* spp and *Acacia drepanolobium* (Table 5.4). The decline in abundance of these species was generally attributed to overgrazing, harvesting for building and fencing, decline in rain-days, clearing of land for settlement and cultivation, overgrazing, and charcoal burning. On the other hand, some exotic species such as *Prosopis juliflora*, *P. chilensis*, *Opuntia ficus-indica* (cactus) and *Euphorbia tirucalii* introduced in the area during the early 1980s, have increased in abundance. The most widespread and most social and ecologically influential species is *P. juliflora*. According to the local communities, since its introduction, *P. juliflora* has colonized initially bare grounds and invaded critical grazing areas, thereby suppressing herbaceous growths. The findings

indicate that while soil fertility, forage production, vegetation cover have been declining during the period under investigation, soil erosion has been on the increase. Loss of vegetation cover was mentioned as the main factor that predisposes soil to wind and water erosion. Soil erosion was mentioned to have contributed to declining forage and crop productivity, and consequent poor status of livelihoods in the study area.

Table 5.3: Reasons for the observed trends in vegetation and soil characteristics

Attribute	Reason for the observed trend	Frequency (N = 105)	Percentage of respondents
Forage production	Frequent droughts	61	58.1
	Decline in rain-days	24	22.9
	Overgrazing	11	10.5
	Human population pressure	9	8.5
Plant diversity	Human population pressure	56	53.3
	Clearing for settlement and cultivation	23	21.9
	Construction and fencing	12	11.4
	Overgrazing	7	6.7
	Decline in rain-days	7	6.7
Vegetation cover	Overgrazing	51	48.6
	Frequent droughts	21	20
	Human population pressure	14	13.3
	Clearing for settlement and cultivation	13	12.4
	Decline in rain-days	5	4.8
	Construction and fencing	1	0.9
Soil erosion	Overgrazing	55	52.4
	Clearing for settlement and cultivation	43	40.9
	Construction and fencing	5	4.8
	Human population pressure	2	1.9

Table 5.4: Plant species that have declined in abundance in the past 40 years

Plant species		Growth form	Uses	Reasons for decline
Scientific Name	Local Name*			
<i>Aristida adscensionis</i> L.	<i>Chehwoyon</i> (T) <i>Chehwowis</i> (T)	Perennial grass	Forage and Thatching material	Cutting for thatching, and decline in rainfall
<i>Aristida mutabilis</i> Trin. & Rupr.	<i>Nyorikibsowe</i> (P)	Perennial grass	Forage/fodder	Decline in rainfall
<i>Cynodon dactylon</i> (L.) Pers.	<i>Longeri</i> (N) <i>Seretion</i> (P)	Perennial grass	Forage/fodder	Overgrazing and decline in rainfall
<i>Eragrostis superba</i> Peyr.	<i>Chaya</i> (P)	Perennial grass	Used to make bedding and aromatic smoke Forage/fodder	Overgrazing and decline in rainfall
<i>Heteropogon contortus</i> (L.) Beauv. ex R. & Sch.	<i>Salwan</i> (T)	Perennial grass	Forage/fodder	Overgrazing and decline in rainfall
<i>Indigofera schimperi</i> Jaub. & Spach	<i>Longortomia</i> (N) <i>Barkelat</i> (T) <i>Mbirkwo</i> (P)	Shrub	Forage/fodder	Overgrazing and decline in rainfall
<i>Ficus thonningii</i> Blume	<i>Iing'aboli</i> (N) <i>Tipoiwa</i> (P) <i>Boyotwa</i> (T)	Tree	Used for making bee hives	Clearing for settlements and cultivation
<i>Acacia drepanolobium</i> Harms ex Sjoestedt	<i>Ngowo</i> (T) <i>Ayelion</i> (P) <i>Luai</i> (N)	Tree	Forage/fodder	Overgrazing
<i>Acacia nilotica</i> (L.) Del.	<i>Chebiwey</i> (T) <i>Kopkwo</i> (P)	Tree	Construction posts	Cutting for building and fencing, and clearing for cultivation
<i>Terminalia brownii</i> Fres.	<i>Koloswet</i> (T) <i>Koloswo</i> (P)	Tree	Edible fruits, medicine for yellow fever, forage and timber	Cutting for building and fencing, and clearing for cultivation
<i>Zizyphus pubescens</i> (Oliv.)	<i>Tangarurwet</i> (T)	Shrub	Forage and food	Decline in rainfall
<i>Acacia nubica</i> Benth.	<i>Ildepe</i> (N) <i>Pilil</i> (P)	Tree	Forage/fodder	Decline in rainfall
<i>Cordia sinensis</i>	<i>Salabani</i> (N/T) <i>Adomeon</i> (P)	Shrub	Forage/fodder	Charcoal burning
<i>Grewia</i> spp K. Schum	<i>Ilkogomi</i> (N) <i>Toronwo</i> (P/T)	Shrub	Forage/fodder	Cutting for building and fencing

*P = Pokot; T = Tugen; N = Njemps (Il Chamus)

According to de Groot *et al.* (1992), in the 19th century, most of the study area was covered with luxuriant grasses because thorny scrubs were suppressed by periodic fires and that at one time "... a European explorer had to stand on a table to shoot elephants". Similarly, Otieno and Rowntree (1986) indicate that loss of vegetation diversity and cover in Baringo District begun during the colonial administration as a result of land reforms that restricted mobility of pastoralists, and increased cultivation in the area. Krugmann (1996), in his study carried out in Rombo location of Kajiado District, reported a reduction in, and disappearance of particular tree and grass species such as *Albizia anthelmintica* (*Olmokotan* in Maasai), used as a wormicide. The author also reported a general decline in grass species and increasing bush encroachment and invader species such as *Ipomea kituensis*, which has colonized grazing areas of Kajiado District.

5.4.5 Traditional natural resources management practices

A number of cultural practices for managing range resources and coping with the vagaries of nature were mentioned by the respondents. The findings of this study revealed that most of the coping mechanisms have been rendered ineffective during the past four decades. The traditional adaptive strategies mentioned include deferred grazing, mixed-species herds, burning of pasture, keeping of large herds, herd mobility, polygamy, and social alliances (stock friendship). Table 5.5 presents the factors that are perceived by local communities to have undermined the traditional institutions and practices. Increased human population and accompanying competition to secure livelihoods was named as the main factor that undermines the traditional ways of managing natural resources. Other factors include land tenure reforms, tribal conflicts, and government policies that do not recognize traditional institutions and that favour agriculture at the expense of pastoralism. Formal education, poverty and land-use changes were noted for their role in further disregard of cultural practices. The rest of the factors that have contributed to further breakdown of traditional institutions and organizations were indicated to be as a result of the first three.

Many authors (Tadingar, 1994; Niamir, 1990; Krugmann, 1996; Wasonga *et al.*, 2003) have faulted conventional range management techniques for disregarding the traditional pastoral institutions and practices, and blamed them for the failures of the past range development programmes in Africa. It is now widely held that greater success can be achieved through

development interventions built on the existing traditional systems of resource use and management.

Table 5.5: Factors that undermine traditional institutions and practices as perceived by local communities

Factor	Frequency (N=105)	Percentage of respondents
Human population pressure	53	50.5
Tribal conflicts	16	15.2
Government policies	8	7.6
Poverty	3	2.8
Formal education	6	5.7
Land-use changes	2	1.9
Land tenure changes	17	16.2

5.4.6 Local perceptions on land degradation

This study revealed that there is an extensive awareness among the local communities as concerns the threats of environmental degradation. Soil erosion, overgrazing, tree cutting and poverty were mentioned as indicators of land degradation. Whereas the respondents were unanimous that productivity of the land has declined over the years, and that this has affected their livelihoods, they did not quite agree on who was responsible for the observed trend. Although most (50%) of the respondents blamed the problem of land degradation on increased human population, other factors such as restricted mobility, poverty, and lack of alternative livelihoods (Table 5.6) were perceived to have contributed further to deterioration of the range. The scenario is made worse by adverse climate typical of semi-arid rangelands.

Table 5.6: Drivers of land degradation in the study area as perceived by local communities

Factor	Frequency (N=105)	Percentage of respondents
Restricted mobility	21	20
Poverty	13	12.4
Lack of alternative livelihoods	12	11.4
Human population pressure	53	50.5
Adverse climate	6	5.7

The respondents indicated the need for more proactive soil conservation measures to solve the problem of land degradation. They, however, believe that little success can be achieved under the current land tenure system. As much as they are aware that change in land ownership from communal to private would alter the land-use pattern and livelihood strategies, the respondents stressed that a fundamental change of land ownership is necessary to come up with a permanent solution to the problem of land degradation. It appears a paradox particularly after blaming the pre-independence land reforms for the current condition of the range, to suggest the same intervention in the form of individualisation of land to solve the problem of land degradation. However, this study found that private land ownership would be an incentive to pastoralists to conserve the environment. Reduction of household herd size as a way of easing pressure on grazing land proved to be a controversial issue, as was expected, in communities whose main occupation is livestock husbandry. Whereas destocking household herds was only mentioned as a measure of checking overgrazing by a few of the interviewed pastoralists, it was apparent that a number would be willing to reduce their herds given viable alternative options of livelihood, and only if this would help solve the problem of land degradation.

Although most of the times respondents seemed to refer to soil erosion to imply land degradation, it was later understood that they were particularly making reference to the indicators of land degradation, and that they clearly understood the processes involved in diminution of land's productive capacity. The results revealed that the local communities have a broader perception of land degradation including both social and ecological aspects. It was clear that it is not about the extent of soil erosion and vegetation loss but how these affect their livelihoods. The respondents mentioned cultivation of high potential grazing areas, continuous grazing of the range and privatisation of land as some of the changes in land-use pattern arising from restricted mobility and human population pressure. Krugmann (1996) reported similar reasons for land degradation in the rangelands of Kajiado District. First, he indicated a growing encapsulation of the extensive livestock economy that used to be the sole basis of livelihood for the Maasai nomadic pastoralism. He also pointed at lack of access to grazing and water sources, especially in the dry season, and lack of sufficient herd mobility due to spreading agriculture and population growth. He concluded that the livestock economy seems to be fast losing its viability as the sole basis of livelihood for the Maasai.

Concerning measures to be undertaken to reverse the trend of land degradation, private enclosures and pasture reseeding, which have gained a lot of popularity in the area since early 1980s were the most preferred methods of rehabilitation (Table 5.7). Privatisation of land, soil conservation measures such as terracing, keeping of few and improved livestock, promotion of alternative livelihoods, afforestation and protection of grazing reserves, were other measures perceived to be important towards checking land deterioration. Surprisingly, restoration of mobility and communal land ownership were not mentioned as possible measures of reversing the range condition trend. It later became apparent that the respondents were of the opinion that it is easier to adapt to the changing situations than to revert to the old system given the current land tenure system in the regions neighbouring the study area.

Table 5.7: Measures to combat land degradation suggested by local communities

Suggested measure	Frequency (N=105)	Percentage of respondents
Soil conservation e.g. terracing	12	11.4
Private land enclosures and pasture reseeding	54	51.4
Afforestation	4	3.8
Keeping few and improved livestock	11	10.5
Land privitisation	12	11.4
Protection of grazing reserves	1	1.0
Alternative livelihood options	11	10.5

5.5 CONCLUSIONS AND RECOMMENDATIONS

The results of this study reveal a changing vegetation structure, declining plant diversity and herbaceous cover and increasing soil erosion in past four decades. These trends are attributed to the land use pressure associated with rise in both human and livestock populations in addition to rainfall anomalies. As perceived by the local communities, despite the decline in rain-days, heavy torrents accompanied by floods have become common in the past 40 years. The rising trend of alternative sources of livelihood in the study area is a response to the decline in range productivity and social changes. These findings show that pastoralists have a good understanding of their environments and that their knowledge and perceptions provide a

rich source of historical information. The general concurrence of these results with those that are conventionally generated indicates the potential of local knowledge systems as complimentary sources of data, especially by bridging the gap in historical data. There is, therefore, need for more research on local knowledge and perceptions to generate information for the purpose of augmenting available data, especially at local levels.

These findings suggest that pastoralism in Baringo is a system in transition, attempting to maintain itself while at the same time trying to adapt progressively to a continuously shrinking resource base. The results give an indication that it is easier to adapt to the changing social and ecological environments in the Njemps Flats than to revert to the old systems. It would, therefore, be appropriate to encourage the pastoralists to venture into alternative viable activities than try to improve their productivity under the traditional production systems. Livelihood diversification should, however, not undermine the pastoral system of production but modify it to conform to the current socio-ecological conditions to ensure its sustainability as the key livelihood activity.

Despite the possibilities for improvement, the need to reduce pressure on the land resources calls for reduction of the number of people supported, and this implies that efforts must also be directed towards facilitating their absorption into agro-pastoral agriculture, rural or urban employment and any other viable alternatives. More research needs to be carried out on the receptiveness and adoption rate of the pastoralists to alternative livelihood options, and the means of improving them.

5.6 REFERENCES

- Alemu, D. T., D.M. Nyariki and K.O. Farah. 2000. Impact of land-use system and socio-economic roles of vegetation in semi-arid Africa: The case of the Afar and Tigray of Ethiopia. *Journal of Social Science*, 4 (2 – 3): 199 – 206.
- Al-Kodmany, K. 2001. Bridging the gap between technical and local knowledge: Tools for promoting community-based planning and design. *Journal of Architectural and Planning Research*, 18: 110 – 130.
- Anantha, K.D., G. Ikiara, M. Manundu, W. Nyangena, R. Sinange. 2000. Land tenure, land use, Environmental degradation and conflict resolution: a PASIR analysis for the Narok District, Kenya. *Working Paper No. 33*, International Institute for Environment and development (IIED), London, and Institute for Environmental Studies, Amsterdam.
- Campbell, D.J. 1999. Response to drought among farmers and herders in southern Kajiado district, Kenya: A comparison of the 1972 – 1976 and 1994 – 1995. *Journal of Human Ecology*, 27 (3),): 377 – 416.
- Campbell, D.J., H. Gichohi, R. Reid, A. Mwangi and L. Chege. 2003. Interactions between people and wildlife in south east Kajiado District, Kenya. *LUCID Working Paper Series No. 18*.
- de Groot, P., A. Field-Juma and D.O. Hall. 1992. *Reclaiming the Land: Revegetation in Semi-arid Kenya*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- Evangelou, P. 1984. *Livestock Development in Kenya's Maasailand*. Boulder, C.O: Westview Press.
- Farah, K.O. 1996. Management and Development of the Arid Communal Rangelands in Northern Kenya. A critical analysis of the past and the present. Working paper series number 7. The African Pastoral Forum, Pastoral Information Network Program, *Working paper series No. 7*. University of Nairobi, Kenya
- Johansson, J. and J. Svensson. 2002. Land degradation in semi-arid catchment of Lake Baringo, Kenya. A minor field study of physical with socio-economic aspect. Earth science Centre, Department of Physical Geography, Göteborg University.
- Kipkorir, E.C. 2002. Analysis of rainfall climate on the Njemps Flats, Baringo District, Kenya. *Journal of Arid Environments*, 50: 445 – 458.

- Kristjanson, P., M. Radeny, D. Nkedianye, R. Kruska, R. Reid, H. Gichohi, F. Atieno and R. Sanford. 2002. Valuing Alternative Land-Use Options in the Kitengela Wildlife Dispersal Area of Kenya. ILRI, Nairobi.
- Krugmann, H. 1996. Towards Improved Indicators to Measure Desertification and Monitor the Implementation of the Desertification Convention. <http://www.idrc.ca/books/focus/794/krugmann.html>.
- Lambin, E.F., H.J. Geist, E. Lepers. 2003. Dynamics of land-use and land cover change in tropical regions. *Annual Review of Environmental Resources*, 28: 206 – 241.
- Leneman, M. R.S, Reid. 2001. Pastoralism beyond the past. *The Society for International Development, Sage Publications*, 44 (4): 85 – 89.
- Maitima, J. R.S. Reid, L.N. Gachimbi, A. Majule, H. Lyaruu, D. Pomeroy, S. Mugatha, S. Mathai and S. Mugisha. 2004. The linkages between land-use change, land degradation and biodiversity across East Africa. LUCID Working Paper Series No.42.
- Mugenda, O.M. and A.B. Mugenda. 1999. *Research Methods: Quantitative and Qualitative approaches*. ACTS Press, Nairobi, Kenya.
- Mulaku, G.C. 2000. In search of an appropriate land tenure model for pastoral communities. Working paper series No. 22, The African Pastoral Forum, Pastoral Information Network Program, University of Nairobi, Kenya.
- Ngugi, R.K. and D.M. Nyariki. 2005. Rural livelihoods in the arid and semi-arid environments of Kenya: Sustainable alternatives and challenges. *Agriculture and Human Values*, 22: 65 – 71.
- Niamir, M. 1990. *Herders Decision-making in Natural Resources Management in Arid and Semi-arid Africa*. FAO, Rome.
- Njoka, T.J. 1979. Ecological and socio-cultural trends of Kaputei group ranches in Kenya. Ph.D. Thesis, university of California, Berkeley.
- Njoka, T.J., G.W. Muriuki, R.S. Reid and D.M. Nyariki. 2003. The Use of Sociological Methods to Assess Land-use Change: A Case Study of Lambwe Valley, Kenya. *Journal of Social Sciences*, 7(3): 181 – 185.
- Oba, G. 1992. Ecological factors in land use conflicts, land administration and food insecurity in Turkana, Kenya. Overseas Development Institute (ODI) Network paper No. 33a.
- Oba, G. and W. Lusigi. 1987. An overview of drought strategies and land use in African pastoral systems. Paper No. 23a, www.odi.org.uk/pdn/papers.

- Onyando, J.O, P. Kisoyan and M.C. Chemelil. 2005, Estimation of potential soil erosion for river Perkerra catchment in Kenya. *Water Resources Management*, 19: 133 – 143.
- Otieno, A.K. and K.M. Rowtree. 1986. *A comparative study of land degradation in Machakos and Baringo District, Kenya*. Institute of British Geographers, Reading, England.
- Rietbergen-McCracken, J. and D. Narayan. 1998. *Participation and Social Assessment: Tools and Techniques*. The International Bank for Reconstruction, USA.
- Robinns, P. 2003. Beyond ground truth: GIS and the environmental knowledge of herders, professional foresters, and other traditional communities. *Human Ecology*, 31 (2): 233 – 253.
- ROK. 1990. *Kenya Population and Census, 1989. Volume I*. Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi Kenya.
- ROK. 2001. *Kenya Population and Census, 1999. Volume I*. Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi Kenya.
- Rutten, M.M.E.M. 1992. *Selling Wealth to Buy Poverty*. Verlag breitenbach publishers. Saarbrucken, Germany.
- Seaman, J., P. Clarke, T. Boudrea and J. Holt (Eds.). 2000. *The Household Economy Approach. Save the Children Development Manual No. 6*. Save the Children, London.
- Tadingar, T. 1994. Pastoral Development in Sub-Saharan Africa: The role and significance of indigenous technical knowledge. The African Pastoral Forum *Working Paper Series* No. 1. Pastoral Information Network Program, University of Nairobi, Kenya.
- Tokida, K. 2001, The Study on the integrated Rural Development Project in the Baringo Semi Arid Land Area, Master Plan, Japan International Cooperation Agency (JICA), Ministry of Agriculture and Rural Development (MOARD).
- Turner, M.D. and P. Hiernaux. 2002. Turner and P. Hiernaux, The use of herders' accounts to map livestock activities across agropastoral landscapes in semi-arid Africa, *Journal of Landscape Ecology*, 17: 367 – 385.
- UNEP. 2008. *Africa Atlas of our Changing Environment*. UNEP.
www.na.unep.net/AfricaAtlas.
- Walsh, S.J., T.P. Evans and B.L. Turner II. 2004. Population-Environment Interactions with an emphasis on Land-use/Land-cover Dynamics and the Role of Technology. In:

Brunn, S.D. S.L. Cutter and J.W. Harrington (Eds.), *Geography and Technology*, 491 – 519.

Warinda, E. 2000. A socioeconomic survey and economic analysis of land use options in Shompole and Olkiramatian group ranches-Magadi division. African Conservation Centre. Nairobi.

Wasonga, V.O., Ngugi, R.K., and Kitalyi, A. 2003. Traditional range condition and trend assessment: Lessons from the Pokot and Il Chamus pastoralists of Kenya. *Anthropologist*, 5 (2): 79 – 87.

Soil aggregate stability is an important characteristic especially in semi-arid rangelands where soil aggregate stability is crucial for both forage and livestock production. This study was conducted to assess the effects of land-use on soil aggregate stability, surface run-off and soil loss in semi-arid Njempi Flats of Baringo District, Kenya. Two hypotheses were tested; the first that soils under sedentary agro-pastoral land-use system are more susceptible to erosion than those under semi-nomadic pastoral land-use system, and that controlled grazing and enclosure reduces soil susceptibility to erosion. Soil aggregate stability was significantly higher ($P < 0.05$) under semi-nomadic pastoral land-use system (2.76) than in sedentary agro-pastoral land-use system (1.01 ± 0.23). Surface runoff was significantly lower ($P < 0.05$) in semi-nomadic pastoral land-use system (1120 ± 6.7) than in sedentary agro-pastoral land-use system (1326 ± 54.45 mm h⁻¹). Soil loss was significantly higher ($P < 0.05$) in sedentary agro-pastoral land-use system (992 ± 11) than in semi-nomadic pastoral land-use system ($365 \text{ g m}^{-2} \pm 46.21$). Run-off was significantly higher ($P < 0.05$) outside (1390 ± 58.79 mm h⁻¹) than inside (1056 ± 42.28 mm h⁻¹). Soil loss was twice as high ($P < 0.05$) in the open grazing areas (905 ± 77.47 g m⁻²) than in the enclosures (452 ± 69.35 g m⁻²). These results depict land-use system as a determinant of surface run-off and soil erosion. The results also indicate that enclosure is an effective way of reducing susceptibility of soils to erosion.

KEY WORDS: Soil aggregate stability; soil erosion; surface run-off; semi-arid rangelands;

INTRODUCTION

Soil erosion is one of the most discussed and devastating processes that affect productivity and food security in arid and semi-arid rangelands of the world. Land-use changes in these areas have put pressure on the fragile range ecosystems, thereby giving rise to the need for increasing soil sustaining food production, while at the same time conserving natural resources. Land-use and soil productivity in the arid and semi-arid lands are related to the soil water regime. In rangelands where rainfall is low and population demand is high, soil water availability is mainly a function of soil properties that influence soil structure, soil surface area, and therefore water

CHAPTER SIX

6.0 IMPACTS OF LAND-USE ON SOIL PHYSICAL PROPERTIES IN THE NJEMPS FLATS OF BARINGO DISTRICT, KENYA

6.1 ABSTRACT

A clear understanding of soil physical characteristics especially those that influence water infiltration and the ability of soil particles to resist detachment and transportation is imperative for sustainable management of semi-arid rangelands, where soil and water conservation are crucial for both forage and livestock production. This study was conducted to assess the effects of land-use on soil aggregate stability, surface run-off and soil loss in the semi-arid Njemps Flats of Baringo District, Kenya. Two hypotheses were tested; the hypothesis that soils under sedentary agro-pastoral land-use system are more susceptible to erosion than those under semi-nomadic pastoral land-use system, and that controlled grazing through land enclosure reduces soil susceptibility to erosion. Soil aggregate stability was found to be significantly higher ($P \leq 0.05$) under semi-nomadic pastoral land-use system (4.18 ± 0.92 %) than in sedentary agro-pastoral land-use system (1.01 ± 0.25 %). Surface run-off was significantly lower ($P \leq 0.05$) in semi-nomadic pastoral land-use system (1120 ± 54.92 mm h⁻¹) than in sedentary agro-pastoral land-use system (1326 ± 54.45 mm h⁻¹). Soil erosion was significantly higher ($P \leq 0.05$) in sedentary agro-pastoral land-use system (992 ± 81.69 g m⁻²) than in semi-nomadic pastoral land-use system (365 ± 46.21 g m⁻²). Run-off was significantly higher ($P \leq 0.05$) outside (1390 ± 58.79 mm h⁻¹) than inside (1056 ± 42.28 mm h⁻¹) enclosures. Soil loss was twice as high ($P \leq 0.05$) in the open grazing areas (905 ± 77.47 g m⁻²) as inside enclosures (452 ± 69.35 g m⁻²). These results depict land-use system as a major determinant of surface run-off and soil erosion. The results also indicate that enclosure system is an effective way of reducing susceptibility of soils to erosion.

KEY WORDS: Soil aggregate stability; soil erosion; surface run-off; semi-arid rangelands; Njemps Flats.

6.2 INTRODUCTION

Soil erosion is one of the most discussed and devastating processes that affect productivity and livelihood security in arid and semi-arid rangelands of the world. Land-use changes in the recent past have put pressure on the fragile range ecosystems, thereby giving rise to the challenge of increasing and sustaining food production, while at the same time conserving the natural resources. Land-use and soil productivity in the arid and semi-arid lands are closely related to the soil water regime. In rangelands where rainfall is low and evapotranspiration demand is high, soil water availability is mainly a function of soil physical properties that influence soil structure, soil surface area, and therefore water

holding capacity and infiltration capacity (Negassi *et al.*, 2002). These soil physical attributes include texture, bulk density, organic matter content, and clay type. Other important soil factors are soil water properties such as hydraulic conductivity and water-retention characteristics. Soil erosion alters these physical characteristics and leads to increased run-off, reduced water infiltration and further soil loss. A clear understanding of soil physical attributes especially those that are related to the ability of soil to hold water and resist erosion is, therefore, important in the semi-arid rangelands, where soil and water conservation are crucial for both forage and livestock production.

Soil moisture is by far the most important factor in primary productivity in semi-arid rangelands. This is due to low rainfall and high evaporative demands in these areas and, in part, the inability of the soils to store water for long after rainfall. Judicious management of soil moisture in semi-arid areas is, therefore, a prerequisite to improve productivity and sustainability of soil water and vegetation resources (Kironchi, 1998). All the factors that influence water infiltration and the ability of soil particles to resist detachment and transportation are crucial in determining the final soil water content and productivity of semi-arid rangelands. Therefore, an assessment and in-depth understanding of these physical characteristics of soils is imperative in an effort to increase and sustain the productivity of rangelands.

The specific objective of this study was to assess the effects of land-use on soil aggregate stability, surface run-off and soil loss, as indicators of physical degradation of soil in the study area. Two hypotheses are tested in this chapter; the hypothesis that soils under sedentary agro-pastoral system are more susceptible to erosion than those under semi-nomadic pastoral land-use system, and that controlled grazing through land enclosure reduces soil susceptibility to erosion.

6.3 SOIL AGGREGATE STABILITY

Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. The spaces between the aggregates provide pore space for retention and exchange of air and water. Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces (usually associated with water) are applied (USDA, 1996).

Aggregate stability is the relative resistance of soil aggregates against mechanical or physico-chemical destructive forces. Soil aggregation is an important factor in regard to the risk of erosion; a well aggregated soil has clods that are too large to be transported by wind or easily dispersed by water. Aggregate stability is a function of soil texture, soil structure, the type of clay mineral, organic matter content and type, cementing agents and land-use history.

Among the mechanical forces that disturb soil aggregates are soil tillage, impact of heavy machinery, treading by animals and raindrop splash. Physico-chemical forces include slaking, swelling and shrinkage, dispersion, and flocculation. Aggregation influences erosion, movement of water, and plant root growth. Desirable aggregates are stable against rainfall and water movement. Aggregates that break down in water or fall apart when struck by raindrops release individual soil particles that can seal the soil surface and clog pores. This breakdown creates crusts that close pores and other pathways of water and air entry into a soil and, also restricts emergence of seedlings from a soil (USDA, 2001, USDA, 1996).

Soils low in organic matter and high in silt and very fine sand easily form aggregates, which are relatively unstable and easily destroyed by beating action of rain. Soils high in sodium often possess a weak structure and their colloids are deflocculated if the exchange sites are occupied by large amounts of sodium, thereby resulting in low water permeability. On the other hand, certain iron compounds in soils are known to bind clay and other soil grains together resulting in reduced erodibility (Gachene, 1982).

6. 4 SURFACE RUN-OFF

Run-off is depicted when the rate of rainfall exceeds the potential rate of infiltration (Hillel, 1980). When the rate of water supply by rainfall onto the soil exceeds infiltration rate, water starts to accumulate over the soil surface. The volume of water collected before run-off starts depends on the surface roughness and ground slope. Run-off from small fields with little or no rills takes the form of a thin sheet-like flow called overland flow (Morgan, 1986). Land-use and management systems that modify soil surface conditions play a crucial role in partitioning rainfall into run-off, infiltrated water, and influences evapotranspiration within a given environment.

Run-off control is important in semi-arid environments. This is because forage production in the tropical rangelands is principally controlled by rainfall as temperatures are fairly constant throughout the year. The implication is that seasonal variations in yield are largely determined by the amount of water available for plant growth. Therefore, in the semi-arid tropics productivity can be intensified by developing methods of ensuring the best use of rain that falls. Primarily, this means ensuring that as much as possible of the rain infiltrates into the soil and the water conserved by adequate and viable management systems (Vogel, 1994). Run-off can be controlled through protecting the soil surface against raindrop splash; increasing infiltration rate and/or surface storage; and obstructing overland flow to prevent it from gathering velocity.

There are a number of soil surface factors that affect the movement of water through the air-soil intersurface. Cover materials protect the soil surface; on bare soil, lack of cover leads to formation of surface crust under the impact of raindrops. The breakdown of soil structure, compaction, and movement of fine soil particles into pores at or just below the surface leads to crust formation. Surface crusts are characterized by greater density, finer pores and lower saturated conductivity than the underlying soil. Once formed, a crust impedes infiltration, thereby increasing run-off (Gachene, 1982).

Lack of or low vegetation cover makes soils susceptible to crust or surface seal formation due to raindrop impact. The resultant decrease in infiltration capacity leads to increased run-off during high intensity rainfall. Surface cover, by decreasing run-off generation, reduces soil loss. However, response to cover is also dependent on other factors like configuration of cover, whether in contact with the soil or not, soil moisture before rainfall, and surface roughness. Water limiting conditions are caused by high run-off, which is induced by the high intensity and short-duration nature of rainfall, characteristic of the ASALs.

6.5 SOIL LOSS

Soil erosion constitutes the physical removal of topsoil by various agents, including falling raindrops, water flowing over and through the soil profile, wind and gravitational pull. Erosion can also be defined as the wearing away of the land surface by running water, wind or other geological agents (Negassi *et al.*, 2002). It is a two phase process consisting of the

detachment of individual particles from the soil mass and then their transport by erosive agents. The process, therefore, leads to a general decline in soil productivity.

Several soil indicators of land degradation in arid and semi-arid ecosystems have been linked to erosion either by wind or water. Overexploitation of range resources has been reported to result in widespread degradation of land resources and deterioration of rangeland biodiversity. Land-use pressure has led to fewer and less productive species, less vegetation cover, decreased infiltration of rainfall and soil moisture storage and increased soil erosion (Herlocker, 1999). Soil erosion resulting from surface-water run-off is one of the important and easily recognizable indicators of land degradation (RoK /UNEP, 1997).

The most pressing research needs in the arid and semi-arid rangelands revolve around understanding the mechanisms of change in these ecosystems. In order to reduce range degradation and increase range productivity, soil and water conservation measures in the rangelands should be aimed at improving soil moisture, ground cover and forage production. However, it is impractical to identify and apply sustainable soil and water conservation measures in the grazing lands in the absence of reliable information on soil physical properties including run-off patterns and erosion factors. Quantitative data on aggregate stability, run-off, and soil loss, therefore, become of particular value in the semi-arid rangelands where soils are vulnerable to erosion and soil moisture availability is the major factor limiting forage production.

Although a number of studies have been carried out in the study area, some with respect to the assessment of erosion risk and land degradation (Goble, 2006; Johansson and Svensson, 2002; Snelder and Bryan, 1995; Onyando *et al.*, 2005; Rowntree, 1988; Otieno and Rowntree, 1986), none of them has explicitly investigated the soil susceptibility to erosion with respect to land-use. This study attempted to bridge the knowledge gap by assessing the impacts of land-use on soil aggregate stability, surface run-off and soil loss. The current study further compared the above attributes inside and outside enclosures and determined the potential of enclosures as a method of land rehabilitation. The results are expected to inform the methods to be adopted to counter soil degradation and improve productivity in the semi-arid rangelands.

6.6 METHODS

6.6.1 Data collection

Soil sampling was done randomly at four points in each of the six paired plots located in each of the two sites (sedentary agro-pastoral land-use (SAL) and semi-nomadic pastoral land-use (SNL) systems). Sampling was carried out at the peak of the wet (April) and dry (January) seasons, and at the end of wet (June) and dry (February) seasons. This was repeated to capture two wet and two dry seasons during the 2005 – 2006 study period.

6.6.1.1 Determination of soil aggregate stability

Soil samples for determination of aggregate stability were taken at 0 – 30 cm depth using a soil auger. A total of 384 soil samples were collected in this study. Soil aggregate stability was determined using the standard method described by the NRCS Soil Survey Laboratory (USDA, 1996). This procedure involved placing a 25g of soil which had been passed through a 5.00 mm sieve on a 2.00 mm sieve on top of a set 2.00, 0.5, 0.25 and 0.5 mm sieves fixed on endecott test shaker with wet sieving attachment. The samples were wetted and allowed to stand for 10 minutes. The tap was then turned on to give a fine spray in the sample before the shaker was switched on for 10 minutes. The samples retained on each sieve were oven dried at 105°C for 24 hours and weighed. The stability of the aggregates (% SA) was then calculated using the following formula:

$$\% SA = 100 \times \frac{(\text{weight retained}) - (\text{weight of sand retained})}{(\text{total sample weight}) - (\text{total weight of sand})}$$

6.6.1.2 Measurements of surface run-off and soil loss

Measuring soil loss and run-off under simulated rainfall is by far the most promising method for obtaining a quantitative rating of the erodibility of different soils. A portable Kamphorst rainfall simulator (Kamphorst, 1987) was used to determine run-off and soil loss in this study. Each time, rainfall simulation tests were carried out at four randomly selected points inside and outside enclosures at six selected sites in each of the two land-use sites. A total of 384 simulation tests were carried out during the study period.

Prior to simulation tests, it was necessary to standardize the simulation technique through selection and pre-treatment of the test plots to obtain producible results. The test plots measuring 0.0625 m^2 were, therefore, pre-wetted with water before simulation. Simulation tests were run approximately 12 hours after pre-wetting the test plot with water. It was approximated that at least 7 mm is needed to generate a run-off. Plots with a slope of $\leq 4\%$ were prepared for the simulation tests. A slope length of at least 0.4 m was prepared to accommodate both the test plot and the gutter (Plate 6.0). At the bottom of the slope a small trench was made, in which the sample bottle for the collection of run-off and soil loss was placed.



Plate 6.0: The Kamphorst rainfall simulator

After filling the sprinkler, the cork on the filling opening was replaced and the sprinkler was moved with the support to the test plot. The sprinkler was then turned around to its sprinkling position, and after it was ascertained that the plot frame, gutter, and sample bottle were in place, the water level in the reservoir was noted and the simulation was started by removing the cork from the aeration pipe. After five minutes the simulation was stopped by replacing the cork on the aeration pipe. The sediment left behind in the gutter was added to

the contents of the sample bottle with the aid of a wiper. The sample bottles were then taken to the laboratory, where the contents were decanted to separate the sediments from water, which was then measured to determine the amounts of surface run-off in mm h^{-1} . The sediments were weighed and dried to determine the amounts of soil lost in g m^{-2} .

6.6.1.3 Related soil and surface cover characteristics

Besides soil aggregate stability, surface run-off and soil loss, this study determined related soil properties including soil bulk density, porosity, soil organic carbon and texture. In addition to herbaceous cover, these measurements were taken to determine the physical soil and surface characteristics of the study sites for the purpose of supporting discussions on the soil attributes of interest. The same soil samples collected for determination of soil aggregate stability were used for determination of porosity, soil organic carbon and texture. However, for determination of soil bulk density, undisturbed soil samples were taken at 0 – 30 cm depth using core rings. Soil sampling for bulk density was done once during the study period, and a total of 96 soil samples were collected for laboratory analysis.

6.6.1.3.1 Determination of soil bulk density

Soil bulk density is defined as the ratio of mass of oven-dry soil to its total volume expressed as g cm^{-3} (Rowell, 1994). It is an indication of the soil's physical condition, and is usually related to soil porosity, texture, hydraulic conductivity, infiltration rate, aggregation, compaction and organic matter content. Land-use activities that compact the soil, raise bulk density and therefore reduce infiltration (Hanan, 1998). To determine soil bulk density, undisturbed samples collected using core rings of known weight (W1) were dried at 105°C for 48 hours and weighed (W2) (Okalebo *et. al.*, 2002). Bulk density (PB) was computed using the following formula described by Blake and Hartge (1986):

$$PB \text{ (g cm}^{-3}\text{)} = (W2 \text{ g} - W1 \text{ g})/V \text{ cm}^3$$

Where: PB = Bulk density in g cm^{-3} ;

$W2$ = Weight of oven dry sample in grams;

$W1$ = Weight of the core ring; and

V = Volume of sample as determined by the volume of core ring in cm^3

6.6.1.3.2 Determination of porosity

Soil pores are classified by size as macro-pores (diameter $> 0.1 \text{ mm}$), meso-pores (diameter $30 - 100 \text{ }\mu\text{m}$) and micro-pores (diameter $< 30 \text{ }\mu\text{m}$). Macro-pores are mainly responsible for aeration and gravity flow; meso-pores conduct water by rapid capillary flow; and micro-pores are responsible for water retention and slow capillary flow (Anderson and Ingram, 1998). Total porosity, was calculated using the following formula described by Anderson and Ingram (1998):

Total porosity (%) = $\{1 - (\text{bulk density} / \text{particle density})\} \times 100$. The particle density is assumed to be 2.65 g cm^{-3} for most mineral soils.

6.6.1.3.3 Determination of soil organic carbon

In addition to improving the soil structure, aeration and facilitating root and moisture penetration, organic matter is a major supplier of N, P and S, especially in the arid and semi-arid lands where fertilizers are seldom used (Nye and Greenland, 1960). As indicated by Young (1997), the soil organic matter fraction also provides the pH buffering capacity of the soil. Soil organic carbon was determined by chromic acid method. Soil samples were air-dried and then ground to pass through a 0.5 mm sieve. The samples were then analyzed for percent organic carbon (% C). The percent organic carbon was calculated on air-dry matter basis according to the following formula by Walkley and Black (Klute, 1986; Anderson; Ingram, 1993 and Okalebo *et al.*, 2002):

$$\% \text{ cover} = \frac{\text{Total number of hits}}{\text{Total length of transect} / (\text{Total no of 1m intervals})} \times 100$$

$$\% \text{ Organic C} = \frac{(\text{me K}_2\text{Cr}_2\text{O}_7 - \text{me Fe SO}_4 \times 0.003 \times 100 \times (f))}{\text{Weight of air-dry soil (g)}}$$

Where f = Correction factor (1.30).

This method oxidises about 77% of the soil organic fraction, and this factor is taken into account in the formula given above. It is usually assumed that carbon forms an average of 58% of soil organic matter, so that the percentage carbon found is multiplied by 1.724 to give the percentage organic matter: % Organic matter in the soil = % Organic C x 1.724.

6.6.1.3.4 Determination of soil texture

The particle size analysis of a soil estimates the percentage sand, silt and clay contents of soil and is often reported as percentage by weight of oven-dry and organic matter-free soil (Okalebo *et al.*, 2002). Based on the proportions of different particle sizes, a soil textural category may be assigned to the sample. Soil texture was determined using the hydrometer method described by Okalebo *et al.* (2002) and Anderson and Ingram (1998). The first stage in particle size analysis is the dispersion of the soil into the individual particles, which are sand (2.00 – 0.05 mm), silt (0.05 – 0.002 mm) and clay (< 0.002 mm) fractions. This method was used to finally determine percentage sand, silt and clay in the soil samples.

6.6.1.3.5 Measurement of herbaceous cover

The direct estimates of herbaceous cover involved use of line transect methods (Cook and Stubbendieck, 1986). Herbaceous cover was sampled by dropping a vertical point at every 1 m interval along a 25 m transect (see Muchoki, 1988). Two line transects were located randomly inside and outside each of the 6 paired plots located in each of the two sites (sedentary agro-pastoral land-use (SAL) and semi-nomadic pastoral land-use (SNL) systems). The species hit by the vertical point were recorded along the 25m line.

The herbaceous cover was then calculated using the following formula:

$$\text{Percent basal cover} = \frac{\text{Total number of hits}}{\text{Total length of transect (Total no. of 1m intervals)}} \times 100$$

6.6.2 Data analysis

Data on soil attributes were subjected to the analysis of variance (ANOVA) to determine the differences between the two land-use systems, inside and outside the enclosures, and the wet and dry seasons. The means were separated using the Turkey's W procedure as outlined by Lawes Agricultural Trust (2006) and Steel and Torrie (1980).

6.7 RESULTS AND DISCUSSIONS

Table 6.0 presents selected physical characteristics of soils inside and outside enclosures under the sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems. The table also shows the herbaceous cover by land-use system, and inside and outside enclosures in the Njemps Flats.

Table 6.0: Physical soil and surface cover characteristics in the Njemps Flats

Soil attribute	Enclosure	SAL	SNL	SE
Bulk density (g cm ⁻³)	Inside	1.37	1.37	0.03
	Outside	1.38	1.36	0.03
Porosity (%)	Inside	47.96	49.21	1.42
	Outside	45.33	47.33	1.42
Organic carbon (%)	Inside	0.45	0.75	0.07
	Outside	0.41	0.65	0.07
Sand (%)	Inside	36.90	43.10	2.60
	Outside	36.00	50.70	2.60
Silt (%)	Inside	34.46	28.29	1.39
	Outside	33.42	26.17	1.39
Clay (%)	Inside	28.70	28.20	2.10
	Outside	30.20	22.90	2.10
Herbaceous cover (%)	Inside	29.42	46.17	3.30
	Outside	23.83	27.33	3.30

6.7.1 Effects of land-use on soil aggregate stability

Table 6.1 shows soil aggregate stability inside and outside enclosures, and in the two sites during the study period. The stability of soil aggregates was significantly higher ($P \leq 0.05$) under semi-nomadic land-use system (4.18 ± 0.92 %) than in the sedentary agro-pastoral land-use system (1.01 ± 0.25 %). This is confirmed by the multiple regression results that reveal that land-use is the most important factor in determining soil aggregate stability (Table 6.2). There was, however, no significant difference ($P \leq 0.05$) in stability of soil aggregates between the enclosures (2.67 ± 0.74 %) and open grazing areas (2.52 ± 0.68 %). Likewise, the two seasons did not show significant difference ($P \leq 0.05$) in terms of aggregate stability of soil (wet season, 2.70 ± 0.78 %; and dry season 2.50 ± 0.64 %) (Table 6.1 and Figure 6.0).

Table 6.1: Mean soil aggregate stability (%), run-off and (mm h^{-1}) soil loss (g m^{-2}) inside and outside enclosures; under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems; and in the wet and dry seasons

Soil attribute	Land-use			Enclosure			Season		
	SAL	SNL	t	Inside	Outside	t	Wet	Dry	t
Aggregate stability	1.01 ± 0.25	4.18 ± 0.92	3.31*	2.67 ± 0.74	2.52 ± 0.68	0.15	2.70 ± 0.78	2.50 ± 0.64	0.20
Run-off	1326 ± 54.45	1120 ± 54.92	-2.66*	1056 ± 42.28	1390 ± 58.79	4.61*	1189 ± 50.58	1256 ± 61.86	-0.83
Soil loss	992 ± 81.69	365 ± 46.21	6.69*	452 ± 69.35	905 ± 77.47	-4.36*	511 ± 73.20	846 ± 80.28	-3.08*

SAL = Sedentary agro-pastoral land-use system; SNL = Semi-nomadic pastoral land-use system
Two-tailed unpaired t-test; * = Significant at $P \leq 0.05$

The lower aggregate stability under the sedentary agro-pastoral land-use system than in the semi-nomadic pastoral land-use system can be attributed to higher land-use pressure associated with continuous grazing, cultivation and settlement of key grazing areas. These activities directly impact on soil structure through reduction of organic matter and compaction (Trimble et al., 1995; Oztas and Comakli, 2003; Keya, 1998). This is in contrast to less impacting rotational grazing and pasture deferral associated with the semi-nomadic pastoral land-use system. The stability of aggregates is dependent on soil texture, the amount and type of organic matter present, and the type and size of the microbial population, among other soil factors (USDA, 2001).

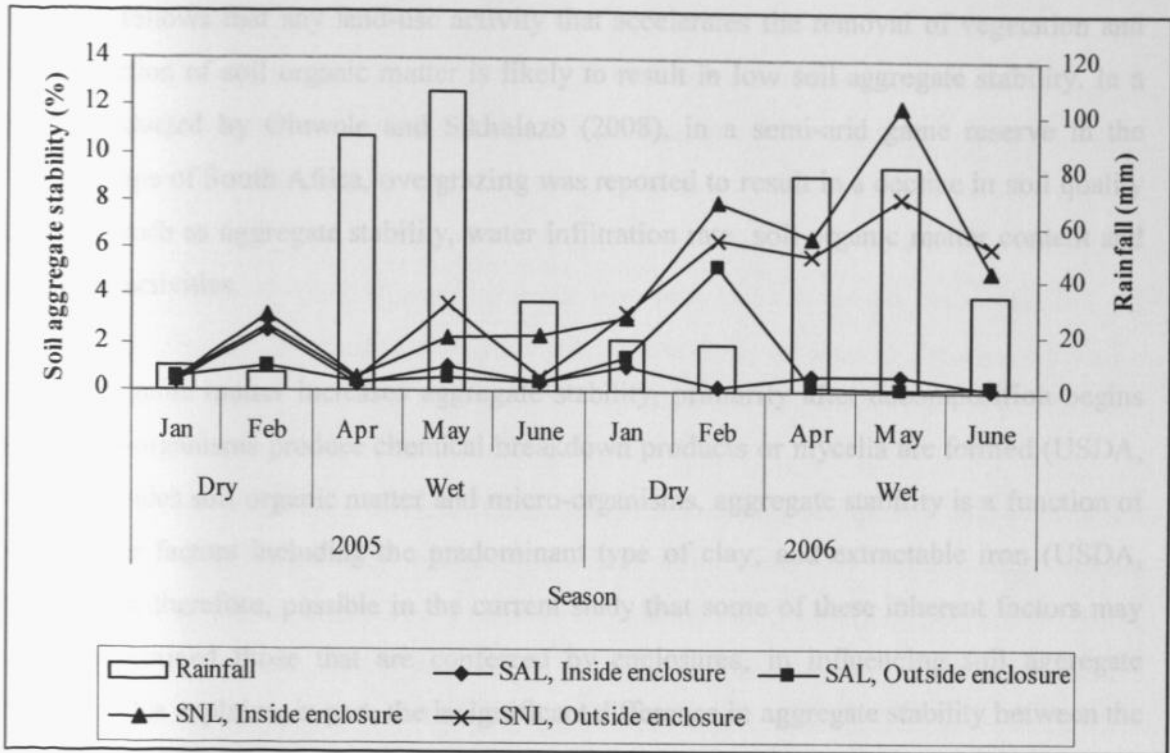


Figure 6.0: Soil aggregate stability (%) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period

Table 6.2: Factors influencing soil aggregate stability in the Njemps Flats

Model	β	SE	t
Constant	15.383	33.352	2.461*
Land-use	3.686	1.364	3.969*
Enclosure	0.390	1.233	0.316
Soil organic carbon	2.197	1.535	3.128*
Silt	-0.027	0.339	-0.079
Clay	-3.188	0.332	-2.566*

Significant at 5%; $R^2 = 0.465$; Adj. $R^2 = 0.485$; $F = 1.674^$; $N = 96$

The equation for the model is $SA = 15.38 + 3.69LU + 0.39EC + 2.20SOC - 0.03SILT - 3.19CLAY$. Where SA = Aggregate stability; LU = Land-use; EC = Enclosure; and SOC = Soil organic carbon.

Mills and Fey (2003) in their review of research findings from various semi-arid areas relate low stability of soil aggregate to a decline in soil organic matter. Soils that have a high content of organic matter have greater aggregate stability (Igwe and Nwokocho, 2006). It

therefore follows that any land-use activity that accelerates the removal of vegetation and thus reduction of soil organic matter is likely to result in low soil aggregate stability. In a study conducted by Oluwole and Sikhalazo (2008), in a semi-arid game reserve in the Eastern Cape of South Africa, overgrazing was reported to result in a decline in soil quality variables such as aggregate stability, water infiltration rate, soil organic matter content and microbial activities.

Adding organic matter increases aggregate stability, primarily after decomposition begins and micro-organisms produce chemical breakdown products or mycelia are formed (USDA, 2001). Besides soil organic matter and micro-organisms, aggregate stability is a function of many other factors including the predominant type of clay, and extractable iron (USDA, 1996). It is, therefore, possible in the current study that some of these inherent factors may have undermined those that are conferred by enclosures, in influencing soil aggregate stability. This explains, in part, the insignificant difference in aggregate stability between the enclosures and open grazing areas in this study. In this study, aggregate stability was expected to be higher during the dry season than in the wet season (Gachene, 1982). However, the slaking process that is as a result of trapped air, which by forcing its way out of the aggregates disrupts the aggregates, may have lowered soil aggregate stability in the wet season. Slaking is a process of structure breakdown under the influence of wetting of soil aggregates, due to swelling of clay minerals, dissolving of cementing agents, air explosion or reduction in pore water suction (USAD, 1996; Gachene, 1982).

6.7.2 Effects of land-use on surface run-off

Table 6.1 presents run-off data inside and outside enclosures, under the agro-pastoral and semi-nomadic land-use systems, and in the wet and dry seasons. In table 6.3, the results of a multiple regression using run-off as the regressand are presented. The results show that land-use, season and enclosures were the major determinant of surface run-off in the study area. There was significantly lower ($P \leq 0.05$) run-off in the semi-nomadic pastoral land-use system ($1120 \pm 54.92 \text{ mm h}^{-1}$) than in sedentary agro-pastoral land-use system ($1326 \pm 54.45 \text{ mm h}^{-1}$). This may have been due to higher interception of raindrop/showers and enhanced infiltration as a result of higher herbaceous cover observed under the semi-nomadic pastoral land-use system than in the sedentary agro-pastoral land-use system. Run-

off was significantly higher ($P \leq 0.05$) outside ($1390 \pm 58.79 \text{ mm h}^{-1}$) than inside ($1056 \pm 42.28 \text{ mm h}^{-1}$) enclosures. This is probably due to a better herbaceous cover that enhances infiltration inside than outside enclosures. There was, however, no significant difference ($P \leq 0.05$) in run-off between the two seasons (dry season, $1189 \pm 50.58 \text{ mm h}^{-1}$; and wet season, $1256 \pm 61.86 \text{ mm h}^{-1}$) (Table 6.1 and Figure 6.1). Run-off was expected to be significantly higher ($P \leq 0.05$) during the dry season with less vegetation cover than the wet season, but slaking, observed in the study area (Plate 6.1), resulted in the formation of a superficial crust thereby reducing water infiltration and enhancing run-off in the wet season.

The process of water entry into the soil depends on soil surface conditions, initial soil water content and natural variation between sites. Infiltration rates and water storage studies consistently report the existence of a positive correlation with amount of plant cover, and a negative correlation with bare ground. In a study carried out in the central semi-arid rangelands of Kenya, Mutunga (1995) reported results that corroborate those of the current study. He found that run-off and infiltration of rain water are influenced mostly by soil cover or soil surface management and that vegetative cover significantly reduced run-off. Using run-off test plots, Mutunga reported that erosivity and vegetative cover accounted for 65% of the variability in rainwater loss. He found that during heavy rains, up to 80% of rainfall was lost as surface run-off from bare and crusted soils. His findings indicate that plots with perennial cover had run-off of less than half that from bare plots.

	SE	t
1016.797	192.129	5.292*
-230.455	70.442	-3.272*
79.355	75.718	0.048
342.781	68.255	5.022*
0.311	2.400	3.130*
25.046	22.580	1.109

$R^2 = 0.851$, Adj. $R^2 = 0.497$, $F = 10.32^*$, $N = 96$

For the model: $\text{Run-off} = 1016.80 - 230.46LU + 79.36SN + 342.78EC + 25.05BD$ Where $LU = \text{Land-use}$; $SN = \text{season}$; $EC = \text{Enclosure}$; $COVER = \text{cover}$; and $BD = \text{Bulk density}$

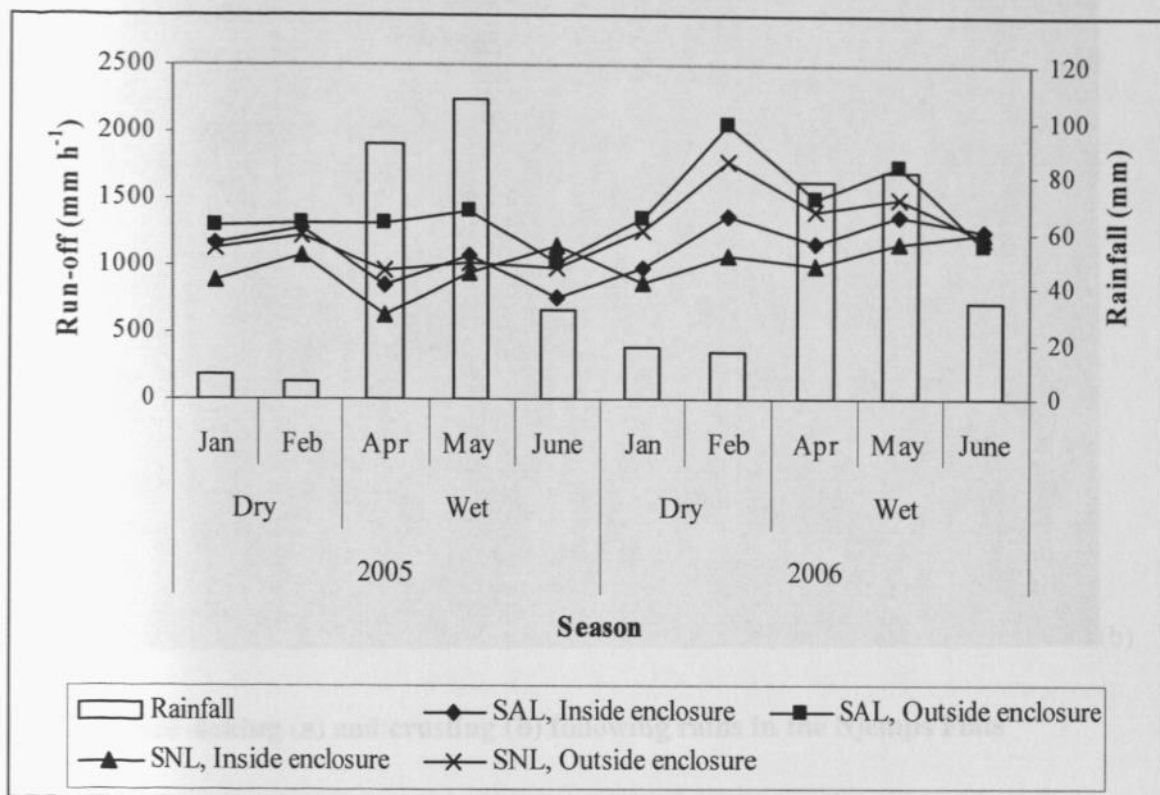


Figure 6.1: Run-off (mm h⁻¹) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period

Table 6.3: Factors influencing surface run-off in the Njemps Flats

Model	β	SE	t
Constant	1016.797	192.129	5.292*
Land-use	-230.455	70.442	-3.272*
Season	79.355	75.718	0.048
Enclosure	342.781	68.255	5.022*
Herbaceous cover	0.311	2.400	3.130*
Bulk density	25.046	22.580	1.109

Significant at 5%; $R^2 = 0.451$; Adj. $R^2 = 0.407$; $F = 10.32^$; $N = 96$

The equation for the model is $\text{Run-off} = 1016.80 - 230.46LU + 79.36SN - 342.78EC + 0.31COVER + 25.05BD$. Where LU = Land-use; SN = season; EC = Enclosure; $COVER$ = Herbaceous cover, and BD = Bulk density

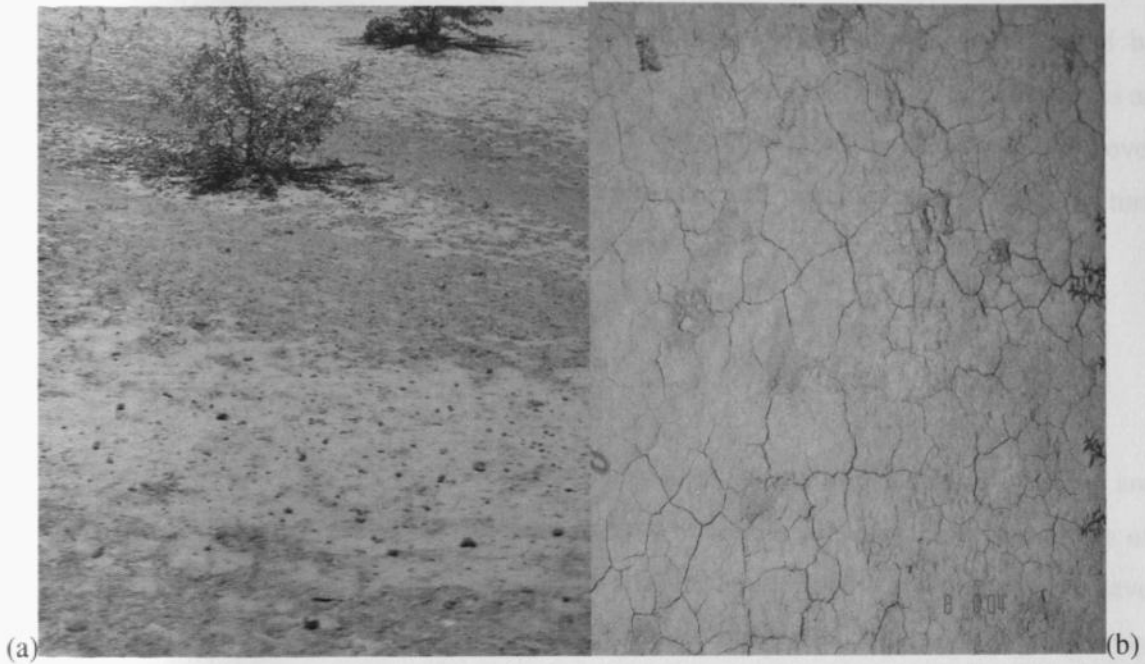


Plate 6.1: Soil slaking (a) and crusting (b) following rains in the Njemps Flats

Tadesse *et al.* (2002) reported high run-off in open access range compared to controlled grazing areas in a semi-arid site in Ginchi, Ethiopia. He attributed this to vegetation removal and trampling by livestock. Livestock grazing alters the natural relationship between infiltration and run-off by reducing the protection afforded by vegetation cover, scattering the litter, and compacting the soil through trampling (Trimble and Mendel, 1995). Heavy grazing, therefore, reduces infiltration, and increases run-off and increases erosion and sediment yield. Lower infiltration rates and higher run-offs have been reported from overgrazed plots by Thomas *et al.* (1981). Using test plots under simulated rainfall in Machakos District of Kenya, they found that bare grazing land and continuously grazed land produced the highest run-off, with pasture protected from grazing producing about 40% less run-off.

In a study carried out by McIvor and Gardener (1995), in a semi-arid rangeland in Australia, runoff and soil movement were found to be related to cover levels on the plots. Their study found that soil movement decreased rapidly as cover increased, and that only small cover levels (40%) were needed to reduce them to a low level. Greene and Wood (1994), working a semi-arid wooded grassland in Australia, concluded that plants increase infiltration and decrease runoff by (i) funnelling water down their stems and (ii) providing macropores at

the base of the plant through which water can rapidly enter the soil. As observed by Kironchi (1998, 1992) in the semi-arid rangelands in Laikipia District of Kenya, cover is an important determinant of run-off in a semi-arid environment. A good vegetation cover increases infiltration capacity of soils by increasing the soil organic matter, which in turn lowers the bulk density and increases porosity.

6.7.3 Effects of land-use on soil erosion

The amounts of soil lost inside and outside enclosures in the two land-use systems are shown in Table 6.1. In Table 6.4, a multiple regression results showing the determinants of soil erosion are presented. The results indicate that land-use, enclosures and season have significant influence on soil erosion in the study area. Soil loss was found to be significantly higher ($P \leq 0.05$) in sedentary agro-pastoral land-use system ($992 \pm 81.69 \text{ g m}^{-2}$) than in semi-nomadic pastoral land-use system ($365 \pm 46.21 \text{ g m}^{-2}$). A possible reason for this may be the lower herbaceous cover and aggregate stability of soils under sedentary agro-pastoral land-use system than in semi-nomadic pastoral land-use system. There was significantly higher ($P \leq 0.05$) soil loss during the dry season ($846 \pm 80.28 \text{ g m}^{-2}$) than the wet season ($511 \pm 73.20 \text{ g m}^{-2}$) (Table 6.1 and Figure 6.2). This may have been as a result of higher surface cover, surface sealing, compaction and higher cohesion that make it difficult to detach the particles during the wet than dry season. Soil loss was twice higher ($P \leq 0.05$) in the open grazing areas ($905 \pm 77.47 \text{ g m}^{-2}$) compared to inside enclosures ($452 \pm 69.35 \text{ g m}^{-2}$). The higher herbaceous cover and the soil binding action of roots may have reduced the ability of showers to detach and transport soil particles inside compared to outside the enclosures.

Soil erodibility is a function of surface cover, management, soil texture and structure (Negassi *et al.*, 2002). According to a study conducted by Snelder and Bryan (1995) to determine the influence of vegetation density on soil loss in the Njemps Flats, a critical threshold occurred at 55% herbaceous cover below which erosion rates rapidly increased. The study, however, showed that storm duration and frequency were important determinants of erosion over more prolonged time periods. Binswanger *et al.* (1980) reported that the combination of intense storms and lack of plant cover promotes soil losses from bare land. Gachimbi (1990) in a study conducted in the semi-arid rangelands in Kibwezi, though used

dead brushwood as cover, reported that cover decreases kinetic energy of raindrop thereby reducing both run-off and soil loss. Mutunga (1995) reported a significant difference in soil loss among different grazing pressures regardless of the slope. Mutunga's study reaffirms the importance of cover in reducing soil erosion—he observed the lowest soil loss in non-grazed plots, while highest soil loss was recorded in grazed plots.

CONCLUSIONS AND RECOMMENDATIONS

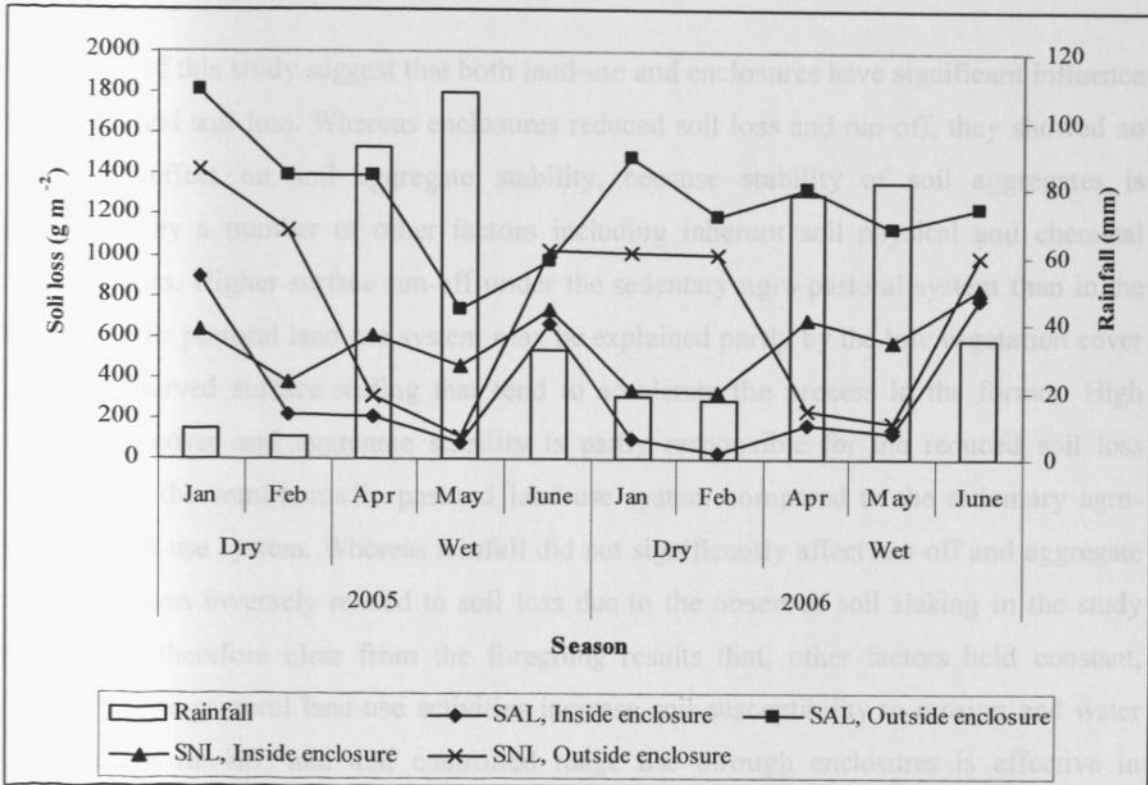


Figure 6.2: Soil loss (g m⁻²) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period

Table 6.4: Factors influencing soil loss in the Njemps Flats

Model	β	SE	t
Constant	679.644	266.590	2.549*
Land-use	-524.409	88.581	-5.920*
Season	338.210	88.404	3.826*
Enclosure	437.787	90.484	4.838*
Herbaceous cover	-1.037	2.789	-4.372*
Run-off	0.047	0.125	0.373
Aggregate stability	6.542	7.935	4.824*

Significant at 5%; R² = 0.644; Adj. R² = 0.592; F = 12.500; N = 96

The equation for the model is $\text{Soil loss} = 679.64 - 524.41LU + 338.21SN + 437.79EC - 1.04COVER + 0.05RUN + 6.54SA$. Where LU = Land-use; SN = season; EC = Enclosure; $COVER$ = Herbaceous cover; RUN = Run-off; SA = Aggregate stability; and BD = Bulk density

6.8 CONCLUSIONS AND RECOMMENDATIONS

The results of this study suggest that both land-use and enclosures have significant influence on run-off and soil loss. Whereas enclosures reduced soil loss and run-off, they showed no significant effect on soil aggregate stability, because stability of soil aggregates is determined by a number of other factors including inherent soil physical and chemical characteristics. Higher surface run-off under the sedentary agro-pastoral system than in the semi-nomadic pastoral land-use system may be explained partly by the low vegetation cover and the observed surface sealing that tend to accelerate the process in the former. High herbaceous cover and aggregate stability is partly responsible for the reduced soil loss observed in the semi-nomadic pastoral land-use system compared to the sedentary agro-pastoral land-use system. Whereas rainfall did not significantly affect run-off and aggregate stability, it was inversely related to soil loss due to the observed soil slaking in the study area. It is therefore clear from the foregoing results that, other factors held constant, sedentary agro-pastoral land-use activities increase soil susceptibility to erosion and water loss through run-off, and that controlled range use through enclosures is effective in conserving soil and water in semi-arid environments.

A number of crucial inferences for developing a strategy to conserve and reclaim denuded land arise from the results of this study. Low aggregate stability, high run-off and soil loss in open grazing land show that ecological restoration of degraded areas may not be possible unless measures are taken to enhance ground cover, improve water infiltration and reduce soil loss.

The results point to the problem of low soil aggregate stability, high surface run-off and soil erosion in the Njemps Flats, particularly under the sedentary agro-pastoral land-use system. In order to reduce soil degradation and restore range productivity, more research is required in the application of soil and water conservation technologies in the study area. There is

need to assess the application of simple and viable methods that would increase infiltration, which would in turn result in increased plant biomass production, and therefore provide forage that is in high demand for the pastoral herds.

1997. *Soil Biology and Fertility: A Handbook of Methods* (2nd Edition). International Centre for Agriculture and Biosciences (CABI International).

1980. P., S. M. Virmani and J. Kampan. 1980. Farming systems components for arid zone in India: evidence from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). *Research Bulletin No 2*, ICRISAT, Patancheru, Andhra Pradesh, India, pp. 44.

1986. and J. Starbuck. 1986. *Rangeland Research: Basic problems and Techniques*. Society for Rangeland Management, Denver, Colorado.

1982. C.K. 1982. Assessing the relative erodibility of some Kenya soils using a rainfall simulator and the prediction of relative erodibility factors. M.Sc. thesis, University of Nairobi.

1990. L.N. 1990. Land Degradation and its control in the Kibwazi area, Kenya. M.Sc. thesis, University of Nairobi.

1994. *Vegetation Change in the Tugen Hills Lake Baringo area, Kenya*. Centre for Observation, University of Yale.

1994. S., P.L.A. Kunsell and J.T. Wood. 1994. Role of plant cover and stock trampling on soil and soil-erosion from semi-arid wooded rangelands. *Australian Journal of Research*, 32 (3): 953 – 973.

1997. *Rangeland resources in East Africa: their ecology and development*. Nairobi.

1965. *Applications of Soil Physics*. Academic Press, New York.

2006. and D. Nwankwa. 2006. Soil organic matter fractions and microaggregation in a forest under cultivation and secondary forest in south-eastern Nigeria. *Australian Journal of Soil Research*, 44 (6): 627 – 635.

2002. *Land degradation in semi-arid catchment of Lake Baringo, Kenya. A minor field study of physical with socio-economic aspect*. Department of Physical Geography, Göttingen University.

1996. *Impact of land use patterns and climate on the vegetation ecology of arid and semi-arid rangeland pastoral ecosystems of northern Kenya*. M.Sc. thesis, University of Trier, Germany.

6.9 REFERENCES

- Anderson, J.M. and J.S.I. Ingram. 1998. *Tropical Soil Biology and Fertility. A Handbook of Methods* (2nd Edition). International Centre for Agriculture and Biosciences (CAB International).
- Binswanger, H. P., S. M. Virmani and J. Kampen. 1980. Farming systems components for selected areas in India: evidence from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). *Research Bulletin* No 2, ICRISAT, Patancheru, Andhra Pradesh, India, pp. 44.
- Cook, W.C., and J. Stubbendieck. 1986. *Range Research: Basic problems and Techniques*. Society for Range Management, Denver, Colorado.
- Gachene, C.C.K. 1982. Assessing the relative erodibility of some Kenya soils using a rainfall simulator and the prediction of relative erodibility factors. M.Sc. thesis, University of Nairobi.
- Gachimbi, L.N. 1990. Land Degradation and its control in the Kibwezi area, Kenya. M.Sc. thesis, University of Nairobi.
- Goble, E. 2006. Vegetation Change in the Tugen Hills Lake Baringo area, Kenya. Centre for Earth Observation, University of Yale.
- Greene, R.S.B., P.I.A. Kinnell and J.T. Wood. 1994. Role of plant cover and stock trampling on runoff and soil-erosion from semi-arid wooded rangelands. *Australian Journal of Soil Research*, 32 (5): 953 – 973.
- Herlocker D. 1999. *Rangeland resources in East Africa: their ecology and development*. GTZ, Nairobi.
- Hillel, D. 1980. *Applications of Soil Physics*. Academic Press, New York.
- Igwe C. A. and D. Nwokocho. 2006. Soil organic matter fractions and microaggregation in a Ultisol under cultivation and secondary forest in south-eastern Nigeria. *Australian Journal of Soil Research*, 44 (6): 627 – 635.
- Johansson and Svensson. 2002. Land degradation in semi-arid catchment of Lake Baringo, Kenya. A minor field study of physical with socio-economic aspect. Department of Physical Geography, Gotenberg University.
- Keya, G.A. 1998. Impact of land use patterns and climate on the vegetation ecology of arid and semi-arid nomadic pastoral ecosystems of northern Kenya. M.Sc. thesis, University of Trier, Germany.

- Khamphorst, A. 1987. A small rainfall simulator for the determination of soil erodibility. *Netherlands Journal of Agricultural Science*, 35: 407 – 415.
- Kironchi, G. 1992. Effects of soil type, vegetation, and land-use on infiltration rate and related soil physical properties in two semi-arid catchments in Laikipia District. M.Sc. thesis, University of Nairobi.
- Kironchi, G. 1998. Influence of soil, climate and land-use on soil water balance in the upper Ewaso Ngiro Basin in Kenya. Ph.D. thesis, University of Nairobi.
- Lawes Agricultural Trust. 2006. GenStat Release 9.1. Lawes Agricultural Trust (Rothamsted Experimental Station).
- McIvor, J.G., J. Williams and C.J. Gardener. 1995. Pasture management influences runoff and soil movement in the semi-arid tropics. *Australian Journal of Experimental Agriculture*, 35 (1): 55 – 65.
- Mills A.J. and M.V. Fey. 2003. Declining soil quality in South Africa: effects of land use on soil organic matter and surface crusting. *South African Journal of Science* 99, September/October 2003.
- Morgan, R.P.C. 1986. *Soil Erosion and Conservation*. Longman, London.
- Muchoki, C.H.K. 1988. A preliminary survey of the efficiency of three methods used in studying rangeland vegetation: The quadrat, Point center centre quarter, and line transect methods. *Technical report* No. 132. Department of Resource surveys and Remote sensing (KREMU), Ministry of Planning and National Development, Kenya.
- Mutunga, N. C. 1995. The influence of vegetative cover on soil loss-A study in Mukogodo, Laikipia District. Masters thesis. Department of Agriculture Engineering, University of Nairobi, Kenya.
- Negassi, A., E. Bein, K. Ghebru and Bo Tengnas. 2002. *Soil and water conservation Manual for Eritrea*. RELMA, Sida, Nairobi.
- Okalebo, J.R., K.W. Gathua and P.L. Woomer. 2002. *Laboratory Methods of Soil and Plant Analysis: A working Manual* (2nd Edition). Tropical Soil Biology and Fertility Programme (TSBF)-CIAT and SACRED Africa, Nairobi, Kenya.
- Oluwole, F. A. and D. Sikhhalazo. 2008. Land degradation evaluation in a game reserve in Eastern Cape of South Africa: Soil Properties and Vegetation Cover. *Scientific Research and Essay*, 3 (3): 111 – 119. <http://www.academicjournals.org/SRE>.
- Onyando, J.O, P. Kisoyan and M.C. Chemelil. 2005, Estimation of potential soil erosion for river Perkerra catchment in Kenya. *Water Resources Management*, 19: 133 – 143.

- Otieno, A.K. and K.M. Rowntree. 1986. A comparative study of land degradation in Machakos and Baringo District, Kenya. Institute of British Geographers, Reading, England.
- Oztas, T., A. Koc and B.Comakli. 2003. Changes in vegetation and soil properties along a slope on overgrazed and eroded rangelands. *Journal of Arid Environments*, 55: 93 – 100.
- RoK /UNEP. 1997. *National Land Degradation Assessment and Mapping*. UNEP, Nairobi, Kenya.
- Rowntree, K. M. 1988. Storm rainfall on the Njemps Flats, Baringo District, Kenya. *International Journal of Climatology*, 8 (3): 297 – 309.
- Snelder D.J.and R.B. Bryan. 1995. The use of rainfall simulation tests to assess the influence of vegetation density on soil loss on degraded rangelands in the Baringo District, Kenya . *CATENA*, 25 (1 – 4): 105 – 116.
- Steel, G.D. and J. H. Torrie. 1980. *Principles and Procedures of Statistics*. McGraw-Hill, London.
- Taddese, G., M. A. M. Saleem, A. Abyie and A. Wagnew. 2002. Impact of Grazing on Plant Species Richness, Plant Biomass, Plant Attribute, and Soil Physical and Hydrological Properties of Vertisol in East African Highlands. *Environmental Management*, 29 (2): 279 –289.
- Thomas, D.B., K.A. Edwards, R.G. Barber and I.G.G. Hogg. 1981. Run-off, erosion and conservation in a representative catchment in Machakos District in Kenya. In: R. Lal and E.W. Russel (EDs.). *Tropical Agricultural Hydrology*.
- Trimble, S., W. Alexandra and C. Mendel. 1995. The cow as a geomorphic agent. A critical review. *Geomorphology*, 13 (1995): 233 – 253.
- United States Department of Agriculture (USDA). 1996. Soil Quality Information Sheet. Soil Quality Indicators: Aggregate Stability. USDA Natural Resources Conservation Service.
- United States Department of Agriculture (USDA). 2001. Soil Quality Information Sheet. Rangeland Soil Quality: Aggregate Stability. USDA, Natural Resources Conservation Service.
- Vogel, H. 1994. Conservation tillage in Zimbabwe: Evaluation of several techniques for the development of sustainable crop production systems in small holder farming. Geographical Bernensia, *African Studies series* No. 11. Berne.

CHAPTER SEVEN

7.0 EFFECTS OF LAND-USE ON HERBACEOUS BIOMASS PRODUCTION, COVER AND SPECIES DIVERSITY IN THE NJEMPS FLATS, BARINGO DISTRICT, KENYA

7.1 ABSTRACT

The herb layer forms an important forage resource for the extensive livestock production systems in the rangelands. Sustainable range management therefore depends on in-depth understanding of herbage production dynamics as a prerequisite for making decisions on utilization and management of pasture. In an attempt to improve the understanding of vegetation dynamics in relation to land-use and determine the potential of enclosures in ecological restoration of degraded rangelands, this study was conducted to assess the standing herbaceous biomass production, herbaceous cover and species diversity in the Njemps Flats. Herbaceous cover was significantly higher ($P \leq 0.05$) under semi-nomadic pastoral land-use (36.8 ± 2.50 %) than under sedentary agro-pastoral land-use (26.6 ± 2.54 %). However, land-use system did not have significant influence ($P \leq 0.05$) on herbage production and herbaceous plant diversity. Enclosures had significantly higher ($P \leq 0.05$) herbaceous biomass (131.9 ± 7.11 g m⁻²) than the open grazing areas (72.9 ± 5.62 g m⁻²). Similarly, herbaceous cover was found to be significantly higher ($P \leq 0.05$) inside enclosures (37.8 ± 2.66 %) than in the adjacent open areas (25.6 ± 2.27 %). These results reveal that land-use is a significant determinant of herbaceous cover, and that enclosures are effective in restoration of productivity of degraded range.

KEY WORDS: Herbaceous biomass production; herbaceous cover; herbaceous diversity; land-use; Njemps Flats.

7.2 INTRODUCTION

Population pressure through settlements and encroachment of cultivation on pastoral prime grazing lands in arid and semi-arid areas of Africa is believed by many (Kristjanson *et al.*, 2002; Alemu *et al.*, 2000; ASAL, 1997; Noor *et al.*, 1999; Warinda, 2001) to be responsible for the reduction of natural vegetation cover and subsequent transformation of land-use systems in the rangelands. Three dominant determinant forces that have shaped the vegetation of African rangelands and continue to impose a measure of natural selection on plant species are fire, herbivory and climate (Lechmere-Oertel, 2003; Cowling *et al.*, 1997). There has been considerable interest in the long-term impact of domestic herbivores on semi-arid rangelands across the world. This arises from the perception that large areas of these rangelands have been transformed through unsustainable livestock production. Such

transformation is primarily recognized through physical changes in the environment, such as loss of vegetation cover, loss of soil and organic matter and reduced water use efficiency (Whitford, 2002). Such physical changes are accompanied by a significant reduction in primary production that supports pastoral livelihoods in these areas.

Sustainable pasture productivity is of concern in all arid and semi-arid rangelands of the world. Declines in the quality and quantity of grassland forage as well as land degradation are becoming more apparent across the globe. These declines have been attributed to high grazing pressure or continuous grazing with no or very short rest periods. Grazing animals affect native pasture properties by both altering plant cover type and density (Bari *et al.*, 1993) and the physical action of their hooves. The effect of prolonged heavy stocking rates on inherent pasture productivity is an important issue for sustainable grazing management. In the short-term, heavy stocking rates usually result in greater economic return, but sustained heavy stocking may degrade the pasture resource, potentially affecting future livestock production and income.

7.3 STANDING HERBACEOUS BIOMASS AND COVER

Large livestock numbers and the expansion of arable land into grazing land are putting increasing pressure on the natural vegetation and have led to decreased and less diverse vegetation cover. It is largely assumed that rest period in grazing land can improve ground cover and so grass production through providing opportunities for maintaining plant vigour (Sanjari, 2006; McIvor *et al.*, 1995). However, there have been some contrary findings as well. Grazing is often implicated in reduction of vegetative cover and the abundance of important forage plants (Loeser *et al.*, 2005). Grazing animals affect range productivity by altering plant cover as well as through physical impact of their hooves on the herbaceous layer. Reduction in vegetation cover is known to increase the effect of raindrops in decreasing water infiltration rates and increasing runoff and soil degradation (Sanjari, 2006). However, as observed by Oba *et al.* (2001), rangelands that are grazed continuously may have lower residual biomass and ground cover, but they may have greater production and better survival than ungrazed range. They argue that grazing, rather than being destructive, is necessary for proper management of arid zone pastures.

According to Lechmere-Oertel (2003), functional semi-arid shrublands efficiently conserve limiting resources such as water and water-borne sediments (soil and organic matter), and that as these rangelands become transformed through unsustainable livestock production, their ability to conserve resources decreases. The primary determinant of landscape function and conservation of resources appears to be the proportional cover of perennial vegetation. In his study on the effects of goat browsing on ecosystem patterns and processes in succulent thicket in a semi-arid rangeland of South Africa, Lechmere-Oertel (2003) states that the switch from a two-phase mosaic dominated by perennial succulent and woody shrubs to a single phase system dominated by an ephemeral field layer would be accompanied by disruption of the mechanisms that conserve resources.

7.4 HERBACEOUS SPECIES DIVERSITY AND RICHNESS

The botanical diversity, sometimes referred to as species heterogeneity, is an expression of community structure and species interaction in ecosystems. It is also a measure of probability of inter-specific encounter. A community is said to have a high species diversity when it has numerous equally or almost equally abundant species (Ekaya, 1998). Diversity indices take into account both species richness and evenness of distribution of individuals among species. Species richness is simply the number of species in the community, whereas evenness is expressed by considering how close a set of observed species abundances are to those from aggregation of species having maximum possible diversity for a given number of individual of a certain species. Changes in plant species composition are central to range management for sustainable production. According to Crawley (1997), as grazing pressure increases, grazing-sensitive or highly preferred species (decreasers) decline in abundance while grazing-tolerant species (increasers) become more abundant. On the other hand, noxious weeds (invaders), which are not preferred by animals tend to encroach on the range as intensity of grazing increases.

Grazing intensity is important because at low intensities, diversity might be low because of competitive exclusion by the dominant plant species. Plant diversity peaks at intermediate grazing intensities when the dominant species is suppressed but other species are not substantially affected. Diversity may be low at the highest grazing intensities if there is only a small pool of grazing tolerant species (Crawley, 1997). Diversity may be reduced either by

competitive displacement or by a high frequency of population reduction, which does not allow some competitors to recover between disturbances.

The effect of grazing by livestock on diversity of plant communities has been investigated in different terrestrial ecosystems, where grazing has been found to reduce, increase or have no effect at all. Kamau (2004) attributes this lack of consistent effect of grazing on plant diversity to differences in grazing intensity, with greater diversity expected at intermediate level of grazing. She further points out that there are likely to be departures between seasonally protected and permanently protected areas with respect to species composition. It is, therefore, not in order to generalize about the impact of herbivory on plant diversity because so few detailed long-term studies have been carried out with inconsistent results (Crawley, 1997). Lechmere-Oertel (2003) found that significant changes in plant composition (species and functional types) and cover can occur in response to unsustainable livestock grazing pressure. Likewise, Osem *et al.* (2002) observed that diversity is usually low in environments in poor condition but increases with improvement on range condition.

The herbaceous layer forms an important forage resource for the extensive livestock production systems in the rangelands. However, in recent years, increased grazing pressure resulting primarily from exogenous influences has had enormous impact on this very basic resource. Njemps Flats in Baringo District is an example of rangelands in Kenya where socio-ecological factors have led to ecological transformations (Johansson and Svensson, 2002; Otieno and Rowntree, 1986; de Groot *et al.*, 1992; Myerhoff, 1991). The result is land degradation and a threat to the very existence of the pastoralists and their herds.

Although there is some knowledge on vegetation characteristics in the Njemps Flats, data on the effects of land-use on herbaceous biomass production, cover and species diversity are scanty. Recent studies on vegetation looked specifically at the abiotic and herbaceous vegetational characteristics (Ekaya *et al.*, 2001) and primary productivity, energy flow and nitrogen cycling (Ekaya, 1998), in reseeded enclosures. To bridge this information gap, a study was conducted to determine standing herbaceous biomass, herbaceous cover and species diversity in relation to land-use in the Njemps Flats. The central focus of this study was to improve the understanding of vegetation dynamics in relation to land-use, and the potential of enclosures in ecological restoration of degraded rangelands. It is expected that

the results of this study will set a foundation upon which future management of semi-arid rangelands can be improved and large-scale restoration initiated.

7.5 METHODS

7.5.1 Data collection

Vegetation sampling for herbaceous cover, herbaceous biomass production and diversity were carried out along a 25 m transect in each of the six paired plots located in each of the two land-use sites (SAL and SNL). Sampling was done at the peak of the wet (April) and dry (January) seasons, and at the end of wet (June) and dry (February) seasons. The procedure was repeated to capture two wet and two dry seasons during the 2005 – 2006 study period.

7.5.1.1 Estimation of herbaceous cover, standing biomass and diversity

The direct estimates of herbaceous cover, standing biomass and plant diversity involved use of line transect and quadrat methods (Cook and Stubbendieck, 1986; Muchoki, 1988). Herbaceous cover was sampled by dropping a vertical point at every 1 m interval along the 25 m transects (see Muchoki, 1988). This was a modification of the point frame method similar to the point-step method, which involves pacing across the field along a transect and recording whatever is encountered at the tip of the boots as hits. This modification was necessary to suit the field situations while maintaining accuracy and precision.

The species hit by the vertical point were recorded but if missed a plant, the nearest plant to the hit was recorded. The total number of 1m intervals (25) was equated to the total number of pins in the point frame method. A 0.25 m² quadrat frame was placed at an interval of 5 m along the same transects to sample for frequency and herbaceous biomass production. All species rooted within the quadrat were identified and recorded before all the standing plants was clipped at ground level and put into paper bags with corresponding sampling point reference numbers. In the laboratory, the harvested material was separated into grasses and forbs. These were put into paper bags of known weight and oven dried for 24 hours at 80°C and weighed for dry matter determinations (Roberts *et al.*, 1993). A total of 400 herbaceous

vegetation samples were obtained for determination of herbaceous standing biomass. From the 12 paired plots, 2,400 hits on herbaceous species were recorded and used for determination of herbaceous cover and species richness.

The herbaceous cover was calculated using the following formula:

$$\text{Percent basal cover} = \frac{\text{Total number of hits}}{\text{Total length of transect (Total no. of 1m intervals)}} \times 100$$

$$\text{Percent composition for species } A = \frac{\text{Total number of hits for species } A}{\text{Total number of hits}} \times 100$$

Species diversity was calculated using Shannon-Weinner Diversity Index (H') (Zar, 1999; Mueller-Dumbois, 1974). Shannon's diversity index is probably the most popular measure of species diversity because, in addition to taking into account species richness, it is highly flexible and has a wider scope. One can use density, percent cover, percent composition, and biomass measurements to calculate species diversity. Shannon's formula is expressed as:

$$H' = - \sum_{i=1}^n \frac{n_i}{N} \log \frac{n_i}{N}$$

Where n_i/N is the proportion of species i in the sample.

Sørensen's coefficient (SC_s) was used to measure the similarity of the vegetation communities under the sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems as well as inside and outside enclosures. The SC_s , also known as quotient of similarity or index of similarity, measures the ratio of the common and unique species (Sørensen, 1948). Sørensen's coefficient is expressed as follows:

$$SC_s = \frac{c}{\frac{1}{2}(A+B)} \times 100 = \frac{2c}{A+B} \times 100$$

Where c is the number of common species; A is the total number of species in community A ; and B is the total number of species in community B . The expression $(A+B)/2$ represents the sum of the theoretically realizable coinciding occurrences. The Sørensen formula gives greater weight to species common to both communities and less to species unique to either community.

7.5.2 Data analysis

Data on herbaceous biomass production, basal cover and diversity were subjected to the analysis of variance (ANOVA) to determine the differences between the two land-use systems, inside and outside the enclosures, and the wet and dry seasons. The means were separated using the Turkey's W procedure as outlined by Lawes Agricultural Trust (2006) and Steel and Torrie (1980).

7.6 RESULTS AND DISCUSSIONS

7.6.1 Effects of land-use on standing herbaceous biomass production

Statistical analysis shows significant difference in herbaceous biomass production in relation to enclosures but not land-use system (Table 7.0). Contrary to the expectation of this study, herbage production under sedentary agro-pastoral land-use ($95.7 \pm 7.65 \text{ g m}^{-2}$) was not significantly higher ($P \leq 0.05$) than under the semi-nomadic pastoral land-use system ($109.0 \pm 7.65 \text{ g m}^{-2}$). This outcome is re-affirmed by the regression results, which show that, unlike land-use, enclosure and season have significant influence on herbage production (Table 7.1). It was hypothesized in this study that rotational grazing under semi-nomadic pastoral system would result in higher herbaceous cover and therefore standing herbage production than in the sedentary agro-pastoral system. A possible explanation for the contradictory observation is that herbage production in the semi-nomadic pastoral site may have been undermined by shorter deferment and large herds that currently characterize nomadic pastoral systems. An alternative explanation would be that plants under grazing pressure respond by increasing production of cytokins, which promote increased tillering (McNaughton, 1983). However, as indicated by Mworira *et al.* (1996), this does not necessarily lead to greater biomass production, and severe defoliation will always lead to decreased standing crop and seed production (Allison *et al.*, 1985).

Herbage production inside enclosures ($131.9 \pm 7.11 \text{ g m}^{-2}$) was found to be almost twice that of open grazing areas ($72.9 \pm 5.62 \text{ g m}^{-2}$). This is attributed to protection from grazing and other destructive human activities in enclosed plots as opposed to continuous use in the unprotected areas. Figure 7.0 shows that herbage production in the Njemps Flats is closely

correlated with rainfall pattern, with higher production being recorded in the wet season ($120.0 \pm 8.83 \text{ g m}^{-2}$) than in the dry season ($84.7 \pm 5.26 \text{ g m}^{-2}$) (Table 7.0). This shows that other factors held constant, rainfall is a critical determinant of forage production in semi-arid rangelands.

Table 7.0: Mean herbaceous biomass production ($\text{g m}^{-2} \pm \text{SE}$) inside and outside enclosures; under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems; and in the wet and dry seasons

Herbage	Land-use			Enclosure			Season		
	SAL	SNL	t	Inside	Outside	t	Wet	Dry	t
Grass	37.3± 2.91	42.5± 2.91	-1.24	51.4± 2.74	28.4± 2.23	6.52*	46.8± 3.42	33.0± 2.14	3.44*
Forbs	58.4± 4.62	66.5± 4.62	-1.24	80.5± 4.34	44.5± 3.44	6.52*	73.2± 5.43	51.7± 3.24	3.44*
Total	95.7± 7.65	109.0±7.65	-1.24	131.9± 7.11	72.9± 5.62	6.48*	120.0± 8.83	84.7± 5.26	3.44*

SAL = Sedentary agro-pastoral land-use system; SNL = Semi-nomadic pastoral land-use system
Two-tailed unpaired t-test; * = Significant at $P \leq 0.05$

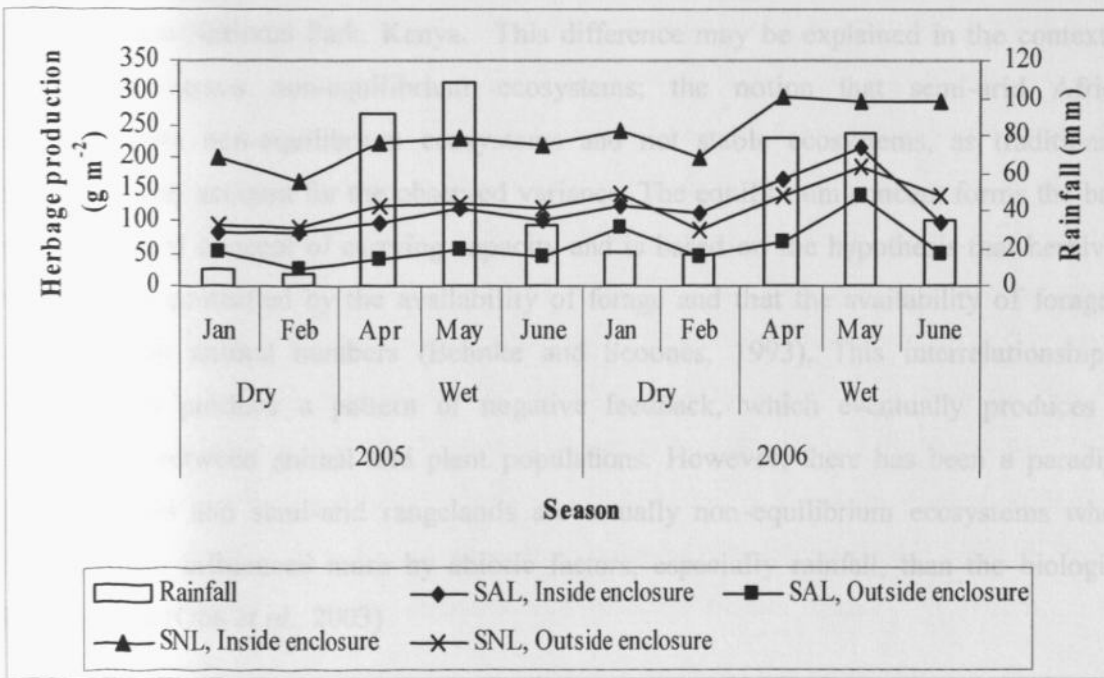


Figure 7.0: Standing herbaceous biomass production (g m^{-2}) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period

Table 7.1: Factors influencing herbaceous biomass production in the Njemps Flats

Model	β	SE	t
Constant	136.589	29.291	4.663*
Land-use	100.120	10.766	0.300
Season	-53.762	8.895	-6.044*
Enclosure	-94.380	10.068	-9.374*
Run-off	-0.013	0.013	1.030
Soil loss	-0.037	0.011	3.264*

Significant at 5%; $R^2 = 0.765$; Adj. $R^2 = 0.746$; $F = 40.95^$; $N = 96$

The equation for the model is $HERB = 136.59 + 100.12LU - 53.76SN - 94.38EC - 0.01RUN - 0.04LOSS$. Where $HERB$ = Herbaceous biomass production; LU = Land-use; SN = season; EC = Enclosure; RUN = Run-off; and $LOSS$ = Soil loss.

The results of this study do not support those of de Leeuw and Nyambaka (1987) who reported a threefold increase in primary productivity when grass cover increased from 20 to 80% in Tsavo National Park, Kenya. This difference may be explained in the context of equilibrium versus non-equilibrium ecosystems; the notion that semi-arid African rangelands are non-equilibrium ecosystems and not stable ecosystems, as traditionally perceived, may account for the observed variance. The equilibrium concept forms the basis of the standard concept of carrying capacity and is based on the hypothesis that herbivore numbers are controlled by the availability of forage and that the availability of forage is controlled by animal numbers (Behnke and Scoones, 1993). This interrelationship is perceived to produce a pattern of negative feedback, which eventually produces an equilibrium between animal and plant populations. However, there has been a paradigm shift that arid and semi-arid rangelands are actually non-equilibrium ecosystems whose dynamics are influenced more by abiotic factors, especially rainfall, than the biological determinants (Oba *et al.*, 2003)

Many range scientists (Behnke and Scoones, 1993, 1992; Ellis *et al.*, 1993; Ellis and Swift, 1988) have argued against the equilibrium paradigm and are in agreement that African range ecosystems operate far from equilibrium, and that rainfall is by far the most important determinant of range ecosystem dynamics. In agreement with this paradigm, de Leeuw and Nyambaka (1987) reported that herbaceous biomass production increased positively with the total rainfall amount per season in Athi plains, Tsavo National Park, Kiboko Research

Station, Amboseli, and Serengeti study sites. Likewise, Rosiere (1987), while evaluating grazing intensity influence on California annual range, found that herbage production was impacted more by annual growing conditions than by grazing regime.

The results of the current study concur with those of Gebremeskel (2006). In his study, Geremeskel reported a higher biomass production in the moderately grazed sites compared to severely grazed ones in a semi-arid northern-eastern region of Ethiopia. Kamau (2004), working in a range ecosystem in Mbeere District of Kenya, reported a higher biomass production in the enclosed sites than the open grazing sites. The findings of the current study also corroborate those of Ekaya (1998), in the same study area, and Gichohi (1996) in a semi-arid southern rangelands of Kenya, that standing herbaceous primary production closely followed the trend in rainfall with the highest biomass production being recorded just after the rainfall peaks. Gichohi (1996) reported a higher herbaceous biomass production only nine months after the establishment of enclosures.

Oba *et al.* (2001) investigated the impacts of seasonal exclosures on various vegetation attributes in arid rangelands of northern Kenya. They reported more biomass production within seasonal exclosures than in continuously grazed areas. While studying the effect of stocking rate, rainfall and their interaction on primary production in a South African semi-arid rangeland, Fynn and O'Connor (2000) found that although long-term heavy grazing resulted in a decline in herbaceous production, rainfall had the most marked effect on variability in herbaceous production and therefore a better predictor of cattle performance than herbaceous biomass itself. The authors observed that depletion of herbaceous biomass in a paddock when grazed heavily was more pronounced if botanical composition had changed as a result of drought and grazing. Fynn and O'Connor, however, contradicted the notion that semi-arid African savannas are non-equilibrium systems in which rainfall overrides grazing.

The findings of the current study contradict those of Keya (1997) who conducted a study on the effects of herbivory on the production ecology of the perennial grass *Leptothrium senegalense* (Kunth.) in the arid lands of northern Kenya. His study found peak standing aboveground production on the grazed plots to be higher than that of protected sites during a 3-year period. The author reported significant influence of rainfall on production on the

protected and seasonally grazed sites, and further indicated that the direct effect of grazing was a reduction in plant size. Similarly, Bertiller and Defosse (1990), working in semi-arid *Festuca pallelescens* grassland of northwestern Patagonia, Argentina, reported that aboveground net primary production of grasses was greater for grazed than ungrazed plants during the early growing season while the inverse occurred during the late growing season. The authors recommended that a reduction in stocking rate during the late growing season was necessary to increase aboveground primary productivity.

Working in northwestern New Mexico, Orodho and Trilica (1990) reported no significant difference in crown biomass of Indian ricegrass between grazed and ungrazed treatments. They ascribed the results to possible differences in soil moisture and plant competition. However, they reported that any defoliation caused significant reduction in crown biomass of Indian ricegrass compared with unclipped plots. In southern Utah and northern Arizona, Jeffries and Klopatek (1987) found that a site which had been under 10 years recovery from heavy grazing showed no significant difference in vegetation production from that which had been under heavy grazing for 100 years. This implies that it may not be easy to restore productivity of a pasture after long-term heavy grazing.

Short duration grazing has been reported to increase forage production and utilization compared to other grazing systems, and this can sustain higher stocking rates. Ralphs *et al.* (1990) found that the standing crop of all major forage classes declined as stocking rate increased in Texas Agricultural Experiment Station. However, the rate of decline was less than proportional to an increase in stocking rate during the growing season. In the rangelands of Corvallis, Oregon State. Motazedian and Sharrow (1990), reported that both quantity and quality of pasture produced vary with frequency and intensity of plant defoliation.

7.6.2 Effects of land-use on herbaceous vegetation cover

The mean percent herbaceous cover was compared between the two land-use systems, enclosures and open range, and the wet and dry season. Table 7.2 shows significant difference in herbaceous cover between the two land-use systems and between enclosures and open areas. The regression results presented in Table 7.3 indicate that land-use,

enclosures and season have significant influence on herbaceous cover. Significantly higher ($P \leq 0.05$) herbaceous cover was recorded under the semi-nomadic pastoral land-use ($36.8 \pm 2.50\%$) than under sedentary agro-pastoral system ($26.6 \pm 2.54\%$). The intensive land-use pressure due to activities related to sedentary production systems is a likely cause for the observed result in the study area. Some of these activities include clearing of vegetation to give way for cultivation and settlement, and overgrazing due to restricted herd mobility. Other trends of far reaching consequence for agro-pastoral land-use systems include the excessive demand on woody vegetation for house construction, cattle enclosures and fuel, and sedentarization of pastoralists into centres of human and livestock concentrations (de Leeuw and Tothill, 1990).

Herbaceous cover was significantly higher ($P \leq 0.05$) in the enclosures ($37.8 \pm 2.66\%$) than in the unprotected grazing areas ($25.6 \pm 2.27\%$). This can be attributed to the protection from grazing inside enclosures as opposed to continuous use in the open sites. Herbaceous cover closely followed rainfall trend during the study period (Figure 7.1). It was significantly higher ($P \leq 0.05$) during the wet season ($40.6 \pm 2.47\%$) than the dry season ($22.8 \pm 2.07\%$) (Table 7.2). The boom of the ephemerals species can account for this observation during the wet season. The short-lived species encountered in the Njemps Flats emerge at the onset of rains, complete their life cycle within the growing season and die-off thereafter.

Table 7.2: Mean herbaceous cover (% \pm SE) inside and outside enclosures; under sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems; and in the wet and dry seasons

Herbage	Land-use			Enclosure			Season		
	SAL	SNL	t	Inside	Outside	t	Wet	Dry	t
Grass	11.5 \pm 1.09	15.8 \pm 1.07	2.84*	16.3 \pm 1.14	11.0 \pm 0.98	-3.49*	17.5 \pm 1.06	9.8 \pm 0.89	-5.54*
Forbs	15.1 \pm 1.44	21.0 \pm 1.42	2.84*	21.5 \pm 1.52	14.6 \pm 1.29	-3.49*	23.1 \pm 1.41	13.0 \pm 1.18	-5.54*
Total	26.6 \pm 2.54	36.8 \pm 2.50	2.84*	37.8 \pm 2.66	25.6 \pm 2.27	-3.49*	40.6 \pm 2.47	22.8 \pm 2.07	-5.54*

SAL = Sedentary agro-pastoral land-use system; SNL = Semi-nomadic pastoral land-use system
Two-tailed unpaired t-test; * = Significant at $P \leq 0.05$

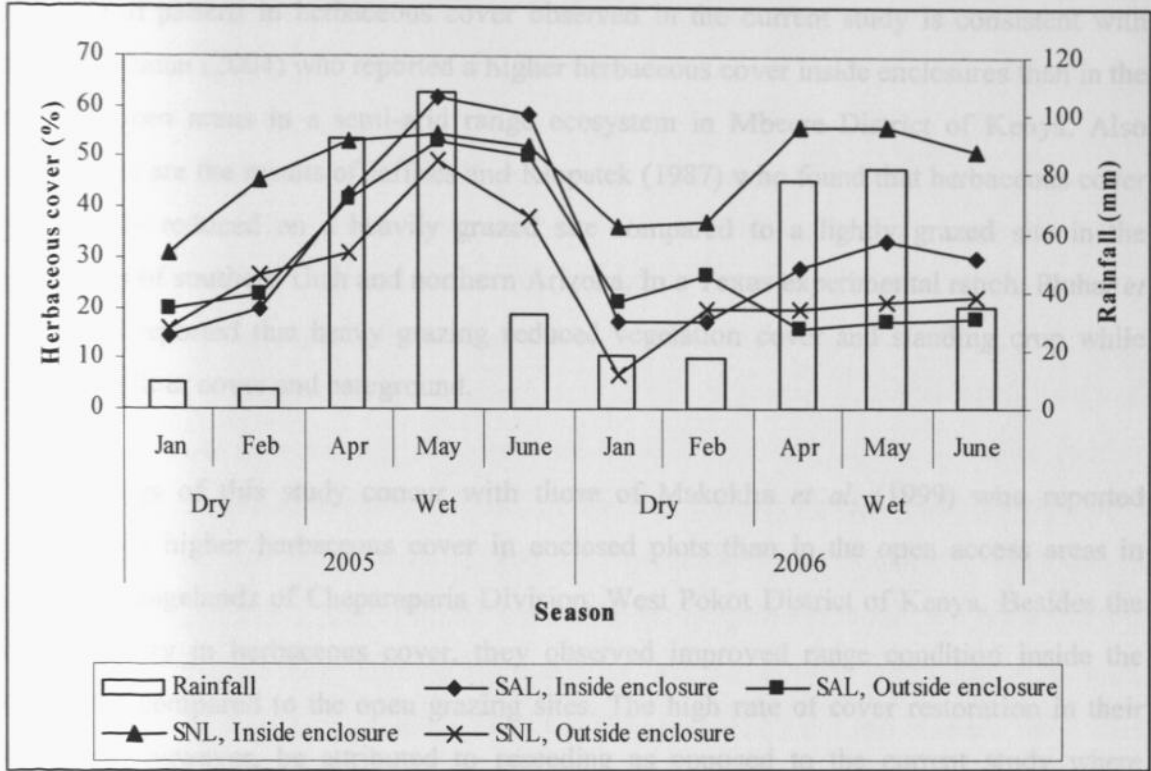


Figure 7.1: Herbaceous cover (%) in relation to rainfall amount and distribution in the Njemps Flats during 2005 – 2006 study period

Table 7.3: Factors influencing herbaceous cover in the Njemps Flats

Model	β	SE	t
Constant	2.696	10.286	0.262
Land-use	8.366	3.780	-2.213*
Season	-15.829	3.123	-5.068*
Enclosure	-11.525	3.535	-3.260*
Run-off	0.001	0.005	0.172
Soil loss	0.002	0.004	0.485

Significant at 5%; $R^2 = 0.514$; Adj. $R^2 = 0.475$; $F = 13.29^$; $N = 96$

The equation for the model is $COVER = 2.70 - 8.37LU - 15.83SN - 11.53EC + 0.001RUN + 0.002LOSS$. Where $COVER$ = Herbaceous cover; LU = Land-use; SN = season; EC = Enclosure; RUN = Run-off; and $LOSS$ = Soil loss.

The overall pattern in herbaceous cover observed in the current study is consistent with those of Kamau (2004) who reported a higher herbaceous cover inside enclosures than in the adjacent open areas in a semi-arid range ecosystem in Mbeere District of Kenya. Also comparable are the results of Jeffries and Klopatek (1987) who found that herbaceous cover was greatly reduced on a heavily grazed site compared to a lightly grazed site in the rangelands of southern Utah and northern Arizona. In a Texas experimental ranch, Pluhar *et al.* (1987) reported that heavy grazing reduced vegetation cover and standing crop while increasing litter cover and bareground.

The findings of this study concur with those of Makokha *et al.* (1999) who reported significantly higher herbaceous cover in enclosed plots than in the open access areas in semi-arid rangelands of Cheparaparia Division, West Pokot District of Kenya. Besides the 77% recovery in herbaceous cover, they observed improved range condition inside the enclosures compared to the open grazing sites. The high rate of cover restoration in their study can, however, be attributed to reseedling as opposed to the current study where sampling was conducted on naturally regenerated enclosures.

Contrary to the foregoing findings, Loeser *et al.* (2005), while assessing the herbaceous canopy cover following 5 years of cattle removal in the rangelands of northern Arizona, reported that the canopy cover of forbs was generally unaffected by cattle removal. This observation suggests that removing cattle is unlikely, by itself, to lead to rapid improvements in the forb cover.

7.6.3 Effects of land-use on diversity of herbaceous plants

The results of statistical tests on the herbaceous species composition and diversity are shown on Tables 7.4, 7.5, 7.6 and 7.7. Herbaceous layer in the study area is composed of entirely ephemeral grasses and forbs with the exception of *Cenchrus ciliaris*, which is a perennial grass. The forbs recorded in the study area include *Gisekia pododiskos*, *Gisekia pharnaceoides*, *Tribulus terrestris*, *Pancratium trianthium*, *Boerhavia coccinea*, *Barleria acanthoides* and *Heliotropium subulatum*. The main grass species encountered were *Tetrapogon spatheceous*, *Dactyloctenium indicum*, *Digitaria gayana*, *Digitaria veluntina*,

Cenchrus ciliaris, *Brachiaria ericiformis*, *Eragrostis superba*, *Eragrostis tenuifolia*, *Aristida adscensionis* and *Tragus berteronianus* (Table 7.4).

The regression results in Table 7.6 show that only season had a significant influence on herbaceous species diversity. No significant difference ($P \leq 0.05$) in herbaceous species diversity was observed between the two land-use systems. Similarly, there was no significant difference ($P \leq 0.05$) in plant diversity between enclosures (0.05 ± 0.06) and open sites (0.03 ± 0.05). A significant difference ($P \leq 0.05$) in species diversity was, however, observed between seasons with the wet season (0.09 ± 0.08) having a higher species diversity than the dry season (0.03 ± 0.06) (Table 7.5). Species richness significantly varied with land-use, enclosures and season (Table 7.7). Herbaceous species richness was found to be significantly higher ($P \leq 0.05$) under the semi-nomadic pastoral land-use system (17.8 ± 1.20) than in the sedentary agro-pastoral land-use system. (13.4 ± 0.50). The enclosures were found to be significantly richer ($P \leq 0.05$) in species (17.2 ± 1.00) than the open sites (16.0 ± 1.1). Similarly, species richness was found to be significantly higher ($P \leq 0.05$) in the wet (17.5 ± 0.90) than the dry season (13.2 ± 0.90) (Table 7.5). Despite the differences in species richness between the two land-use systems, and inside enclosures and open grazing areas, the quotient of similarity (ratio of common species to the average number of species in the two communities) showed high community similarity between the two land-use systems as well as inside and outside enclosures (Tables 7.8 and 7.9).

Land-use system	Enclosure		Open		Season	
	Mean	SE	Mean	SE	Mean	SE
Herbaceous species diversity	0.05 ± 0.06	0.02	0.03 ± 0.05	0.02	0.09 ± 0.08	0.03
Plant diversity	0.05 ± 0.06	0.02	0.03 ± 0.05	0.02	0.09 ± 0.08	0.03
Species richness	17.8 ± 1.20	0.30*	13.4 ± 0.50	0.16	17.5 ± 0.90	0.30*

Land-use system: SMIL = Semi-nomadic pastoral land-use system; Sed = Sedentary agro-pastoral land-use system.
 * Significant at $P \leq 0.05$.

Factors influencing plant species diversity in the Njemp Plains

Factor	B	SE	F
Land-use system	0.047	0.029	1.589
Enclosure	0.014	0.009	1.578
Season	-0.023	0.014	-1.982*
Error	-2.345	0.341	-2.056*

$R^2 = 0.706$, Adj. $R^2 = 0.133$, $F = 2.80$, $N = 96$

Table 7.4: Percent herbaceous species composition (% ± SE) inside and outside enclosures; under sedentary agro-pastoral and semi-nomadic pastoral land-use systems; in the wet and dry seasons

Species	Land-use		Enclosure		Season	
	SAL	SNL	Inside	Outside	Wet	Dry
<i>Digitaria gayana</i> (AG)	2.5 ± 0.41	3.3 ± 0.09	13.4 ± 3.22	1.7 ± 0.23	13.1 ± 4.02	1.5 ± 0.48
<i>Digitaria velutina</i> (AG)	3.1 ± 0.52	4.6 ± 0.61	10.1 ± 4.12	1.1 ± 0.51	12.2 ± 3.67	2.1 ± 0.37
<i>Chenchrus ciliaris</i> (PG)	2.6 ± 0.32	4.2 ± 0.77	5.9 ± 1.40	1.2 ± 0.39	3.4 ± 1.04	3.1 ± 0.49
<i>Brachiaria eruciformis</i> (AG)	3.1 ± 0.40	5.3 ± 1.07	12.8 ± 2.9	0.7 ± 0.09	9.2 ± 2.47	1.1 ± 0.38
<i>Eragrostis superba</i> (AG)	2.4 ± 0.23	6.3 ± 0.87	8.4 ± 2.03	3.2 ± 0.97	7.4 ± 1.96	4.3 ± 1.04
<i>Eragrostis tenuifolia</i> (AG)	4.3 ± 0.61	8.7 ± 1.02	6.5 ± 0.76	4.3 ± 1.09	5.4 ± 1.04	5.1 ± 2.22
<i>Dactyloctenium indicum</i> (AG)	1.4 ± 0.50	7.8 ± 0.40	6.4 ± 1.07	2.1 ± 0.84	4.7 ± 1.01	3.3 ± 0.4
<i>Tetrapogon spatheceous</i> (AG)	2.6 ± 0.4	9.5 ± 3.11	2.1 ± 0.72	1.3 ± 0.26	3.2 ± 0.76	5.4 ± 3.01
<i>Aristida adscensionis</i> (AG)	4.1 ± 0.69	8.3 ± 2.89	8.7 ± 0.41	8.5 ± 2.22	10 ± 3.20	6.0 ± 4.01
<i>Tragus berteronianus</i> (AG)	13.5 ± 4.53	10.4 ± 2.76	5.8 ± 0.79	11.1 ± 3.37	8.7 ± 1.11	7.2 ± 3.06
<i>Tribulus terrestris</i> (EF)	5.7 ± 2.38	1.6 ± 0.32	2.3 ± 0.5	1.2 ± 0.05	4.2 ± 0.52	11.2 ± 5.4
<i>Barleria acanthiodes</i> (EF)	11.5 ± 3.40	10.5 ± 3.33	4.6 ± 0.4	14.5 ± 4.34	4.7 ± 0.63	9.8 ± 2.41
<i>Gisekia pharnaceoides</i> (EF)	13.4 ± 4.56	7.2 ± 2.76	4.3 ± 1.41	15.6 ± 5.61	5.2 ± 1.07	8.6 ± 2.21
<i>Gisekia pododiskos</i> (EF)	12.4 ± 3.67	4.5 ± 0.72	5.6 ± 1.03	16.1 ± 6.73	3.5 ± 0.46	15.1 ± 5.14
<i>Heliotropium subulatum</i> (EF)	9.9 ± 3.07	2.5 ± 0.87	1.4 ± 0.49	12.6 ± 4.62	2.8 ± 0.12	10.6 ± 3.44
<i>Pancratium trianthium</i> (EF)	3.2 ± 1.57	4.1 ± 1.02	0.6 ± 0.09	1.3 ± 0.60	0.9 ± 0.09	2.3 ± 0.25
<i>Boerhavia coccinea</i> (EF)	4.3 ± 2.3	1.2 ± 0.42	1.1 ± 0.21	3.5 ± 0.98	1.4 ± 0.18	3.3 ± 0.32

AG = Annual grass; EF = Ephemeral forb; PG = Perennial grass

Table 7.5: Mean Shannon-Weinner diversity index (H' ± SE) and species richness (Mean ± SE) inside and outside enclosures; under sedentary agro-pastoral and semi-nomadic pastoral land-use systems; in the wet and dry seasons

Herbage	Land-use			Enclosure			Season		
	SAL	SNL	t	Inside	Outside	t	Wet	Dry	t
Diversity index	0.04 ± 0.07	0.04 ± 0.05	0.24	0.05 ± 0.06	0.03 ± 0.05	-1.53	0.09 ± 0.08	0.03 ± 0.06	3.24*
Species richness	13.4 ± 0.50	17.8 ± 1.20	3.39*	17.2 ± 1.00	16.0 ± 1.10	2.60*	17.5 ± 0.90	13.2 ± 0.90	3.30*

SAL = Sedentary agro-pastoral land-use system; SNL = Semi-nomadic pastoral land-use system

Two-tailed unpaired t-test; * = Significant at P < 0.05

Table 7.6: Factors influencing plant species diversity in the Njemp Flats

Model	β	SE	t
Constant	0.047	0.029	1.589
Land-use	0.014	0.009	1.528
Enclosure	-0.025	0.014	-1.982*
Season	-2.345	0.341	-2.056*

Significant at 5%; R² = 0.206; Adj. R² = 0.133; F = 2.80; N = 96

The equation for the model is $H' = 0.05 + 0.01LU - 0.05EC - 2.35SN$. Where H' = Herbaceous cover; LU = Land-use; SN = Season; and EC = Enclosure.

Table 7.7: Factors influencing plant species richness in the Njemp Flats

Model	β	SE	t
Constant	17.266	2.942	5.869*
Land-use	0.193	1.026	5.188*
Season	-0.233	1.082	4.216*
Enclosure	-2.388	1.045	-2.286*
Herbaceous cover	0.002	0.032	0.067
Soil loss	-0.002	0.001	-2.102

Significant at 5%; $R^2 = 0.411$; Adj. $R^2 = 0.308$; $F = 3.99^$; $N = 96$

The equation for the model is $RICH = 17.27 + 0.19SITE + 0.23SN - 2.39EC + 0.002COVER - 0.002LOSS + 0.05CEC - 1.29SOM$. Where $RICH$ = species richness; LU = Land-use; SN = season; EC = Enclosure; $COVER$ = Herbaceous cover; and $LOSS$ = Soil loss.

Table 7.8: Mean Sørensen's quotient of similarity ($SC_s \pm SE$) between herbaceous vegetation communities in the two land-use systems, and in the wet and dry seasons

Sørensen's quotient of similarity	Land-use			Season			Similarity/Disimilarity index	
	SAL	SNL	t	Wet	Dry	t	Similarity index	Disimilarity index
SC_s (land-use)	52.7 ± 4.7	56.5 ± 5.1	-0.54	54.1 ± 4.7	55.1 ± 5.2	-0.13	54.6 ± 2.5	45.4 ± 2.5

SAL = Sedentary agro-pastoral land-use system; SNL = Semi-nomadic pastoral land-use system

Table 7.9: Mean Sørensen's quotient of similarity ($SC_s \pm SE$) between herbaceous vegetation communities inside and outside enclosures, and in the wet and dry seasons

Sørensen's quotient of similarity	Enclosure			Season			Similarity/Disimilarity index	
	SAL	SNL	t	Wet	Dry	t	Similarity index	Disimilarity index
SC_s (enclosure)	60.8 ± 4.4	61.9 ± 6.5	-0.13	64.1 ± 5.2	58.6 ± 5.7	0.70	61.4 ± 2.4	38.7 ± 2.4

SAL = Sedentary agro-pastoral land-use system; SNL = Semi-nomadic pastoral land-use system

As observed by Crawley (1997), a marked inconsistency surrounds the effect of grazing on species diversity and richness. While a number of studies have shown increased plant species richness under herbivory (Loeser, 2005; Oba *et al.*, 2001), a few have shown

reduced species richness, and several have shown no effect of herbivory on species at all (Kamau, 2004). In trying to understand the effects of cattle grazing in the rangelands of northern Arizona, Loeser *et al.* (2005) studied the potential hiding cover provided by standing live and dead herbaceous matter as well as forb richness following 5 years of cattle removal. The study found that after cattle removal forb species richness was 16% lower in exclosures than in an adjacent grazed pasture.

In this study, species diversity was found to be higher during the wet than in the dry seasons. This result corroborates that of Ekaya (1998) in the same study area. He attributed this observation to an increase in soil moisture due to rainfall, which is expected to stimulate growth and thereby increase the number of species and biomass per species. This, however, may not always be the case, especially where rainfall distribution is poor as is the case in most arid and semi-arid rangelands. In a study conducted in Kapiti plains of Kenya, Gichohi (1996) reported a higher species diversity inside than outside exclosures. Similar to his findings, the current study found that the species in the two land-use systems and those in exclosures remained markedly similar with that of the adjacent open grazing areas. The results of the current study also agree with those of Mutungi *et al.* (1996) who reported similar diversity indices between disturbed and undisturbed sites in semi-arid rangelands of Kibwezi District in Kenya. They also found a high quotient of similarity between the two vegetation communities, implying that they were similar in floristic composition.

In northern Kenya arid rangelands, Oba *et al.* (2001) conducted a study to compare vegetation structure, species richness and composition on open range and exclosures at five sites. The objective of the study was to elucidate the potential mechanisms behind variation in species richness. The results of their study showed that exclosure plots had more abundant species compared with open plots, which had more rare and occasional species. They, however, found that species richness declined with an increase in the age of exclosures. They concluded that seasonal grazing exclosures may increase species richness to a certain level, but the decline in species richness with the age of exclosures indicates that long-term exclusion of grazing may not necessarily increase species richness in arid grazing lands. Geremeskel (2006), while working in a rangeland in Afar region of Ethiopia, stratified his study area into four different sites based on vegetation cover (severely degraded, moderately to severely degraded, moderately degraded and lightly degraded sites). He reported a high

abundance of annual species than perennial species in severely degraded sites. The converse was true for moderately degraded and lightly degraded sites. The study further reported that an increase in species cover inside enclosures did not automatically result in increased species diversity. In semi-arid rangelands in Mbeere District of Kenya, Kamau (2004) reported a higher species diversity and evenness in the open than in the enclosed sites.

Lechmere-Oertel (2003) conducted a study on the effects of goat browsing on ecosystem patterns and processes in succulent thicket in the semi-arid rangelands of South Africa. The study found that the transformed habitats (open grazing sites) had significantly lower Shannon's indices and species richness compared to intact habitats (protected sites). The author also reported that the open range had significantly greater biomass of ephemeral forbs and grasses than the enclosed areas. Similar patterns of species composition have been reported by Kerley *et al.* (1995) in the rangelands of Eastern Cape in South Africa. They summarized the changes due to pastoralism as being characterized by a replacement of perennial and palatable by annual and unpalatable species, and by reduced primary productivity due to a loss of phytomass, soil nutrients and organic matter, and severe soil erosion.

Fynn and O'Connor (2000), in a study conducted in a semi-arid rangeland in South Africa, reported that even though changes in botanical composition were strongly influenced by rainfall variability, stocking rate had an additional effect over time. Their study found that high rainfall and light grazing promoted tufted perennial grasses; heavy grazing and low rainfall promoted some annuals; and that weakly tufted perennial grasses were favoured by heavy grazing and high rainfall.

7.7 CONCLUSIONS AND RECOMMENDATIONS

The current study has revealed that while land-use system in the study area influenced herbaceous cover and species richness, it did not have significant impact on herbaceous biomass production and species diversity. Herbaceous cover and species richness were significantly lower under sedentary agro-pastoral land-use than in the semi-nomadic pastoral land-use system. It is, however, evident from the findings of this study that the vegetation dynamics observed in the Njemps Flats reflect combined effects of land-use and rainfall and

not either of them singly. It can therefore be concluded that, in this study, the combined effects of rainfall and grazing were ecologically important in determining the herbaceous biomass production, cover, species diversity and richness. These results also confirm that rainfall, having influenced all the attributes measured in this study, is a major determinant of vegetation community structure and productivity in the semi-arid rangelands. Efforts to understand and tackle the land degradation problem in the study area must therefore take this fact into account.

Sorensen's quotient of similarity reveals that despite differences in species richness between enclosures and open range, the two vegetation communities had generally similar species composition. The higher species richness, herbaceous cover and herbage production inside enclosures than in the open access areas show that the process of land degradation in the study area is reversible. The results of this study explicate the enclosure system as an effective way of restoring herbaceous cover and range productivity. It is, therefore, in order to recommend enclosures for out-scaling as a method of range rehabilitation in areas with similar ecological conditions as the study area.

7.8 REFERENCES

- Alemu, D. T., D.M. Nyariki and K.O. Farah. 2000. Impact of land-use system and socio-economic roles of vegetation in semi-arid Africa: The case of the Afar and Tigray of Ethiopia. *Journal of Social Science*, 4 (2 – 3): 199 – 206.
- Allison, C.D. M.M. Kothman, and L.R. Rithenhouse. 1985. Efficiency of forage harvest by grazing cattle. *Journal of Range Management*, 35 (3): 351 – 354.
- ASAL 1997. *Framework for District Natural Resources Use and Management*. ASAL Programme Ministry of Planning and National Development. Republic of Kenya.
- Bari, F., M. K. Wood, and A. L. Murray. 1993. Livestock grazing impacts on infiltration rates in a temperate range of Pakistan. *Journal of Range Management*, 46: 367 – 72.
- Behnke, R.H. 1992. Rethinking range ecology: Implications for rangeland management in Africa. International Institute for Environment and development (IIED) *Issues Paper no. 33*.
- Behnke, R.H. and I.Scoones.1993. Rethinking range ecology: Implications for rangeland management in Africa. In: Behnke, R.H., I. Scoones and C. Kerven (Eds.). *Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptations in African Savannas*. ODI, London.
- Bertiller, M.B. and G.E. Defosse. 1990. Grazing and plant growth interactions in a semi-arid *Festuca palllescens* grassland. *Journal of Range Management*, 34 (6): 300 –303.
- Cook, W.C., and J. Stubbendieck. 1986. *Range Research: Basic problems and Techniques*. Society for Range Management, Denver, Colorado.
- Cowling, R.M., Pierce, S.M. and Richardson, D.M. 1997. *The Vegetation of Southern Africa*. Cambridge University Press, Cape Town.
- Crawley, M.J. 1997. *Plant-herbage dynamics*. Blackwell Science, London.
- de Groot, P., A. Field-Juma and D.O. Hall. 1992. *Reclaiming the Land: Revegetation in Semi-arid Kenya*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- de Leeuw, P.N. and J.C. Tohill. 1990. The concept of rangeland carrying capacity in Sub-Saharan Africa-myth or reality. ODI Pastoral Development *Network Paper No. 29b*.
- de Leeuw, P.N. and R. Nyambaka. 1987. The prediction of rangeland production from rainfall data in arid and semi-arid Eastern Africa. *Proceedings of the third Workshop held at the International Conference Centre Arusha, Tanzania, 27 – 30 April 1987*. Pasture Network for Eastern and Southern Africa (PANESA)

- Ekaya, W.N. 1998. Primary productivity, energy flow and nitrogen cycling in a rangeland ecosystem. PhD thesis, University of Nairobi.
- Ekaya, W.N., J.I. Kinyamario and C.N. Karue. 2001. Abiotic and herbaceous vegetational characteristics of an arid rangeland in Kenya. *African Journal of Range and Forage Science*, 18: 117–124.
- Ellis, J.E. and D.M. Swift. 1988. Stability of African Pastoral Ecosystems: Alternative paradigms and implications for development. *Journal of Range Management*, 41: 450 – 459.
- Ellis, J.E. M.B. Coughenour and D.M. Swift. 1993. Climate variability, ecosystem stability and the implications for range and livestock development. In: Behnke, R.H., I. Scoones and C. Kerven (eds.). *Range Ecology at Disequilibrium: New models of Natural Variability and Pastoral Adaptations in African Savannas*. ODI, London.
- Fynn, R. W. S. and T. G. O'Connor . 2000. Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. *Journal of Applied Ecology*, 37 (3): 491–507.
- Gebremeskel, K. 2006. Rangeland potential, quality and restoration strategies in Northern-Eastern Ethiopia: A case study conducted in the southern Afar Region. A Ph.D. thesis University of Stellenbosch.
- Gichohi, H.W. 1996. The ecology of a truncated ecosystem: The Athi Kapiti Plains. PhD thesis, University of Leicester.
- Jeffries, D.L. and J.M. Klopatek. 1987. Effects of grazing on the vegetation of the Blackrush Association. *Journal of Range Management*, 40 (5): 390 – 392.
- Johansson, J. and J. Svensson. 2002. Land degradation in semi-arid catchment of Lake Baringo, Kenya. A minor field study of physical with socio-economic aspect. Department of Physical Geography, Göteborg University.
- Kamau, P. 2004. Forage diversity and impact of grazing management on rangeland ecosystems in Mbeere District, Kenya. LUCID *Working Paper Series* No. 36.
- Kerley, G.I.H., M.H. Knight and M. De Kock. 1995. Desertification of subtropical thicket in the Eastern Cape, South Africa: Are there alternatives? *Environmental Monitoring and Assessment*, 37: 211-230.
- Keya, G. A. 1997. Effects of herbivory on the production ecology of the perennial grass *Leptothrium senegalense* (Kunth.) in the arid lands of Northern Kenya. *Agriculture, Ecosystems and Environment*, 66 (2): 101–111.

- Kristjanson, P. M. Radeny, D. Nkedianye, R. Kruska, R. Reid, H. Gichohi, F. Atieno and R. Sanford. 2002. *Valuing alternative land-use options in the Kitengela wildlife dispersal area of Kenya*. ILRI, Nairobi, Kenya.
- Lawes Agricultural Trust. 2006. GenStat Release 9.1. Lawes Agricultural Trust, Rothamsted Experimental Station.
- Lechmere-Oertel R.G. 2003. The effects of goat browsing on ecosystem patterns and processes in succulent thicket, South Africa. PhD. Thesis, University of Port Elizabeth, South Africa.
- Loeser, M. R., S.D. Mezulis, T.D. Sisk, and T.C. Theimer. 2005. Vegetation cover and forb responses to cattle exclusion: Implications for Pronghorn. *Rangeland Ecology and Management*, 58 (3): 234 – 238.
- Makokha W, Lonyakou S, Nyang M, Kareko K.K, Holdings C, Njoka TJ, and Kitanyi A. 1999. *We work together: Land Rehabilitation and Household Dynamics in Cheparaparia Division, West Pokot District, Kenya*. RELMA Technical Report Series No. 22. Nairobi: RELMA.
- McIvor, J.G., J. Williams and C.J. Gardener. 1995. Pasture management influences runoff and soil movement in the semi-arid tropics. *Australian Journal of Experimental Agriculture*, 35 (1): 55 – 65.
- McNaughton, S.J. 1983. Compensatory plant growth as response to herbivory. *Oikos* 40: 329 – 336.
- Motazedian, I. and S.H. Sharrow. 1990. Defoliation frequency and intensity effects on pasture forage quality. *Journal of Range Management*, 34 (6): 202 – 204.
- Muchoki, C.H.K. 1988. A preliminary survey of the efficiency of three methods used in studying rangeland vegetation: The quadrat, point centre quarter, and line transect methods. *Technical Report No. 132*. Department of Resource surveys and Remote sensing (KREMU), Ministry of Planning and National Development, Kenya.
- Mueller-Dumbois, D. and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley and Sons, New York.
- Mutungi, E.M., K.O. Farah and N.K.R. Musimba. 1996. Factors affecting honey production in south Kenya Rangelands: A case study of Kibwezi, Makueni District. Pastoral Information Network Programme (PINEP), *Working Paper Series No. 9*.
- Mworia, J.K., N.K.R. Musimba and A.B. Orodho. 1996. In: P.O. Fungo and G.C.O. Mbadi (eds): *Focus on agricultural research for sustainable development in a changing*

- economic environment. *Proceedings of the 5th Kenya Agricultural Research Institute (KARI) Scientific Conference*.
- Myerhoff, E. 1991. *Taking Stock: Changing Livelihoods in a Agropastoral Community*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- Noor, A.A., K.O. Farah and N.K. Musimba. 1999. Socio-economic impact of small holder irrigation schemes on the pastoral nomads of Garissa District, North-eastern Kenya. *Working Paper Series* No. 19, the African Pastoral Forum, Pastoral Information Network Program, University of Nairobi, Kenya
- Oba, G., O.R. Vetaas and N.C. Stenseth. 2001. Relationships between Biomass and Plant Species Richness in Arid-Zone Grazing Lands. *The Journal of Applied Ecology*, 38 (4): 836 – 845.
- Oba, G., R. B. Weladji, W. J. Lusigi and N.C. Stenseth. 2003. Scale-dependent effects of grazing on rangeland degradation in northern Kenya: A test of equilibrium and non-equilibrium hypotheses. *Journal of Land Degradation and Development*, 14: 83 – 94
- Orodho, A.B. and M.J. Trlica. 1990. Clipping and long-term grazing effects on biomass and carbohydrates reserves of Indian ricegrass. *Journal of Range Management*, 34 (6): 52 – 57.
- Osem, Y., A. Perevolotsky and J. Kigel. 2002. Grazing effect on diversity of animal plant communities in a semi-arid rangeland: Interactions with small-scale spatial and temporal variation in primary production. *Journal of Ecology*, 90: 936 – 946.
- Otieno, A.K. and K.M. Rowtree. 1986. *A comparative Study of Land Degradation in Machakos and Baringo District, Kenya*. Institute of British Geographers, Reading, England.
- Pluhar, J.J., R.W. Knight and R.K. Heitschmidt. 1987. Infiltration rates and sediment production as influenced by grazing systems in the Texas Rolling plains. *Journal of Range Management*, 40 (3): 240 – 243.
- Ralphs, M.H., M.M. Kothmann and C.A. Taylor. 1990. Vegetation response to increased stocking rates in short duration grazing. *Journal of Range Management*, 34 (6): 104 – 108.
- Roberts, M.J., S.P. Long, L.L. Tieszen and C.L. Beadle. 1993. Measurement of plant biomass and net primary production of herbaceous vegetation. In: Hall, D.O., J.M.O. Scurlock, H.R. Bolhar-Nordenkampf, R.C. Leegood and S.P. Long (Eds.).

Photosynthesis and Production in Changing Environment—A field and Laboratory Manual, Chapman and Hall, UK.

- Rosiere, R.E. 1987. An evaluation of grazing intensity influences on California Annual Range. *Journal of Range Management*, 40 (2): 160 — 165.
- Sanjari, G., H. Ghadiri and C. Ciesiolka. 2006. Grazing management and its effects on Groundcover and Runoff Control in Queensland. Australia. *The 14th International Soil Conservation Organization Conference. Water Management and Soil Conservation in Semi-Arid Environments. Marrakech, Morocco, May 14 — 19, 2006 (ISCO 2006).*
- Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analysis of the vegetation on Danish commons. *Biol. Skr (K. Danske vidensk. Selsk. N.S.)* 5, 1—34.
- Steel, G.D. and J. H. Torrie. 1980. *Principles and Procedures of Statistics*. McGraw-Hill, London.
- Warinda, E. 2001. A socioeconomic survey and economic analysis of land use options in Shompole and Olkiramatian group ranches-Magadi division. African Conservation Centre. Nairobi.
- Whitford, W.G. 2002. *Ecology of Desert Systems*. Academic Press, San Diego.
- Zar, J.H. 1999. *Biostatistical Analysis* (4th Ed). Prentice Hall, London.
- X. Poverty, sedentary agro-pastoral land-use system; semi-nomadic pastoral

CHAPTER EIGHT

8.0 THE DETERMINANTS OF HOUSEHOLD POVERTY IN THE NJEMPS FLATS OF BARINGO DISTRICT, KENYA

8.1 ABSTRACT

An emerging issue in the poverty debate is how to explain the notably close links between poverty, land-use and resource degradation that cause low crop and livestock productivity, and consequently poverty. The mainstream view is that sedentarization of pastoralists, the accompanying restricted mobility and cultivation of critical grazing areas induce land degradation, leading to insecure livelihoods and impoverishment of pastoral households. The alternative argument is that sedentarization and the resultant land degradation, contrary to the view that they have adverse effects on pastoral livelihoods, may actually offer more opportunities to diverse and secure livelihoods. This study was conducted to determine the relationship between land-use, land degradation and poverty in the Njemps Flats of Baringo District. The parametric estimates of the determinants of poverty indicate that the number of livelihood sources, herd splitting, distance to pasture, ownership of enclosure, and age of the household head, household size, distance to nearest market and relief food are the most important determinants of poverty in the Njemps Flats. The number of livelihood sources, distance to pasture and age of the household head were found to be positively related to per capita daily income. The households that practiced herd splitting were better off than those that did not. In contrast to the *à priori* expectation, a negative relationship was observed between per capita daily income and household size and ownership of enclosure in sedentary agro-pastoral system. Similarly, distance to nearest market and relief food had positive influences on poverty level. These findings reveal that settled pastoralists despite living in degraded environments are wealthier than the nomadic ones, implying that poverty declines with the increase in sedentarization and land degradation. This scenario is explained by the enhanced diversification of livelihoods among settled pastoral households compared to their semi-nomadic counterparts. Reversing the current trends in land degradation and destitution in Kenya's rangelands can therefore be achieved through sustainable land-use planning, and provision of livelihood alternatives to reduce over-reliance on livestock and land as primary sources of livelihood.

KEY WORDS: Poverty; sedentary agro-pastoral land-use system; semi-nomadic pastoral land-use system; Njemps Flats.

8.2 INTRODUCTION

In the past four decades, pastoralists in East Africa have increasingly settled in response to the problem of shrinking rangeland caused by population growth, the expansion of cultivation in pastoral land, and to the impact of increased commercialization and privatization (Roth and Fratkin, 2005). Recent studies on pastoral sedentarization have pointed to a variety of costs to people changing their lifestyles. Several authors point to problems of increased range degradation due to overgrazing and impoverishment of sedentary pastoralists (Farah *et al.*, 2003; Meyeroff, 1991; Krugmann, 1996; Campbell, 1999; Little, 1985; Talle, 1999; Hogg, 1986). Although concerns about poverty are at the top of the development agenda in many developing countries, they are more so in arid and semi-arid areas of Africa, where environmental resource base is constantly under pressure from ecological, economic and socio-political factors. An emerging issue in the poverty debate is how to explain the notably close link between poverty, land-use and resource degradation that causes low crop and livestock productivity, leading to declining capital productivity followed by less marketable output and consequently poverty. One of the explanations attempting to address the phenomenon is the argument that poverty and resource degradation in arid and semi-arid areas, governed by a complex set of variables, occurs in a downward spiral thereby causing destitution (Reardon and Vosti, 1995; Millenium Ecosystem Assessment, 2003; Ekbom and Bojo, 1999; ICARDA/ICRISAT, 2002; Nyangena, 2001).

Despite the importance of in-depth understanding of, among other factors, links between resource use, range condition and poverty in the formulation of appropriate pastoral policies, there has been little empirical work to ascertain the exact relationship between these three key factors. Reardon and Vosti (1995) reckon that dynamic links between poverty and environment are often neglected in the existing literature. Similarly, Nyangena (2001) observes that several studies have provided useful insights on land-use and resource degradation but the links to poverty are not yet adequately addressed. Kabubo-Mariara (2003, 2002), in her studies conducted in Kajiado District of Kenya, reported a complex interrelationship between poverty, property rights and the range environment. She found that poverty, measured in per capita expenditure, discouraged migration and therefore induced land degradation. She noted that wealthy herders under common property regime are less

likely to migrate compared to their poor counterparts. This illustrates a rather complex positive feedback between poverty and land degradation. She goes further to indicate that the effect of migration on the environment is more significant under common than private land ownership. However, given the complexity of the links between poverty, resource use and land degradation, these findings may not be directly applicable to all pastoral ecosystems in the country.

Okwi *et al.* (2006) in their study on spatial determinants of poverty in rural Kenya underscore the heterogeneity in the links between poverty, environment and other conditioning factors. In an attempt to bridge the knowledge gap, this study was conducted to determine the relationship between land-use, land degradation and poverty in the Njemps Flats of Baringo District, Kenya. Njemps Flats share a number of similarities with Kajiado District including a long history of pastoral development interventions dating back to the colonial era (Otieno and Rowntree, 1986), sedentarization of pastoralists, changing property rights regime, and general changing lifestyle among the settled pastoralists (Kristjanson *et al.*, 2004). The study had two main objectives:

1. To identify the determinants of poverty in the Njemps Flats.
2. To recommend policy interventions required to address problems related to land-use, land degradation and poverty in the study area.

The hypothesis tested was that there is a downward spiral relationship between land-use, land degradation and poverty in the Njemps Flats. There are two contesting views regarding this hypothesis. One is that sedentarization of pastoralists, the accompanying restricted mobility and cultivation of critical grazing areas induce land degradation, leading to insecure livelihoods and impoverishment of pastoral households. The alternative argument is that sedentarization and the resultant land degradation, contrary to the view that they have adverse effects on pastoral livelihoods, may actually offer more opportunities to diverse and secure livelihoods.

8.3 METHODS

8.3.1 Data collection

A stratified random sampling procedure as described by Mugenda and Mugenda (1999) was used in data collection. The two pre-determined land-use system sites (SAL and SNL) were considered separate strata. A sample size of 40 households was randomly drawn from each stratum for the individual interviews. The interviews were conducted two times during the study period. The first interviews were conducted during the wet season; the same households were revisited during the dry season. A total of 160 copies of the questionnaire were administered but 30 of them were incomplete and therefore were excluded from the statistical analysis. The incomplete copies were a result of either failure to reach the respondents on a repeat visit or their unwillingness to continue with the interviews. Pastoralists were asked questions on selected attributes that were hypothesized to influence poverty at household level. These attributes, which were considered to vary between the sedentary agro-pastoral and semi-nomadic pastoral land-use systems, were used to model the link between land-use, land degradation and poverty in the study area.

8.3.2 Data analysis

Data analysis involved both descriptive statistics and regressions. Regression models were constructed for discrete and binary dependent variables to identify determinants of poverty level (poverty index) and poverty incidence (probability of a household being poor), respectively.

8.3.3 Determinants of poverty in the Njemps Flats

This study adopts a conceptual framework developed by Reardon and Vosti (1995), that assumes that a household's objective is to maximize food security and other livelihood objectives subject to a set of natural resources, human capital and on-farm and off-farm physical and financial capital as well as a set of external conditioning factors. All the activities brought together are expected to have environmental consequences, which on the

other hand alter the household's access to resources and capital (Kabubo-Mariara, 2003). From the foregoing logic, this study hypothesized that livelihood security and poverty in the rangelands are a function of pastoral coping strategies among other variables that determine access to factors of production and assets. Based on the same reasoning, poverty is considered to be the product of deprivation of basic resources for production. The per capita daily income, based on adult equivalents (AE), is used as a measure of poverty in this study. Per capita daily income and therefore poverty measure is conceptualized as mainly a relationship between pastoral coping strategies, assets, and access to resources needed for production. A general model for poverty can be expressed as:

$POV = f_1(CS) + f_2(AS) + f_3(AC)$. Where POV represents poverty, CS stands for coping strategies, AS denotes assets, and AC are factors that determine access to factors of production.

8.3.4 Description of the hypothesized variables

1. Per capita daily income

The per capita daily income based on adult equivalents was used in this study as a dependant variable. The first step in the computation of per capita daily income involved the determination of annual household income in Kenya Shillings. The annual household income was obtained by aggregation of yearly sales of farm produce, livestock, livestock products, value of produced goods consumed at home, wage of employed household head, and remittances from members of households employed elsewhere. To obtain the household's daily income, the annual household income was divided by the number of days in a year (365). This was further divided by the total household adult equivalents to arrive at per capita daily income. The level of a household's income is a major determinant of food security (Nyariki *et al.*, 2002), livelihood security and therefore a measure of poverty level. Households with high income per adult equivalent are expected to be more livelihood and food secure than those with low income levels. The per capita daily income was used to determine whether a household is living below or above the poverty line. Poverty line is the level of income below which one is considered poor—it is the poverty threshold, the minimum level of income deemed necessary to achieve an adequate standard of living in a given country (RoK, 2000). In this study, the poverty line of US\$1.25 released by the World

Bank (Chen and Ravallion, 2008) was adopted. Assuming that US\$1 equals KSh.78, the international poverty line (US\$1.25) was estimated at KSh.98. For binary logit regressions, all households with a per capita daily income equal to or more than KSh.98 were considered 'not poor' and assigned a value of 1, while those with a per capita income below the poverty line were considered 'poor' and assigned a value of 0.

2. Poverty index

Poverty index is an indication of the standard of living in a household, and takes into account both the number of poor and the extent of their poverty (ILO, 2009). It is computed by dividing the per capita daily income by the poverty threshold. The following formula was used to compute the poverty index:

$$\text{Poverty index} = \left(\frac{\text{Household income / adult equivalent / day}}{\text{Povertyline (KSh.98)}} \right)$$

According to the above formula, the higher the index, the richer the household and vice versa

3. Gender of household head

Although the government of Kenya has made efforts to promote women's rights, as observed by Marinda and Heidhues (2004) while working in West Pokot District of Kenya, there are still clear gender inequalities in pastoral areas. Because of cultural and religious norms, women are deprived of property ownership rights and given lower status in all of the pastoral communities. They are denied participation in traditional leadership and control of key assets, given marginal benefits from divorce and inheritances of common properties (Emana *et al.*, 2005; Gritli, 1997). In all pastoral communities in Kenya, the head of the household, usually a male, owns most important physical and financial assets and is responsible for all important decisions concerning the use and management of household resources. Such rights are not readily transferable to women even in cases where they are rendered heads of households when their husbands are employed elsewhere or dead. This implies that women headed households may be disadvantaged with regard to access to natural resources and decisions important in pursuance of sustainable livelihoods. It was hypothesized in this study that female headed households are likely to be poorer than the male headed households (Muyanga, 2008; Place *et al.*, 2003). Gender of household head

was a dummy variable where a value of 1 was allocated to male headed households and 0 to female headed households.

4. Age of household head

The age of a household head in years is expected to determine a household's access to and ownership of livelihood assets and means of production. This in turn determines the amount of wealth at a household's disposal and therefore poverty level. A household headed by a young person (less than 30 years) is therefore expected to be poorer than that headed by an older person (30 – 60). However, beyond a certain age (over 60 years) the reverse may be true as assets are shared out among siblings and wealth creation declines. It is expected that lack of experience in youth headed households is likely to lead to the inability to make timely and appropriate decisions that enhance sustainable livelihoods and wealth creation making them poorer than households headed by older persons. Shiferaw and Holden (1998) underscored the positive correlation between age and perception of problems in a farming system. However, Bellon and Taylor (1993) argued that older persons are less likely to engage in productive farming practices. The age of a household head was a categorical variable and was assigned a value of 1 if less than 30 years, 2 if aged between 30 – 60 years, and 3 if over 60 years.

5. Education of household head

The level of education attained by the head of a household is expected to influence access to information, decision making, income and consequently livelihood security of a household. Poverty, whether transient or chronic, is therefore considered a decreasing function of education. Households headed by educated heads are less likely to be poor compared to those of uneducated heads. This is because educated heads have higher income earning potential and more alternative income earning opportunities, and are therefore better able to improve the quality of their respective households' welfare (Krishna *et al.*, 2004; Mango *et al.*, 2004). Muyanga (2008) points out that education provides an opportunity for pastoral households to diversify their livelihood portfolios especially through employment as a source of wage and remittances. The level of education of a household head was assigned a value of 1 if not educated, 2 if attained primary education, 3 for secondary education, and 4 if attained post secondary education.

6. Property rights regime

It is assumed that lack of well-specified property right institutions, policies, and infrastructure favourable to pastoralists is likely to result in the destruction of spatial adaptation strategies meant to reduce environmental degradation. While communal land rights are seen as a constraint to conservation practices, they are a prerequisite for herd mobility, and are hypothesized to increase range productivity and improve livelihoods, thus reducing poverty in pastoral households (Kabubo-Mariara, 2003). On the other hand, private property rights are seen to be destructive in areas where pastoralism is being practised. Property right was a categorical variable where 1 represented communal ownership, 2 family-owned land, and 3 settlement in a scheme.

7. Mobility

Migration is a traditional pastoral strategy used to track forage and water as well as escape from natural shocks including diseases, droughts and tribal conflicts. Mobility is also used to spread pressure on land and therefore conserve the environment. According to Nyariki and Ngugi (2002), herd mobility makes land a “variable rather than a fixed resource” and ensures optimal use of the range. Migration is expected to increase productivity and consumption and therefore reduce poverty (Kabubo-Mariara, 2002). In this study, migration was regarded as an indicator variable assigned a value of 1 if the herder migrates in search of pasture and water, otherwise 0 for not migrating.

8. Distance to pasture

Forage availability is the determinant of the direction and distance of the opportunistic movements by the African pastoralists to make use of different ecological niches (Sanford, 1983; Niamir, 1994). The assumption in this study is that the distance travelled in search of pasture is an indicator of forage availability, a reflection of range condition and productivity and therefore livestock productivity. Because secure livelihoods can only be attained when resources needed for production are accessible, this leads to the hypothesis that the longer the distance to pasture, the less secure the livelihoods and thus the poorer are the households. Daily distance travelled by a herder and his livestock in search of pasture was measured in kilometers.

9. Herd size

The size of a household herd is a measure of its wealth. Mango *et al.* (2004) found that the Il Chamus of Njemps Flats in Baringo are unlikely to consider income from any other source as wealth, unless it is invested in buying livestock. In most pastoral communities, wealth and well being are measured in terms of the number of livestock owned. It is assumed in this study that the level of poverty of a pastoral household is a function of its herd size, among other variables. This, however, depends on the extent to which a pastoral household relies on livestock for its basic needs. Although different herd sizes have varying labour requirements (Dahl and Hjort, 1979), the number of persons supported by a herd is assumed to be proportional to its size. Herd size was measured in terms of Tropical Livestock Units (TLUs) per household, where one TLU was taken as an equivalent of a mature live animal weighing 250 kg as defined by KARI/ODA (1996). The TLUs were derived using average weights of the different sex and age categories of cattle, sheep and goats (Kristjanson *et al.*, 2004). In this study a bull was equivalent to 1.29 TLU, a cow = 1 TLU, a calf = 0.4 TLU and a sheep or goat = 0.11 TLU. Conversion of livestock holdings into TLU equivalents was for the purpose of standardizing different animal kinds and classes into a universal unit to allow comparisons between households and strata.

10. Household size

The size of a family is assumed to be directly proportional to its demand for food and income to secure other necessities. Larger pastoral families are expected to be secure in terms of labour provision, and therefore can afford to maintain larger herds compared to smaller households. However, this is not a linear relationship as noted by Dahl and Hjort (1979). The authors indicate that depending on the herd size a household has to strike a balance between labour requirement and output. Generally, larger households are expected to be poorer than their smaller counterparts due to higher expenditure, and that the only way to remain viable as a production unit is to get the surplus members to be employed elsewhere. The above arguments notwithstanding, availability of labour is expected to facilitate migration with livestock, leading to higher productivity and lower poverty.

This study considers the size of a household as the sum total of a pastoralist, his spouse, offspring and dependants present at the time of interview. The number of persons comprising a household was converted to adult equivalents, where any person in the age

category of 15 years and above was assumed to be equivalent to one AE, 5 – 14 years was equivalent to 0.65 AE, and 0 – 4 years 0.24 AE (RoK, 2000; Kristjanson *et al.*, 2002). The concept of AE assumes that life-cycle stages have an important influence on the needs of members or individuals of the same household. Others have used different conversions rates, for example Nyariki *et al.* (2002). This discrepancy is due to the fact that the concept of AE is based on the differences in nutrition requirements according to age and sometimes sex, and this is expected to vary with the environment and the kind and level of activity in which one is involved. For example, the nutrition requirements of a pastoralist will vary from that of an agro-pastoralist. This has led to the proposal of various conversion rates to suit different conditions. In this study, the consumption weights used by the Ministry of Finance and Planning, RoK (2000) were adopted.

11. Relief food

Relief food is food that a household acquires from sources outside their main livelihood activities, normally from the government, the United Nations Organizations, non-governmental organizations (NGOs) or religious organizations. Relief food is usually obtained without any type of payment (Seaman *et al.*, 2000). Dependence on relief food indicates poverty, a decline in human support capacity of the land, and non-functioning of pastoral mitigation strategies. Reliance on relief food was considered a dummy variable where a value of 1 was assigned to households that received relief food, and 0 to those that did not receive relief food.

12. Remittances

Employment outside the pastoral sector is one important way of diversifying sources of livelihood in pastoral areas. It is important to note that although some offspring may be adults currently living off-pastoral sector for various reasons such as employment and marriage, by tradition, most of them remit part of their wages to their families back home, thereby favourably altering their resource base. Wage transfers received from employed members is assumed to ease the dependency on livestock and land resource base, and lower poverty (Kabubo-Mariara, 2003). Household receiving remittances are therefore expected to be less dependent on livestock for their needs, and more secure in food and other needs than their counterparts that do not receive remittances. This variable was given a value of 1 if

household received wage transfers from its members employed elsewhere, and 0 if they did not receive remittances.

13. Wage employment

Wage employment is a source of cash income that supplements subsistence from livestock (Campbell, 1999). Households with one or more of their members in formal employment are hypothesized to be less dependent on land. They are expected to be less affected by precarious production trends that characterize the pastoral systems and are therefore more secure in terms of livelihoods. This variable was given a value of 1 if a member of the household was employed, and 0 if none was employed.

14. Number of livelihood sources

Livestock production is no doubt the main livelihood activity in the semi-arid rangelands of Kenya. However, due to high risk and uncertainty that characterize pastoral production systems, pastoralists normally rely on fall-back livelihoods to cushion them from natural shocks such as droughts (Herlocker, 1999; Oba and Lusigi, 1987). The importance of alternative livelihoods is underscored by Mango *et al.* (2004). Cultivation of crops, for example, is one of the major strategies used by the pastoralists to supplement milk and meat during bad seasons (Sikana and Kerven, 1991). Other alternative livelihoods include honey production, trading and charcoal burning, among others. Expanding livelihood portfolios in ways that encourage local growth linkages is usually meant to augment subsistence from livestock. Therefore, households that have alternative livelihoods are expected to be richer and more food secure than their counterparts that depend on livestock alone.

15. Ownership of enclosure

For decades, pastoralists in the study area have been practicing the enclosure system to restore degraded land and reserve pasture for dry spells. The enclosure system involves fencing certain areas using thorny branches to exclude grazing animals and other human activities in order to allow regeneration. Besides providing fodder during dry periods, enclosures are a source of grass seeds and thatch, which are in great demand in the Njemps Flats and the surrounding pastoral areas. Whether established for fodder, crops or as a conservation measure, enclosures are hypothesized to increase range productivity and household income (Makokha *et al.*, 1999). Therefore households with enclosures are

expected to have secure livelihoods and wealthier compared to their counterparts without. Ownership of an enclosure was assigned a value of 1, otherwise 0.

16. Size of enclosure

When an enclosure owned by a household is considered a source of fodder for livestock, grass seeds and thatch for sale, the size is expected to influence the household income. According to a study done by Makokha *et al.* (1999) in West Pokot, households with enclosures recorded a number of positive effects including increased land value, more grass for livestock and thatching, increased milk yield and increased animal health condition. The size of enclosures was measured in hectares.

17. Social networks

Social transfers (gifts between households) are a longstanding means of managing shocks and sharing risks in pastoral communities (PARIMA, GL-CRSP, 2005). Pastoralists traditionally use their livestock for making social bonds within and beyond their territories. These social ties form the basis of risk spreading, and post drought herd rebuilding. Nyariki and Ngugi (2002), referring to the pastoral social networks as the “economy of affection”, point out that the social alliances built through livestock transfers to friends and relatives as loans serve as post drought insurance. Campbell (1999) refers to it as ‘moral economy’, that which denotes networks of support, communications and interactions among structurally defined groups that are related by blood, kin, community or other affinities (Nyariki *et al.* (2005). Besides the positive effects of spreading grazing pressure, strong social linkages are expected to enhance livelihood security, and therefore reduce poverty in a given household. The existence of social linkages was given a value of 1, otherwise 0.

18. Distance to the nearest market

The rising impoverishment of pastoral communities has been linked to the settlement of pastoralists around water resources, trading centres and other social services and amenities. The argument is that due to diminishing grazing land and restricted mobility, pastoralists tend to settle and when they do so, they degrade the range thereby compromising range productivity. Consequently, land degradation leads to poor livestock productivity, insecure pastoral livelihoods and ultimately impoverishment of pastoral households. This argument forms the basis for the downward spiral relationship between land-use, land degradation and

poverty. Generally, as Chabari (1994), Herlocker (1999) and Coppock (1994) note, the majority of pastoralists that live near urban centres are poor. They argue that this is evident in increasing sale of milk and milk products, that are traditionally for subsistence, for cash. It is therefore hypothesized in this study that the further a household lives from the trading centre, the wealthier it is. Distance to the nearest trading centre was measured in kilometers.

19. Herd splitting

Herd splitting is part and parcel of herd mobility. It entails the division of a household herd based on class, type, health and physiological status. Just like mobility itself, it is a risk aversion strategy employed by the pastoralists (Oba and Lusigi, 1987). It is a central tenet of pastoral production, which if curtailed may result in reduced production of livestock and productivity of pastoral herds. Herd splitting was considered a dummy variable, where a value of 1 was assigned if a household split their herd, otherwise 0.

8.3.5 Model Specification

8.3.5.1 Determination of poverty level

An Ordinary Least Squares (OLS) regression technique was used to determine the relationship between poverty level (poverty index) and the hypothesized explanatory variables. In order to eliminate multicollinearity, a correlation analysis was conducted to identify variables, which were significantly correlated (correlation coefficient, $r \geq 0.5$) prior to performing a multiple linear regression. Pairs of variable with highly significant correlation coefficients were scrutinized and either of them dropped depending on their influence (t-value) on the regressand. Variables with higher t-values (more influence on the dependent variable) were retained for the Ordinary Least Squares (OLS) regressions. A general equation for a multiple linear regression (OLS) given k variables (a regressand and $(k-1)$ regressors) is specified as below (Gujarat, 2003):

$$Y_i = \beta_1 + \beta_2 X_{1i} + \beta_3 X_{2i} + \dots + \beta_k X_{ki} + \mu_i$$

Where Y is the dependent variable, in this study, poverty index, X_1, \dots, X_k is a set of explanatory variables, i denotes i^{th} household, μ is the error or disturbance term associated with the model, and β_1, \dots, β_k are coefficients representing parameters estimators of the variables in the model.

A series of multiple regressions were conducted using poverty index as the regressand until the best fit of the model was attained. The criteria for determining the variables that best defined the estimated model (goodness of fit) was based on the coefficient of determination (R^2); adjusted R^2 , F statistic, significance of explanatory variable (t-value), the sign or direction of influence of the independent variables, and the number of significant explanatory variables in the model. Because of the low R^2 in the OLS and the suspicion of existence of heteroscedasticity, a form of weighting was applied before running an OLS regression to derive Weighted Least Squares (WLS) parameters.

8.3.5.2 Determination of poverty incidence

A multivariate analysis was performed using per capita daily income as a binary dependent variable to test the probability that a household is poor or not. Binary regression is the most suitable method for analyzing discrete binary data in which the dependent variable evokes a yes or no response (Farah *et al.*, 2003). The approaches used to estimate models involving dichotomous response variables include the logit, probit and linear probability model (LPM) regressions. As opposed to OLS regression, the logit and probit models guarantee that the estimated probabilities lie in the 0 – 1 range and that they are non-linearly related to the explanatory variables. The logit is slightly less involved than the probit because by taking the logarithm of the odds ratio it converts what appears to be highly non-linear model into a linear one and this can therefore be estimated using the OLS approach. This implies that in the logit model, the regressand is the logarithm of the odds that a particular choice will be made—in the current study, the probability that a household is poor. The logit model was chosen because the properties of estimation procedures are more desirable than those associated with the choice of a uniform distribution, which require a normal probability distribution model, resulting in a probit model (Pindyck and Rubinfeld, 1981). In the logit regression model, parameters are determined through maximum likelihood estimation (MLE) procedure. The probability that a household is poor can be specified as:

$$P_1 = F(\alpha + \beta x_i) = \frac{1}{1 + e^{-(\alpha + \beta x_i)}} \quad (1)$$

Where P_1 is the probability that the i^{th} household will be poor given x_i , where x is a vector of explanatory variables and e is the natural logarithm. Equation (1) can be rewritten as:

$$P_1 = \left[1 + e^{-(\alpha + \beta x_i)} \right]^{-1} \quad (2)$$

Where $\alpha + \beta x_i = \log \left[\frac{P_1}{1 - P_1} \right]$ and $\frac{P_1}{1 - P_1}$ is the likelihood ratio, whose log gives the odds that a household is poor.

The model to be estimated for *SAL* is specified as:

$$\text{Log} \left[\frac{P_1}{1 - P_1} \right] = \alpha + \beta_0 \text{LIV}_i + \beta_1 \text{DIP}_i + \beta_2 \text{HS}_i + \beta_3 \text{EC}_i + \beta_4 \text{TLU}_i + \beta_5 \text{AGE}_i + \beta_6 \text{DIM}_i + \beta_7 \text{EDUC}_i + \beta_8 \text{HHS}_i + \beta_9 \text{RF}_i + \beta_{10} \text{REM}_i$$

The model to be estimated for *SNL* is specified as:

$$\text{Log} \left[\frac{P_1}{1 - P_1} \right] = \alpha + \beta_0 \text{LIV}_i + \beta_1 \text{LAND}_i + \beta_2 \text{HS}_i + \beta_3 \text{EC}_i + \beta_4 \text{SN}_i + \beta_5 \text{AGE}_i + \beta_6 \text{DIM}_i + \beta_7 \text{SEX}_i + \beta_8 \text{HHS}_i + \beta_9 \text{RF}_i + \beta_{10} \text{REM}_i + \beta_{11} \text{SEC}_i$$

Where i denotes i^{th} household (1,...,65); *LIV* is the number of livelihood sources; *DIP* is distance to pasture, *HS* is the herd splitting; *EC* is enclosure; *SEC* is the size of enclosure; *DIM* is distance to the nearest market, *AGE* is age of the household head; *EDUC* is education of the head of household; *HHS* is the household size; *RF* is relief food; *REM* is remittances; *TLU* is herd size; *LAND* is property rights regime; *SEX* is gender of household head; *SN* is social network; and α and β_1, \dots, β_k are coefficients representing parameters estimators of the variables in the model.

8.4 RESULTS AND DISCUSSIONS

8.4.1 Descriptive statistics

Table 8.0 shows descriptive statistics associated with the explanatory variables used in this study. These results indicate that there were more poor households under semi-nomadic land-use system (75%) than under sedentary agro-pastoral land-use system (69%). Similarly, sedentary agro-pastoral households had more sources of livelihood (average of 3) than the semi-nomadic pastoralists (average of 2). In the contrary, semi-nomadic pastoral households had larger herds (27.24 TLUs) and more members (6.53 AEs) than their sedentary counterparts with an average of 18.02 TLUs and 5.70 AEs, respectively. The one unit

difference in household size may be attributed to the 9 units difference in herd size. This corroborates the findings of Farah *et al.* (2003) who reported a reduced labour availability for herding following sedentarization of pastoralists around small-scale irrigation schemes in Northern Kenya.

Table 8.0: A summary of the variables used in the models and descriptive statistics

Variable	Definition	Average recorded	
		Sedentary agro-pastoral land-use system (N = 65)	Semi-nomadic pastoral land-use system (N = 65)
1. Per capita daily income	A household's income per AE per day in KSh. Variable used to determine how many households are living below poverty line. Poverty line is the level of daily income below which one is considered poor. This is assumed to be US\$ 1.25 (KSh.98). Per capita daily income is used as a proxy for poverty: 1 for per capita daily income equal to or more than KSh.98, otherwise 0	Average daily income per AE is KShs.133.83. 45 out of 65 households (69%) are poor.	Average daily income per AE is KShs.78.02. 49 out of 65 households (75%) are poor.
2. Poverty index	Per capita daily income divided by Poverty line (KSh.98). The higher the index the richer the household.	Mean poverty index is 1.37	Mean poverty index is 0.80
3. Gender of household head	Sex of the household head. Binary: 1 for male, 0 for female	61 out of 65 households (94%) are male-headed (mode = 1)	57 out of 65 households (88%) are male-headed (mode = 1)
4. Age of household head	Age of household head in years. Scaled 1– 3: the larger the older	58 out of 65 household heads (89%) are between 30 – 60 years (mode = 2)	53 out of 65 household heads (82%) are between 30 – 60 (mode = 2)
5. Education of household head	Level of education attained by household head. Scaled 1– 4: the larger the higher	37 out of 65 household (57%) heads attained secondary and tertiary education (mode = 3)	6 out of 65 household heads (6%) attained secondary and tertiary education (mode = 2)
6. Household size	Residents present at the time of interview in AEs. A person in the age category of 15 years and above is equivalent to one AE; 5 – 14 years is equivalent to 0.65	Average household size is 5.70AEs	Average household size is 6.53AEs

	AEs; and 0 — 4 years is equivalent to 0.24 AEs (RoK, 2000)	The mean size of enclosure is 4.3 acres	The mean size of enclosure is 3.8 acres
7. Herd size	The livestock holding of a household in tropical livestock units (TLU). One TLU is taken as an equivalent of a mature live animal weighing 250Kg as defined by KARI/ODA (1996).	Average herd size is 18.02TLU	Average herd size is 27.24TLU
8. Property rights regime	Grazing access rights. Scaled 1— 3: the higher the tendency towards privatization	43 out of 65 households (66%) have communal rights to land (mode = 1)	57 out of 65 households (88%) have communal rights to land (mode = 1)
9. Number of livelihood sources	The total number of livelihood activities that a household is engaged in.	Mean number of livelihood sources is 3	Mean number of livelihood sources is 2
10. Ownership of enclosure	A dummy for ownership of enclosure. Binary: 1 for yes, 0 for no	39 out of 65 households (60%) own enclosure (mode = 1)	46 out of 65 households (71%) own enclosure (mode = 1)
11. Mobility	A dummy for migration. Binary: 1 for yes, 0 for no	19 out of 65 households (29%) migrate (mode = 0)	38 out of 65 households (59%) migrate (mode = 1)
12. Employment	A dummy for off-farm employment of household head: Binary: 1 for yes, 0 for no	33 out of 65 household (51%) heads are employed (mode = 1)	19 out of 65 household (29%) are employed (mode = 1)
13. Social network	A dummy for social network or social alliance. Binary: 1 for yes, 0 for no	38 out of 65 households (41%) had no social networks (mode = 0)	45 out of 65 households (31%) had no social networks (mode = 0)
14. Relief food	A dummy variable indicating a household's access to relief food. Binary: 1 for yes, 0 for no	38 out of 65 households (59%) received relief food (mode = 1)	39 out of 65 households (60%) received relief food (mode = 1)
15. Remittances	A dummy for household's receipt of transfers from employed members: Binary: 1 for yes, 0 for no	38 out of 65 households (42%) did not received wage transfers (mode = 0)	48 out of 65 households (26%) did not receive wage transfers (mode = 0)
16. Distance to pasture	Total daily distance traveled by a pastoralist and his livestock to pasture (km)	Average distance to pasture is 9.04km	Average distance to pasture is 5.31km
17. Distance to the nearest market	Distance to the nearest trading centre (km)	Average distance to centre is 3.47 km	Average distance to centre is 2.13 km
18. Herd splitting	Division of a household livestock holding into separate herding units as a risk aversion	17 out of 65 households (26%) split their herds	18 out of 65 households (28%) split their herds

	strategy. Binary: 1 for yes, 0 for no		
19. Size of enclosure	Area in acres enclosed by a household for the purpose of rehabilitating degraded areas, reserving grass for livestock and thatching, and as a source of grass seeds for sale.	The mean size of enclosure is 4.3 acres	The mean size of enclosure is 3.3 acres

Household heads under sedentary agro-pastoral system were found to be more educated with 57% of them having attained secondary and tertiary education compared to only 6% under semi-nomadic pastoral system. More household heads were employed under sedentary agro-pastoral system (51%) than under the semi-nomadic system (26%). Similarly, more sedentary agro-pastoral households (42%) received remittances than their semi-nomadic counterparts (26%). Probably out of necessity and as an adaptation following sedentarization, sedentary agro-pastoral pastoral households had more social network than the semi-nomadic ones. These results suggest that the number of livelihood sources, education and employment of the household head, social network and remittances are some of the key determinants of the observed difference in poverty between the two land-use systems. Other factors held constant, it is an indication that poverty reduces with increase in sedentarization of pastoralists, opportunities for diversifying household economies, employment of household head, education of household head, social network and remittances. These results are consistent with those of Okwi *et al.* (2006) that settled areas represent tendencies towards urbanization, and more urbanization lowers poverty levels. Their results imply that people tend to settle in areas where they can enhance their incomes, for example, through farming, and such areas end up having low poverty levels.

8.4.2 Results of the OLS, WLS regression models

Tables 8.1, 8.2, 8.3 and 8.4 represent OLS and WLS regressions results for the sedentary agro-pastoral land-use and semi-nomadic pastoral land-use systems. Based on the coefficient of determination (R^2), adjusted R^2 , F statistic, significance of explanatory variable (t-value) and the number of significant explanatory variables in the model, WLS regressions were adopted for determination of poverty level in this study. The WLS regressions results show that ownership of enclosure and herd splitting were the key determinants of the level of poverty under the sedentary agro-pastoral land-use system (Table 8.3). While herd splitting had significant ($P \leq 0.05$) positive effect on household poverty level, ownership of enclosure was negatively related to poverty level. A higher level of poverty was observed among the pastoral households with enclosures than those without. This outcome shows that enclosure system is mainly practiced by impoverished pastoral households as a desperate measure to secure livelihoods. The households that practiced herd splitting to avert risks and maximize on scattered grazing resources were found to be wealthier than those that did not.

Under the semi-nomadic pastoral land-use system, poverty level was mainly determined by household size, distance to market centre, herd splitting, dependence on relief food and distance to pasture (Table 8.4). The size of household had a negative and significant ($P \leq 0.05$) influence on the level of poverty, implying that larger households were poorer than smaller ones. This was attributed to a higher demand on limited resources in larger families than in smaller ones. This finding is contrary to the view that the larger the household size, the more the herding labour and, therefore the higher the livestock productivity. However, this positive feedback requires that the number of people supported be proportionate to the herd size, and may only apply upto a given threshold beyond which an additional member of household results in a decline in food and income available to the household. Distance to nearest market centre had a significant ($P \leq 0.05$) and negative influence on poverty level, indicating that households near to market centres were wealthier than those far away. This finding is contrary to Herlocker (1999), Chabari (1994) and Coppock (1994) that pastoralists settled around trading centres are poorer than the nomadic ones. As observed under the sedentary agro-pastoral land-use system, herd splitting showed a positive and significant ($P \leq 0.05$) influence on poverty level under the semi-nomadic land-use system.

Dependence on relief food had a negative and significant ($P \leq 0.05$) influence on poverty level. The households who received relief food were found to be poorer than those that did not, suggesting that reliance on relief food by pastoral households is an indicator of poverty. Contrary to the *á priori* expectation, distance to pasture was positively and significantly ($P \leq 0.05$) related to poverty level, indicating the pastoral households that trek longer distances access better pastures than those that rely on pastures around settlements. This translates into higher livestock productivity, more food and income for those who make longer movements than their counterparts who do not.

Table 8.1: Factors influencing poverty in SAL: OLS estimation using poverty index as the regressand

Model	β	SE	t
Constant	1.550	1.867	.830
Gender of the household head	-1.763	1.096	-1.609
Education of household head	.671	.311	2.159**
Household size	-.094	.089	-1.062
Number of livelihood sources	-.241	.216	-1.115
Enclosure ownership	-.823	.554	-1.486
Herd splitting	.913	.627	1.456
Herd size of household	.046	.023	2.010**
Relief food	1.120	.520	2.153**
Remittances	-.344	.506	-.679

Significant at 5%; *Significant at 10%; $R^2 = 0.339$; Adj. $R^2 = 0.230$; $F = 3.128^{}$; $N = 65$

Table 8.2: Factors influencing poverty in SNL: OLS estimation using poverty index as the regressand

Model	β	SE	t
Constant	-1.016	1.095	-.928
Household size	-.076	.060	-1.284
Number of livelihood sources	.344	.271	1.271
Property rights regime	.681	.547	1.245
Enclosure ownership	-.306	.387	-.790
Size of enclosure	.181	.087	2.093**
Distance to nearest market	.554	.204	2.722**
Mobility	-.561	.356	-1.576
Herd splitting	-1.002	.396	-2.529**
Relief food	-.968	.356	-2.724**
Distance to pasture	.113	.053	2.138**
Remittances	-.011	.388	-.029

Significant at 5%; *Significant at 10%; $R^2 = 0.360$; Adj. $R^2 = 0.227$; $F = 2.707^{}$; $N = 65$

Table 8.3: Factors influencing poverty in SAL: WLS estimation using poverty index as the regressand and herd size as the weighting variable

Model	β	SE	t
Constant	.032	.021	1.584
Gender of household head	.502	.329	1.526
Education of household head	.218	.127	1.722*
Household size	.035	.031	1.134
Number of livelihood sources	-.116	.095	-1.220
Enclosure ownership	-.864	.203	-4.247**
Herd splitting	1.003	.430	2.331**
Relief food	.231	.225	1.025
Remittances	.015	.218	.067

Significant at 5%; *Significant at 10%; $R^2 = 0.462$; Adj. $R^2 = 0.385$; $F = 6.008^{}$; $N = 65$

Table 8.4: Factors influencing poverty in SNL: WLS estimation using poverty index as the regressand and herd size as the weighting variable

Model	β	SE	t
Constant	.001	.017	.085
Household size	-.121	.046	-2.604**
Number of livelihood sources	-.084	.217	-.385
Enclosure ownership	.220	.282	.781
Size of enclosure	.139	.081	1.717*
Distance to nearest market	-.750	.220	-3.413**
Herd splitting	1.219	.337	3.621**
Relief food	-.932	.328	-2.836**
Distance to pasture	.073	.032	2.277**
Remittances	.028	.346	.082

Significant at 5%; *Significant at 10%; $R^2 = 0.472$; Adj. $R^2 = 0.386$; $F = 5.472^{}$; $N = 65$

8.4.3 Results of the binary logit regression models

The criteria for selecting the best fit for the binary logit model was based on the significance of chi-square (χ^2) and Wald and the $-2\log$ -likelihood values. Table 8.5 presents the results of binary logit regression for the sedentary agro-pastoral land-use system. The results indicate that herd splitting, age of household head, and distance to pasture had positive and significant ($P \leq 0.05$) influence on poverty incidence, as represented by per capita daily income with respect to poverty line. Ownership of enclosure exerted a significant ($P \leq 0.05$) but negative effect on household poverty incidence. The number of livelihoods and level of education attained by the household head also had a significant ($P \leq 0.10$) and positive

influence on poverty. Although not significant, another variable that showed positive relationship with poverty incidence is herd size. The rest of the variables, distance to the nearest market, household size, remittances and relief food had negative but insignificant effect on poverty incidence.

Table 8.5: Factors influencing poverty in SAL: Logit estimation using per capita daily income as the regressand

Model	β	SE	Wald	Exp (β)
Constant	-17.029	6.362	7.165**	.000
Education of household head	1.071	.599	3.199*	2.918
Household size	-.140	.133	1.096	.870
Number of livelihood sources	.750	.422	3.159*	2.118
Enclosure ownership	-2.268	1.011	5.026**	.104
Distance to nearest market	-.170	.154	1.218	1.185
Herd splitting	2.932	1.032	8.065**	18.756
Relief food	-1.372	.888	2.388	3.945
Distance to pasture	.185	.091	4.128**	1.203
Remittances	-1.235	.784	2.481	.291
Herd size	.038	.035	1.153	1.039
Age of household head	4.275	1.871	5.221**	71.858

Significant at 5%; *Significant at 10%; Chi-square = 29.884, -2log-likelihood = 50.357**, N = 65

In the semi-nomadic pastoral land-use system (Table 8.6), regression results exhibited a few similarities and differences compared to the sedentary agro-pastoral land-use system. Similarities are observed in the effect of herd splitting and number of livelihood sources on poverty (positively correlated and significant at 5%). Some of the differences observed between the two land-use systems is significant ($P \leq 0.10$) and negative influence of distance to the nearest market on poverty incidence; significant ($P \leq 0.10$) and positive effect of size of enclosure on poverty; and significant ($P \leq 0.10$) and negative influence of household size on poverty incidence. Explanatory variables that showed positive but insignificant influence on poverty are gender of the household head, social network, age of household head, and property rights regime. As in the sedentary agro-pastoral land-use system, relief food and remittances had negative and insignificant effects on poverty incidence. However, ownership of enclosure showed a negative but insignificant influence on poverty.

Table 8.6: Factors influencing poverty in SNL: Logit estimation using per capita daily income as the regressand

Model	β	SE	Wald	Exp (β)
Constant	-5.057	4.375	1.336	.006
Gender of household head	1.366	1.420	.926	3.920
Age of household head	.738	1.108	.444	2.092
Household size	-.306	.200	2.989*	.737
Number of livelihood sources	2.099	.813	6.667**	8.162
Property rights regime	1.445	1.138	1.612	4.241
Enclosure ownership	-1.022	.877	1.357	.360
Size of enclosure	.422	.246	2.936*	1.525
Distance to nearest market	-.904	.523	2.986*	2.471
Herd splitting	3.308	1.422	5.414**	.037
Social network	.723	1.014	.508	2.060
Relief food	-1.011	.876	1.334	.364
Remittances	-.662	.985	.452	.516

Significant at 5%; *Significant at 10%; Chi-square = 27.110; -2log-likelihood = 45.439**; N = 65

The regression results of this study indicate that under both the sedentary agro-pastoral and semi-nomadic land-use systems, the number of alternative sources of livelihood plays a significant role in determining a household's per capita daily income and therefore whether a household is poor or not. Alternatives to livestock production such as crop cultivation, bee keeping, charcoal burning, livestock trading, and other off-farm sources of income and food, are particularly important during dry spells in pastoral areas. Although these alternatives mainly serve as fall-back livelihood activities, most of them are practiced alongside livestock production to augment subsistence from livestock and provide income for purchase of other basic needs.

The level of diversification of livelihoods determines a household's level of output, per capita income and ability to cope with the inherent natural shocks. Naturally, households with a variety of income sources are less likely to be poor. As reported by Gamba *et al.* (2004) and Mango *et al.* (2004) in Baringo and Marsabit Districts of Kenya, high crop diversification significantly reduces all poverty components. The higher the number of sources of livelihood for a given household, the higher the per capita income, and therefore the lower the poverty. This explains why sedentary agro-pastoral households with more livelihood sources are better-off than semi-nomadic pastoral families with fewer livelihood sources. Although only a few households, 28% in Loruk and 26% in Marigat practice herd

splitting, the model depicts herd splitting as a significant factor in determining poverty in the study area. The results show that poverty reduces with the practice of splitting household livestock holdings into separate herding units for the purpose of averting risk and optimizing range use.

These results are important with respect to policies on ASAL development and pastoral livelihoods. Many pastoralists have already chosen or been forced to leave livestock-based livelihoods, while others are rapidly diversifying their livelihoods and others, the majority, are continuing to pursue pastoralism through an array of adaptations. This calls for policies that provide appropriate support to whichever pathway particular pastoral communities or individual households choose to follow. As pointed out by Deveruex and Scoones (2008), two key principles ways to achieve this are to expand people's options and to maximize their physical, economic and social mobility. They give an example of providing education, especially to girls and women, to enhance access to non-agricultural livelihood activities, while lifting constraints to movement and trade across borders expands the area within which pastoralists pursue their livelihoods and alleviate the carrying capacity constraint. Mango *et al.* (2004) in their study done to determine the social aspects of dynamic poverty traps in Vihiga, Baringo and Marsabit Districts of Kenya, associate escape from poverty with education, getting a well paying job, diversification in on-farm and off-farm activities, and wider social networks. On the other hand, they identify the reasons for falling into to poverty as death of income earner; loss of employment; reduced land sizes; unproductive land; increased dependencies; and frequent natural catastrophes, among other factors.

Other important determinants of poverty under sedentary agro-pastoral land-use system are age and education of the household head and distance to pasture. The positive correlation of age of household head and poverty suggests that early marriage promotes poverty. In a pastoral set-up, a young head of household, besides lack of experience that undermines his ability to make right decisions, has limited assets, livelihood portfolio and access to factors of production. Provision of formal education that ensures that boys and girls spend most of their youth in school is a possible way of delaying marriage until appropriate age is attained. The model shows that households headed by educated persons are richer than those headed by less or non-educated persons, re-affirming that education is an important factor for reducing poverty in pastoral areas. This finding corroborates that of Kabubo-Mariara (2002)

in Kajiado District that as the level of education of the household head increases, the probability of a household being poor decreases.

The importance of education in poverty reduction is also highlighted in earlier works on poverty dynamics in Kenya (Place *et al.* 2003; Roth and Fratkin, 2005; Gamba *et al.*, 2004), which reported that poverty components decrease with the highest level of education attained by the household head. Similarly, Muyanga (2008) found that households that have heads without formal education contribute 54% and 76% percent to transient and chronic poverty in rural Kenya, respectively. He justifies the results that educated heads have higher income earning potential and more alternative income earning opportunities, and are thus better able to improve the quality of their respective households' welfare. In the current study, however, the influence of age and education of household head are only significant under sedentary agro-pastoral land use, again indicating that these variables become important as pastoralists settle thereby making education necessary for creating non-pastoral opportunities and diversification of economy in general. This has an implication on the age of marriage as the interest shift from early marriage to provide labour for livestock to diversifying livelihoods and reducing dependence on livestock.

Distance to pasture was found to be positively correlated to per capita daily income and longer under sedentary agro-pastoral land-use than in the semi-nomadic system. These results are not obviously explicable as they counter *à priori* expectation that the longer the distance to pasture, the lower the productivity of livestock, and hence the poorer the household. This is in contrast to the findings of Farah *et al.* (2003) that sedentary pastoral households have shorter herding distances. A possible explanation for the positive relationship between distance to pasture and per capita income is that in the initial stages, sedentary pastoralism reduces distance of pastoral migration as livestock rely on pastures within and around the settlements. However, as these pastures get depleted due to continuous grazing, they are forced to move longer distances to access pasture. At this stage, the further the household herds trek away from the settlements, the more pasture they access in terms of quantity and quality. This is expected to translate into higher herd productivity, higher per capita income and thus lower poverty.

In semi-nomadic land-use system, distance to the nearest market showed significant effect on the per capita daily income, albeit negatively. This implies that distance to trading centers, which besides providing market for livestock and their products are centers for social services and amenities, is a more important variable under the semi-nomadic pastoral system compared to the sedentary agro-pastoral system. This may be because agro-pastoralists often settle around these centers and therefore access the markets and social services easier than their nomadic counterparts. This result is, however, contrary to the finding of Muyanga (2008) that despite confounding relationships between distance to markets and poverty components, the relationships between the two are not statistically significant in the rural areas of Kenya. The current study shows that the nearer a household is to the trading center, the higher the per capita daily income and thus the lower the poverty. This has an important implication on policy with respect to provision of infrastructure and taking social services close to pastoralists, and in particular proper marketing channels so that pastoralists get reasonable value for their livestock.

Under sedentary agro-pastoral land-use system, household with enclosures were found to be poorer than those without. This contradicts the findings of Makokha *et al.* (1999) in Chepararia Division of West Pokot District. They reported a number of beneficial effects of enclosures including increased land value, more grass for livestock and thatching, increased milk yield and increased animal health condition. In semi-nomadic land-use system, it was the size of the enclosure that significantly influenced the per capita daily income of households and not just ownership of an enclosure. Those with smaller enclosures were found to be relatively poorer than those with larger ones. Ideally, ownership of an enclosure should mean that a household has reserve pasture, grass seeds and thatch for sale and therefore more income than a household without. The negative relationship between per capita daily income and ownership of enclosure in sedentary agro-pastoral system suggests that enclosure system may have evolved due to the dispossession of pastoralists. If so, then it is a pointer to land degradation, desperation, inability to split herd and migrate due to lack of herding labour, and therefore a resort for the poor households. However, under semi-nomadic pastoralism, where land may be less degraded and herding labour and mobility is not limiting, the size of the enclosure, as a measure of output becomes an important determinant of household income. Based on these results, it is appropriate to recommend

use of enclosures by households in semi-nomadic areas as a way of reserving pasture for drought periods and diversifying income sources.

Contrary to a number of literature on poverty and the *á priori* expectation, household size had a negative and significant coefficient for the semi-nomadic pastoral households, implying that larger households are poorer than smaller ones. This concurs with Place *et al.* (2003) that chronically poor households are likely to be large. They argue that as household size expands, households experience reduced expected chronic poverty, reaching a minimum threshold (three members), then thereafter, chronic poverty increases. While this observation confirms the hypothesis that larger families are more likely to fall into poverty, it also shows that extremely small households are disadvantaged. These results confirm the findings of Kristjanson *et al.* (2004), Krishna *et al.* (2004), Nyariki *et al.*, 2002, Kabubo-Mariara, 2002, and Mango *et al.* (2004) that high burdened households are more likely to drift into chronic poverty. Although it shows consistency with a number of studies on poverty this finding contrasts the hypothesis of economies of size that due to availability of labour, the poor's chief asset (Reardon and Vosti, 1995), larger households may face lower risk of poverty than their smaller counterparts (Nyariki *et al.*, 2002; Kabubo-Mariara, 2002). Nyariki *et al.* (2002) observed an inverse relationship between household size and calorie consumption in the semi-arid Makueni District of Kenya. They ascribe this to a possible higher dependency ratio in poorer households due to larger number of children, and likely underestimation of household sizes due to migration of members seeking off-farm employment. They point out that such households would actually have more off-farm earnings than their neighbours without migrants.

Dependence on relief food was negatively and significantly related to poverty level under the semi-nomadic pastoral land-use system. This is an indication that the semi-nomadic pastoralists in the Njemps Flats are more susceptible to famine, therefore making relief food more relevant to them than their settled counterparts. Although their influences were not significant, the other important determinant of per capita daily income and therefore poverty in the study area was remittances, which was negatively related to per capita daily income. This indicates that households that depend on remittances are poorer than their counterparts, which do not rely on food aid.

The parametric estimates of the determinants of poverty indicate that the most important determinants of poverty are the number of livelihood sources, herd splitting, distance to pasture, distance to nearest market, age of household head, household size, relief food and ownership of enclosure. From the foregoing results, it can be concluded that although sedentarization leads to range degradation around settlements and critical grazing areas in the short run, it exposes pastoralists to available opportunities outside pastoralism and encourages diversification of livelihoods thus reducing overdependence on livestock and their products in the long run. This concurs with the argument of Reardon and Vosti (1995) that the poor may exploit the environment through intensive use without accompanying investment in land conservation, and then use the profits to diversify away from risky livelihoods to protect their medium-term food security, thereby reducing pressure on land in the long run. The diversification of livelihoods is a negative feedback mechanism that is expected to reverse the trend of range deterioration as households get involved in a number of non-pastoral activities that do not directly depend on land. Contrary to many literature on poverty, it is evident from this study that, *ceteris paribus*, semi-nomadic pastoralists are likely to be poorer than the sedentary agro-pastoralists.

The findings of this study therefore refute the mainstream hypothesis of a simple linear downward spiral relationship between land-use, land degradation and poverty in the pastoral areas. The regression results show that the relationship between the three is complex as explained by Nyangena (2001) in his book on perspectives of poverty and resource degradation. The complexity of the links implies that poverty can never be significantly reduced by addressing environmental problems alone and vice versa. In the current study, settlement of pastoralists and accompanying land degradation necessitates more livelihood sources, thereby making sedentary pastoralist relatively wealthier than their semi-nomadic counterparts—"more degradation more livelihoods", that is the scenario in the Njemps Flats. These results introduce a new dimension to the popular thesis of "more people less erosion" by Tiffen *et al.* (1994). This goes on to confirm that unlike the arguments advanced on the basis Malthusian theory, sedentarization does not actually condemn pastoralists into chronic poverty, rather if there are opportunities for diversifying livelihood portfolios, settled pastoralists with many sources of livelihood are better off than their mobile counterparts with no or little alternative to livestock production.

8.5 CONCLUSIONS AND RECOMMENDATIONS

This study reveals a complex feedforward and feedback relationships, which contest a linear positive feedback mechanism between land-use, land degradation and poverty. The findings of this study show that the number of livelihood sources, herd splitting, household size, distance to pasture, distance to nearest market, ownership of enclosure, age of the household head and relief food are the key determinants of poverty in the study area. Several policy gaps emerge from the conclusions of this study. First, it is important to note that households with diversified food and income sources are less likely to fall into chronic poverty. In this study, diversification of sources of livelihoods is seen to have the capacity to mask the adverse effects of sedentarization and accompanying land degradation. The higher dependency on relief food under semi-nomadic pastoral land-use system than in the sedentary agro-pastoral land-use system is mainly as a result of no or fewer alternative sources of livelihood in the former than the latter. Hence, policy interventions should encourage diversification of livelihoods in the precarious environments that characterize arid and semi-arid rangelands.

The process of promoting diversification of household economies in the pastoral areas should be a systemic identification, evaluation and development of viable alternatives to livestock production. Diversification of income sources, in the short-run, could include other income generating activities such as crop production, bee keeping and small and medium business enterprises. In the long-run, and coupled with education and skills, diversification into formal employment is appropriate. This can be achieved through provision of secondary and post secondary bursaries for students from targeted pastoral areas. Education is critical to breaking the cycle of poverty and for the poor parents, the opportunity to obtain primary education for their off-springs is the first empowering step in their journey out of poverty. Formal education also helps to reduce cases of early marriage, a cause for young household heads, which has been demonstrated in this study to increase poverty incidence. Thus, policies aimed at enhancing access to post primary education are crucial in ensuring that pastoralists escape from poverty.

Because of the positive relationship between high poverty and large families, family planning programs that educate households about the virtues of having small families while

supporting them in birth control need to be promoted to assist in reducing rural household sizes and high dependency burdens in the long run. In the medium and long terms, reducing the number of people dependent on pastoral livelihoods provides the only significant way forward. Otherwise, any positive effects from improving the productivity of range and pastoral herds or from diversification of pastoral economy will be undermined by the growth of the pastoral human population almost as rapidly as the improvement can take place.

The negative relationship between poverty level and distance to nearest market has an important implication on policy with respect to provision of infrastructure and taking social services close to pastoralists. In particular, improvement of roads and proper marketing channels would ensure that pastoralists get reasonable value for their livestock, and therefore contribute to reduction of poverty in pastoral areas

In order to facilitate flexibility in herd mobility, which is a prerequisite for herd splitting and a central tenet of pastoral production, land policies are needed that recognize and strengthen communal rights to grazing land where they still exist. As away of reserving pasture for the dry spells, and as a source of income from sales of grass and grass seeds, enclosure system should be up-and out-scaled in the arid and semi-arid areas with the ultimate goal of reducing poverty. In conclusion, the implications of this thesis are that a solution to the fundamental imbalance needs to be found in a combination of the foregoing recommendations.

8.6 REFERENCES

- Bellon, M.R. and J.E. Taylor. 1993. "Folk" soil taxonomy and the partial adoption of new seed varieties. *Economic Development and Cultural Change*, 41: 763 – 786.
- Campbell, D.J. 1999. Response to drought among farmers and herders in southern Kajiado district, Kenya: A comparison of the 1972 –1976 and 1994 – 1995. *Journal of Human Ecology*, 27 (3): 377 – 416.
- Chabari, F, 1994. Livestock Marketing. In: Herlocker, D.J. Shaabani and S. Wilkes (Eds), *Range Management Handbook of Kenya* No. 2 (6). Ministry of Agriculture, Livestock Development and Marketing/GTZ, Nairobi.
- Chen, S. and M. Ravallion (Eds.). 2008. "The developing world is poorer than we thought, but no less successful". World Bank. <http://www.wds.worldbank.org/external/default>.
- Coppock, D.L. (Ed.). 1994. The Borana Plateau of southern Ethiopia: Synthesis of pastoral research, development and change, 1980 – 91. International Livestock Center for Africa (ILCA) *Systems Study* No. 5. Addis Ababa.
- Dahl, G. and A. Hjort. 1979. *Pastoral Change and The Role of Drought*. SAREC Report Swedish Agency for Research Cooperation with Developing Countries.
- Devereux, S. and I. Scoones. 2008. The crisis of pastoralism? Future Agricultures Debate. http://www.future-agricultures.org/pastoralism_debate.html.
- Ekbom, A. and J. Bojo. 1999. Poverty and Environment: Evidence of links and integration into the country assistance strategy process. Environment Group Africa Region, The World Bank *Discussion Paper* No. 4.
- Emana, B., K. Gemtessa, W. Tiki, W. Rebu and L. Asfaw. 2005. The Role of Indigenous Institutions in Pastoral Livelihood Strategies in Ethiopia. www.eaecon.org/Bezabih.
- Farah, K.O., D.M. Nyariki, A.A. Noor, R.K. Ngugi and N.K. Musimba. 2003. The socio-economic and ecological impacts of small scale irrigation schemes on pastoralists and drylands in Northern Kenya. *Journal of Social Science*, 7(4): 267 – 274.
- Gamba, P., Jayne, T., and Mghenyi E. 2004. Rural Poverty Dynamics, Agricultural Productivity and Access to Resources, Tegemeo *Working Paper* No. 21
- Gritli, R. 1997. *Literature Review on Nomadic Women and the Use of Rangelands*. FAO, ROME, Italy.
- Gujarat, D.N. 2003. *Basic Econometrics* (4th Ed.). The McGraw-Hill Company. New York.

8.6 REFERENCES

- Bellon, M.R. and J.E. Taylor. 1993. "Folk" soil taxonomy and the partial adoption of new seed varieties. *Economic Development and Cultural Change*, 41: 763 — 786.
- Campbell, D.J. 1999. Response to drought among farmers and herders in southern Kajiado district, Kenya: A comparison of the 1972 —1976 and 1994 — 1995. *Journal of Human Ecology*, 27 (3): 377 — 416.
- Chabari, F, 1994. Livestock Marketing. In: Herlocker, D.J. Shaabani and S. Wilkes (Eds), *Range Management Handbook of Kenya* No. 2 (6). Ministry of Agriculture, Livestock Development and Marketing/GTZ, Nairobi.
- Chen, S. and M. Ravallion (Eds.). 2008. "The developing world is poorer than we thought, but no less successful". World Bank. <http://www.wds.worldbank.org/external/default>.
- Coppock, D.L. (Ed.). 1994. The Borana Plateau of southern Ethiopia: Synthesis of pastoral research, development and change, 1980 — 91. International Livestock Center for Africa (ILCA) *Systems Study* No. 5. Addis Ababa.
- Dahl, G. and A. Hjort. 1979. *Pastoral Change and The Role of Drought*. SAREC Report Swedish Agency for Research Cooperation with Developing Countries.
- Devereux, S. and I. Scoones. 2008. The crisis of pastoralism? Future Agricultures Debate. http://www.future-agricultures.org/pastoralism_debate.html.
- Ekbom, A. and J. Bojo. 1999. Poverty and Environment: Evidence of links and integration into the country assistance strategy process. Environment Group Africa Region, The World Bank *Discussion Paper* No. 4.
- Emana, B., K. Gemtessa, W. Tiki, W. Rebu and L. Asfaw. 2005. The Role of Indigenous Institutions in Pastoral Livelihood Strategies in Ethiopia. www.eeaecon.org/Bezabih.
- Farah, K.O., D.M. Nyariki, A.A. Noor, R.K. Ngugi and N.K. Musimba. 2003. The socio-economic and ecological impacts of small scale irrigation schemes on pastoralists and drylands in Northern Kenya. *Journal of Social Science*, 7(4): 267 — 274.
- Gamba, P., Jayne, T., and Mghenyi E. 2004. Rural Poverty Dynamics, Agricultural Productivity and Access to Resources, Tegemeo *Working Paper* No. 21
- Gritli, R. 1997. *Literature Review on Nomadic Women and the Use of Rangelands*. FAO, ROME, Italy.
- Gujarat, D.N. 2003. *Basic Econometrics* (4th Ed.). The McGraw-Hill Company. New York.

- Herlocker D. 1999. *Rangeland resource in East Africa: Their ecology and development*. GTZ, German Technical Cooperation, Nairobi, Kenya.
- Hogg, R. 1986. The New Pastoralism: Poverty and Dependency in Northern Kenya. *Africa*, 56 (3): 319 – 33.
- ICARDA/ICRISAT. 2002. Desertification, Drought, Poverty, and Agriculture. *A pre-proposal for a CGIAR Challenge Programme*.
- ILO, 2009. Global employment trends. International Labour Office, Geneva. www.ilo.org/wcmsp/groups/public/dgreports/.
- Kabubo-Mariara, J. 2002. Rural Poverty, Property Rights and Environmental Resource Management in Kenya. Department of Economics, University of Nairobi.
- Kabubo-Mariara, J. 2003. The Linkages between property rights, migration, and productivity: The case of Kajiado District, Kenya. Department of Economics, University of Nairobi.
- KARI/ODA. 1996. *Manual of livestock production systems in Kenya*. Livestock socio-economics and epidemiology project. National veterinary research centre, Kikuyu, Kenya.
- Krishna A., Kristjanson P., Radeny M., Nindo W. 2004. Escaping Poverty and Becoming Poor in Twenty Kenyan Villages. *Journal of Human Development*, 5 (2):211– 226.
- Kristjanson P, Krishna A, Radeny M, Nindo W. 2004. Pathways out of Poverty in Western Kenya and the Role of Livestock. Food and Agriculture Organization, Pro-Poor Livestock Policy Initiative *Working Paper* No. 14. FAO, Rome. www.fao.org/ag/againfo/projects/en/ppipi/project_docs.html.
- Kristjanson, P., M. Radeny, D. Nkedianye, R. Kruska, R. Reid, H. Gichohi, F. Atieno and R. Sanford. 2002. *Valuing Alternative Land-Use Options in the Kitengela Wildlife Dispersal Area of Kenya*. ILRI, Nairobi.
- Krugmann, H. 1996. Toward Improved Indicators to Measure desertification and monitor the Implementation of the Desertification Convention. In: Hambly, H. and T.O. Angura (Eds). *Grassroots Indicators for Desertification: Experience and Perspectives from Eastern and Southern Africa*. International Development Research Centre (IDRC).
- Little, P.D. 1985. Social differentiation and pastoral sedentarization in Northern Kenya. *Africa*, 55 (3): 243 – 261.

- Makokha W, Lonyakou S, Nyang M, Kareko K.K, Holdings C, Njoka TJ, and Kitalyi A. 1999. *We work together: land rehabilitation and household dynamics in Chepararia Division, West Pokot District, Kenya*. RELMA Technical Report Series No. 22. Nairobi: RELMA.
- Mango, N., J. Cheng'ole, G. Kariuki and W. Ongadi. 2004. Social Aspects of Dynamic Poverty Traps: Cases from Vihiga, Baringo and Marsabit Districts, Kenya. *BASIS CRSP research report*. P. Kariuki and J. Owour, 2006. *Geographic Determinants of*
- Marinda, P.A. and F. Heidhues. 2004. Gender Discrimination and Its Impact on Food and Nutrition Security in Kenya. A Case of West Pokot District. *Deutscher Tropentag*, October 5 – 7, 2004, Berlin.
- Meyerhoff, E. 1991. *Taking Stock: Changing Livelihoods in a Agropastoral Community*. African Center for Technology Studies (ACTS) Press, Nairobi and Biomass Users Network, Harare.
- Millennium Ecosystem Assessment. 2003. *Ecosystems and Well-being*. A Framework for Assessment. Island Press.
- Mugenda, O.M. and A.B. Mugenda. 1999. *Research Methods: Quantitative and Qualitative approaches*. ACTS Press, Nairobi, Kenya.
- Muyanga, M. 2008. Household Vulnerability to Transient and Chronic Poverty: Evidence from Rural Kenya. Tegemeo *Working Paper* No. 21, Tegemeo Institute of Agricultural Policy and Development, Egerton University.
- Niamir, M. 1994. Natural Resource Management at Local-Level. In: Pastoral Natural Resource Management and Policy. *Proceedings of the Subregional Workshop held 6 –10 December 1993 in Arusha, Tanzania*.
- Nyangena, W. 2001. Perspectives on poverty and resource degradation. Institute of Development Studies, *Working Paper* No. 532. University of Nairobi.
- Nyariki, D. M., S.L. Wiggins and J.K. Imungi. 2002. Levels and causes of household food and nutrition insecurity in dryland Kenya. *Ecology of Food and Nutrition*, 41: 155 – 176.
- Nyariki, D.M. and R.K. Ngugi. 2002. A review of African pastoralists production system: Approaches to their understanding and Development. *Journal of Human Ecology*, Vol. 13(3): 137 – 250.

- Nyariki, D.M., B.F., Makau, W.E. Ekaya and J.M. Gathuma. 2005. *Guidelines for emergency livestock off-take handbook*. Office of the President, Arid Lands Resource Management Project (ALRMP). Republic of Kenya.
- Oba, G. and W. Lusigi. 1987. An overview of drought strategies and land use in African pastoral systems. *Paper No. 23a*, www.odi.org.uk/pdn/papers.
- Okwi, P.O., G. Ndeng'e, P. Kristjanson, M. Arunga, A. Notenbaert, A. Omolo, N. Henninger, T. Benson, P. Kariuki and J. Owour. 2006. *Geographic Determinants of Poverty in Kenya: A National and Provincial Analysis*. International Livestock Research Institute (ILRI) in Nairobi, Kenya.
- Otieno, A.K. and K.M. Rowtree. 1986. *A comparative study of land degradation in Machakos and Baringo District, Kenya*. Institute of British Geographers, Reading, England.
- PARIMA, GL-CRSP, 2005. Improving Pastoral Risk Management on East African Rangelands. *Annual Report No.200*.
- Pindyck, R.S., and D.L. Rubinfeld. 1981. *Econometrics Models and Economic Forecasts*. McGraw-Hill Book Co. Inc., New York.
- Place, F., P. Hebinck, and M. Omosa. 2003. Chronic Poverty in Rural Western Kenya: Its identification and implications for agricultural development. http://aem.comell.edu/special_programs/AFSNRM/Basics/pdf.
- Reardon, T and S.A. Vosti. 1995. Links between rural poverty and environment in developing countries: Asset categories and investment poverty. *World Development*, 23 (9): 1495 – 1506.
- RoK. 2000. *Poverty in Kenya*, Vol. I, Incidence and depth of poverty. Central Bureau of Statistics and Human and social Resources Department, Ministry of Finance and Planning, Government of Kenya.
- Roth, E.A. and E Fratkin.2005. The social, health and economic consequences of pastoral sedentarization in Marsabit District, northern Kenya. In: Fratkin, E. and E.A. Roth (Eds.). *As pastoralists settle*. Kluwer Academic Publishers, New York.
- Sandford, S. 1983. *Management of pastoral development in the third world*. John Wiley and Sons, Chichester.
- Seaman, J., P. Clarke, T. Boudrea and J. Holt (Eds.). 2000. *The Household Economy Approach*. Save the Children *Development Manual No. 6*. Save the Children, London.

- Shiferaw, B. and S.T. Holden. 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: A case study in Andit Tid, North Shewa. *Agricultural Economics*, 18: 233 – 247.
- Sikana, P.M. and C.K Kerven. 1991. The impact of commercialisation on the role of labour in african pastoral societies. ODI *Pastoral Development Network Paper* No. 31c.
- Talle, A. 1999. Pastoralists at the Border: Maasai Poverty and the Development discourse in Tanzania. In: D.M. Anderson and V. Broch-Due (Eds.). *The poor are not us: Poverty and pastoralism in Eastern Africa*. James Curry, Oxford.
- Tiffen, M., M. Mortimore and F. Gichuki. 1994. *More people less erosion: Environmental recovery in Kenya*. John Wiley, London.

CHAPTER NINE

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The results of this study attest to the widely reported social and ecological downward trends in the Kenyan rangelands. The geo-spatial analysis of the Njemps Flats show a positive relationship between land cover change on one hand, and human and livestock population trends on the other. There is a close link between declining herbaceous cover and rising human and livestock populations as well as distinct difference in the two land-use systems with regard to land cover and populations dynamics. The difference in vegetation structure between the two land-use systems is evident with the sedentary agro-pastoral land-use system showing an increase in closed woodland as opposed to increase in bare ground with scattered shrubs under the semi-nomadic pastoral land-use system. The increase in area under closed woodland is partly attributed to the invasion by *Prosopis juliflora*, an alien species introduced into the study area in the 1980s.

The Njemps Flats have shown a remarkable surge in human population from 38,412 in 1979 to 94,861 in 1999. The results also show that human population has been consistently higher under the sedentary agro-pastoral land-use system than in the semi-nomadic land-use pastoral system. The rising population in the study area is mainly as a result of immigration of farming communities and expanding settlements around trading centres. Similarly, livestock population rose from 729.9 TLUs in 1973 to 1,334.5 TLUs in 1994. Donkey population showed the highest growth (83.3%), suggesting an increasing need for the draught animals for fetching water. The small stock showed the second highest population growth (74.6%) followed by camels (59%) and cattle (39.2%). These changes in pastoral herd composition correspond to changing vegetation type and climate anomalies.

The long-term rainfall analysis reveals increasing rainfall variability and changing pattern. The results indicate high variability in mean annual and monthly rainfall as well as decline in total annual rain-days between 1966 and 2008. While mean annual rainfall showed a slight increase, the total number of rain-days declined over the period under study. Increased intensity per rainfall events may be partly responsible for the widely reported soil erosion in the study area.

Overall, these findings depict land-use activities and livestock and human population pressure as major determinants of landscape change in the study area. The results also corroborate the local perceptions on social and ecological trends, which indicate a downward trend in vegetation cover and diversity, increases in livestock and human populations, and escalating soil erosion and climatic anomalies. The concurrence of the local perceptions with the conventional data confirms that pastoral communities possess profound knowledge and understanding of their environments. This indicates the relevance of local knowledge systems in complementing the scanty conventional research data.

The results on the current range condition show that land-use is a major determinant of soil aggregate stability, surface run-off, soil erosion, vegetation cover and species richness. However, season as dictated by rainfall was also found to be important in determining both soil and vegetation dynamics. Sedentary agro-pastoral land-use activities were found to lower soil aggregate stability, herbaceous cover and species richness, and increase surface run-off and soil erosion. These effects are attributable to the more intense and continuous use under sedentary systems compared to the semi-nomadic ones that offer flexibility in terms of rotation and rest periods. The positive linear relationship between rainfall and herbaceous biomass production, species diversity and richness underscores the disequilibrium nature of the pastoral ecosystems—that rainfall is the single most important determinant of productivity in tropical rangelands. In regard to range rehabilitation, the findings demonstrate the potential of enclosures in ecological restoration of degraded rangelands. This was confirmed by increased herbaceous standing biomass, cover and species richness inside enclosures compared to adjacent open grazing sites. In addition, enclosures conferred beneficial effects on soil physical fertility as reflected in reduced surface run-off and soil erosion. These results indicate that the process of land degradation in the Njemps Flats is reversible.

Using land cover, soil aggregate stability, surface run-off, soil loss, herbaceous cover and species richness as indicators of rangeland degradation, it can be concluded in this study that land degradation is higher under sedentary agro-pastoral land-use than semi-nomadic land-use system.

This study reveals a complex feedforward and feedback relationships, which contest a bi-directional positive feedback mechanism between land-use, land degradation and poverty. The logit model estimates of the determinants of poverty show that the number of livelihood sources, household size, herd splitting, distance to pasture, distance to nearest market, ownership of enclosure, relief food, and the age of the household head are the most important factors affecting poverty in the study area. Households which had access to more alternative livelihoods were found to be wealthier than those with less or no alternatives. The pastoral households which practiced herd splitting, a traditional risk aversion and pasture management strategy, were better off than those which did not. The distance to pasture was found to be positively related to per capita daily income, and was longer under sedentary agro-pastoral land-use than in the semi-nomadic system. These results contrast the hypothesis that the longer the distance to pasture, the lower the productivity of livestock, and hence the poorer the household. However, this scenario is probably due to many alternative livelihoods under sedentary pastoralism that lead to higher household income than in the semi-nomadic land-use system.

The negative relationship observed between per capita daily income and ownership of enclosure in sedentary agro-pastoral system depicts enclosure system as a resort for the poor households. It suggests that enclosures are indicators of land degradation and a desperate effort by the already impoverished pastoralists that are unable to split their herds and migrate due to lack of herding labour and curtailed mobility. The positive relationship between the age of the household head and poverty under agro-pastoral land-use system suggests that early marriage promotes poverty. The explanation is that a young head of household, besides lack of experience that undermines his ability to make right decisions, has limited assets, livelihood portfolio and access to factors of production. Larger households were found to be poorer than smaller ones. This was attributed to a higher demand on limited resources in larger families than in smaller ones. Households near to market centres were wealthier than those far away. This finding is contrary to the widely held view that pastoralists settled around trading centres are poorer than the nomadic ones. The households who received relief food were found to be poorer than those that did not, suggesting that reliance on relief food by pastoral households is an indicator of poverty.

The findings of this study contest the hypothesis of a linear downward spiral relationship between land-use, land degradation and poverty. The results reveal a more complex non-linear relationship between the three—poverty declines with an increase in sedentarization and land degradation, a scenario that can be explained by enhanced diversification of livelihoods among settled pastoral households compared to their semi-nomadic counterparts. It is widely accepted that sedentarization accompanied by intensive agro-pastoralism leads to degradation of rangelands in the short run. However, in the long term, as settled pastoralists seek to diversify their sources of income and food, in response to declining range and livestock productivity, they access a wider range of opportunities that make them wealthier and more secure than the semi-nomadic pastoralists with little or no alternatives.

The analytical DPASIR framework clearly shows that the stage for the current state of natural resources and household well-being in the Njemps Flats was set largely by the colonial policy interventions. These development interventions were informed by the old paradigms on pastoralism that faulted the system as that which was irrational and environment unfriendly—the same policies were adopted by the post-independence government. Even with the new paradigm shifts, it has proved difficult to correct the past mistakes and improve the livelihoods of pastoral communities in the absence of appropriate and adequate policies.

9.2 RECOMMENDATIONS

9.2.1 Policy implications

In view of the foregoing conclusions and considering the socio-economic and ecological change dynamics, of which pastoralists are a part, a number of interventions can be recommended:

- Land-use system has been explicated in this study as the main determinant of soil and vegetation degradation and socio-economic dynamics in the Njemps Flats. More land degradation is associated with the higher population pressure under the sedentary agro-pastoral land-use than semi-nomadic pastoral land-use system. In view of this, appropriate policies that promote diversification of pastoral economies provide the first line of defense for pastoral production in the study area. Livelihood diversification

broadens the food and income base and relieves pressure on land as a primary source of livelihood. The higher reliance on relief food under semi-nomadic pastoral land-use system than in the sedentary agro-pastoral land-use system is mainly as a result of no or fewer alternative sources of livelihood in the former than the latter. The development of infrastructure and promotion of formal education are important ways of increasing access to and opportunities for off-farm sources of income and food. The provision and strengthening of formal education increases the opportunities available to pastoral households to pursue alternative sources of livelihood.

- Policies aimed at enhancing access to post primary education are crucial to breaking the cycle of poverty in pastoral households. In regard to poverty incidences associated with young head of households, provision of formal education ensures that people spend most of their youth in school until they attain the appropriate age for marriage.
- The second line of defense entails formulation of policies that recognize and strengthen communal rights to grazing resources where they exist in pastoral areas to allow more flexibility in herd movement. This is expected to have beneficial impacts on soil and vegetation properties and consequently improved herd productivity.
- The third line of defence would be to directly slow down or reverse the processes of land degradation in the study area. This study reveals that enclosures offer an effective way of rehabilitating degraded rangelands besides providing food and income.
- Livestock production is the key means of livelihood in the semi-arid lowlands of Baringo. This calls for both improvement and transformation approaches to the pastoral production system aimed at modifying pastoralism to conform to the prevailing social and ecological conditions. Despite the possibilities for improvement, the need to reduce pressure on the range resources calls for reduction of the number of people supported, and this implies that efforts must also be directed towards facilitating their absorption into agro-pastoral agriculture, rural or urban employment and any other viable alternatives.
- Sustainable solutions to the problems of land-use, land degradation and poverty can be found in a combination of the foregoing recommendations, among others.

9.2.2 Further research

Despite a number of recommendations arising from the findings of this study, there is still need for more research to further strengthen the basis of decision-making and generate more information to guide development and ameliorative actions:

- This study reveals a positive relationship between land cover change and human and livestock populations. This calls for determination of a threshold of human and livestock populations with respect to land cover change in order to guide decisions on creating a negative feedback between the processes of land degradation and population pressure.
- It is also necessary to project future scenarios of the interrelationships between land cover, rainfall, human and livestock populations for the purpose of planning for interventions.
- Reducing the number of people directly supported by pastoralism involves absorption of pastoralists into agro-pastoral agriculture, rural or urban employment and any other viable alternatives. This, however, require further research on the receptiveness and adoption rate of the pastoralists to alternative livelihood options and the means of improving them.
- This study has reported significant annual and monthly rainfall variability around long-term means. It is, therefore, crucial to assess the impacts of climate variability on poverty incidence and level in the Njemps Flats. There is also need to assess the effectiveness of the existing coping strategies for rangeland degradation and climate variability in the study area.
- Several methods of preventing further land degradation exist. The adoption of any of these methods depends on their implementation costs vis-à-vis the productivity of the land. Most physical soil conservation measures on grazing lands have met with very limited success due to unjustifiable capital requirements that include heavy input in terms of labour and money. This has, therefore, led to the need for concentration of efforts and research in low cost measures for marginal areas. One such low cost measure is to use vegetation as a protection measure and to allow or enhance re-vegetation. Having demonstrated the potential of the enclosure system to restore degraded rangelands, the next step would be to evaluate its economic viability as a pre-requisite for recommending it for out-scaling in areas with the same ecological conditions.

- Besides the soil physical properties, there is need to determine the effects of land-use and enclosures on chemical and biological soil characteristics. Equally important is the determination of the effects of the fallow age of enclosures on the soil and vegetation characteristics.
- This study has demonstrated that the local knowledge system is an important source of information that can be used to augment the conventionally generated data. In view of this, more research is required to identify and document indigenous knowledge for the purpose of bridging the gap in historical data at local levels.
- This study underscores the negative relationship between livelihood diversification and household poverty in the Njemps Flats. It is, therefore, important to assess the level of contribution of individual alternative sources of livelihood to reduction of poverty.

2.1 Name of respondent

2.2 Sex: (1) Male

2.3 Age:

2.4 How long have you lived here?

3.0 Natural resources

3.1 Describe the types of

Resource

Cattle population

Sheep population

Goat population

Wildlife population

Grass cover

Tree cover

Water resources

Soil fertility

Soil erosion

Human population

Overgrazing

Soil salinization

Soil erosion (I)

Soil erosion (II)

Soil erosion (III)

CHAPTER TEN

10.0 APPENDICES

10.1 APPENDIX I: QUESTIONNAIRE FOR INVESTIGATION OF LOCAL KNOWLEDGE AND PERCEPTIONS IN THE NJEMPS FLATS

[Fill in blank space/tick appropriate code]

1.0 General information

1.1 Date of interview:...../...../.....: Questionnaire serial number:...../...../.....

1.2 Name of enumerator:.....

1.3 Division:.....Location:.....Sub-oc:.....Village:.....

1.4 Site: (1) Marigat (0) Loruk

2.0 Respondent's information

2.1 Name of respondent:.....

2.2 Sex: (1) Male (0) Female

2.3 Age: (1) Under 30 years (2) Between 30 – 60 years (3) Over 60 years

2.1 How long have you lived here?.....years

3.0 Natural resources characterization

3.1 Describe the characteristics of the following range resources in your area:

Resource	Trends during the last three decades: (1) Increased (2) Remained constant (3) Decreased	Reasons for the observed trends:	Suggestions to improve the resource
Cattle population			
Sheep population			
Goat population			
Wildlife population			
Grass cover			
Tree cover			
Water in rivers, lakes, dams etc			
Soil fertility			
Human population			
Grazing land			

Codes for reasons for the observed trends: (1) Diseases (2) Lack of pasture (3) Lack of herding labour (4) Changes in land ownership (5) Government policies (6) Poor marketing structure (7) Human population pressure (8) Overgrazing (9) Charcoal burning (10) Building and construction (11) Lack of rainfall (12) Land-use changes (13) Poverty (14) Crop cultivation (15) Others (specify)-Rank in order of importance

3.20 Vegetation characteristics

3.21 Have you observed any changes in the vegetation diversity and its other characteristics since you settled here? (1) Yes (0) No. If yes, fill the table below:

Attribute	Status: 1-Declining; 2-No change; 3-Increasing	Causes for the observed changes	Impacts of the changes on land	Measures undertaken to reduce their impacts on land	What should be done to improve the situation
Diversity					
Abundance					

Codes for causes for the changes: (1) Charcoal burning (2) Building and Fencing (3) Crop cultivation (4) Overgrazing (5) Human population (6) Lack of rainfall (7) Changes in land ownership (8) Herbal medicine (9) Settlements (10) Others (specify)

Codes for impacts of the changes: (1) Reduced sources of livelihoods (2) Decline in production (3) Soil erosion (4) Poverty (5) Others (specify)

Codes for measures undertaken: (1) None (2) Tree planting/protection (3) Terraces (4) Enclosures/Range reseeding (5) Others (specify)

3.22 Are there any particular plant species (trees, shrubs, herbs and grasses) that were available many years ago but are currently not available? (1) Yes (0) No. If yes, fill the table below:

Plant species	Uses	Reasons for loss/decline	Year last seen

Codes for use: (1) Construction materials (poles, grass, fibre etc) (2) Forage/Fodder (4) Herbal medicine (5) Fuelwood (6) Vegetable/Fruit (7) Curving (8) Timber (9) Others (specify)

Codes for causes for decline/loss: (1) Charcoal burning (2) Building and Fencing (3) Crop cultivation (4) Overgrazing (5) Human population (6) Lack of rainfall (7) Changes in land ownership (8) Herbal medicine (9) Settlements (10) Others (specify)

3.30 Soil characteristics

3.31 Have you observed any changes in the soil cover and its other characteristics since you settled here? (1) Yes (0) No. If yes, fill the table below:

Characteristic	Status: 1-Declining; 2-No change; 3-Increasing	Causes for the changes observed	Impacts of the changes on land	Measures undertaken to reduce the impacts on land	Future strategies to protect the soil
Fertility					
Cover					
Erosion					

Codes for causes for decline: (1) Vegetation clearing (2) Overgrazing (3) Crop cultivation (4) Lack of rainfall (5) Others (specify)

Codes for the impacts of the changes: (1) Soil loss (2) Decline in production (3) Reduced sources of livelihoods (4) Others (specify)

Codes for measures undertaken: (1) None (2) Tree planting/protection (3) Terraces (4) Enclosures/Range reseeding (5) Others (specify)

3.40 Key sites

3.41 Are there special sites/niches which you either feel are threatened or should be protected in your area? (1) Yes (0) No. If yes, fill the table below:

Which kind of site?	Where is the site?	Why should it be protected?	Strategies to protect the site

Codes for the kind of site: (1) Dry season grazing reserves (2) Watering points (3) Migratory routes (4) Water catchments (5) Forested areas (ritual sites) (6) Forested hills (source of high value trees/shrubs) (7) Nesting /Breeding site (8) Others (specify)

4.0 Sources of livelihood

(a) List and describe all the livelihood options in your locality as indicated in the table below:

Livelihood option	Inputs	Rank (based on cost/benefit analysis)	Marketing attributes (+/-)	Status 1-Improving; 2-Decreasing; 3-Stable	Impacts on environment	Strategies for improvement
Livestock production						
Crop production						
Apiculture (Bee-keeping)						
Business/Trade						
Charcoal burning						

5.0 Institutional capacity

5.1 In your community, are there regulations or rules governing use of natural resources? (1) Yes (0) No.

5.11 If yes, list and explain them.

.....

.....

.....

.....

.....

5.12 If No, what are the main changes that have affected the traditional management of the natural resources in your locality? Rank the following factors in order of importance:

Factors affecting traditional practices	Rank
Government policies	
Human population pressure	
Land-use changes	
Climate change	
Poverty	
Livestock population pressure	
Formal education	
Security (Tribal conflicts over resources)	
Land tenure changes	
Other (specify)	

5.13 How do you handle disputes concerning natural resources, tick as appropriate: (1) Through law courts (2) Traditionally (3) Other ways (specify)

5.14 Do you use any of the traditional practices listed below to enhance environmental protection or conservation? Write the correct response in relevant space provided below:

Practice	Tick as appropriate	Description and Purpose of the practice	Trend during the last three decades
Deferred grazing (karantile)			
Mixed-species herd			
Burning of pasture			
Large herds			
Migration			
Polygamy			
Social network/alliances (stock-friendship)			
Other (specify)			

Codes for trend: (1) Increasing (2) Declining (3) No change

5.15 If any of the above practices is no longer or declining in use, what do you consider to be the reason?.....

.....

.....

.....

5.16 Are there any institutions (GoK, NGOs, CBOs) involved in natural resource management in your area? (1) Yes (0) No. If yes, fill the table below.

Institution	Activities: (Environmental protection-planting trees & grass; water development-boreholes, pans; livestock health & production etc)	Collaborators: (GoK, community, schools, churches etc)	Weaknesses

6.0 Land-use and environment

6.1 Have you observed any change in land-uses and pattern over past years? (1) Yes (0) No. If yes, explain....

.....

.....

.....

.....

.....

6.2 At the moment, what is the dominant land-use in your area?.....

6.3 What is your view on the current land-uses in your area?

Strengths.....

Weaknesses.....

6.4 In your opinion, do you think your area is undergoing land degradation? (1) Yes (0) No. If yes, list and explain the indicators.....

1.....

2.....

3.....

4.....

5.....

6.....

7.....

8.....

6.5 What do you think are the causes of the indicators (land degradation) you have listed above? Rank in order of importance

	Rank	Suggestions to check and reverse the trend
Overgrazing/Overcultivation		
Destruction of trees		
Poverty		
Rainfall scarcity		
Human population pressure		
Rise in livestock population		
Land tenure changes		
Tribal conflicts (insecurity)		
Land-use changes		
Breakdown of traditional institutions and practices		
Government policies		
Other (specify)		

7.0 Land tenure

7.1 Have you observed any changes in land tenure system since the pre-colonial era? (1) Yes (0) No. If yes, please indicate by ticking the tenure system that coincides with the periods listed:

Property right regime	Pre-colonial era	Colonial era	Post-colonial era	At the moment
Common property (with regulations)				
Open access (No regulations)				
Individual titled ownership (private)				
Group ranch				
Family ownership				
Clan ownership				
Others (Specify)				

8.0 Climate

8.1 Have you ever noticed any changes in the following climatic factors over last 30 years?

Climatic factor		Trends over the years				
		60s	70s	80s	90s	2000s
Rainfall	Amounts					
	Intensity					
	No. of rainy days					
	Reliability					
Temperature						
Wind						
Solar radiation						

Codes for the trends: (1) No change (2) Increasing (3) Decreasing

9.0 Gender roles

9.1 In your opinion, do you think gender roles in natural resource use and management have changed over the years? If yes, please explain giving the changes and their causes.....

.....

.....

.....

.....

10.2 APPENDIX II: CHECKLIST FOR FOCUS GROUP DISCUSSIONS AND KEY INFORMANT INTERVIEWS ON SOCIAL AND ECOLOGICAL TRENDS IN THE NJEMPS FLATS DURING THE LAST 40 YEARS

1. ECOLOGICAL TRENDS

(a) Soil change dynamics in the last 40 years

- i. Soil fertility
- ii. Soil erosion

(b) Vegetation change dynamics in the last 40 years

- i. Forage production
- ii. Plant diversity
- iii. Grass cover
- iv. Bush encroachment

(c) Climatic and hydrological trends in the last 40 years

- i. Rainfall amounts
- ii. Rainfall intensity
- iii. Number of rain-days
- iv. Rainfall reliability
- v. Rainfall variability
- vi. Droughts
- vii. Temperatures
- viii. Wind
- ix. Water level in Dams, rivers and lakes

2. SOCIO-ECONOMIC TRENDS

(d) Trends in livelihood sources

- i. Livestock production
- ii. Crop production
- iii. Honey production
- iv. Business/petty trade
- v. Charcoal burning
- vi. Fishing

(e) Land tenure changes in the last 40 years

- i. Pre-colonial era
- ii. Colonial era
- iii. Post-colonial era
- iv. At the moment

(f) Role of the following in the process of land degradation

- i. Pastoralists
- ii. Climate
- iii. Government
- iv. Modernization

(g) Changes in household characteristics

- i. Literacy levels
- ii. Dietary composition
- iii. Dependency ratio
- iv. Relief food
- v. Poverty

(h) Changes in human population

- i. Total population
- ii. Population density
- iii. Household size

(i) Changes in land-use

(j) Changes in livestock population

- i. Household herd size
- ii. Cattle
- iii. Camel
- iv. Donkey
- v. Sheep

(k) Trends in traditional and cultural practices

- i. Herd splitting
- ii. Mobility
- iii. Mixed-species herds
- iv. Large number of herds
- v. Migration to urban/trading centres for wage employment
- vi. Cultivation
- vii. Social networking/alliances
- viii. Others (specify)

(l) How do you relate the socio-economic and climatic trends to the range condition trend?

10.3 APPENDIX III: PROFILE DESCRIPTION OF SOILS IN THE NJEMPS FLATS

Description of soil profile was done at two selected sites within the study area: on erosion cut in Endao (Plate 10.0) and road cuts in Kaplelchony (Plate 10.1) in the Njemps Flats.

10.3.1 Description of soil horizons at Endao

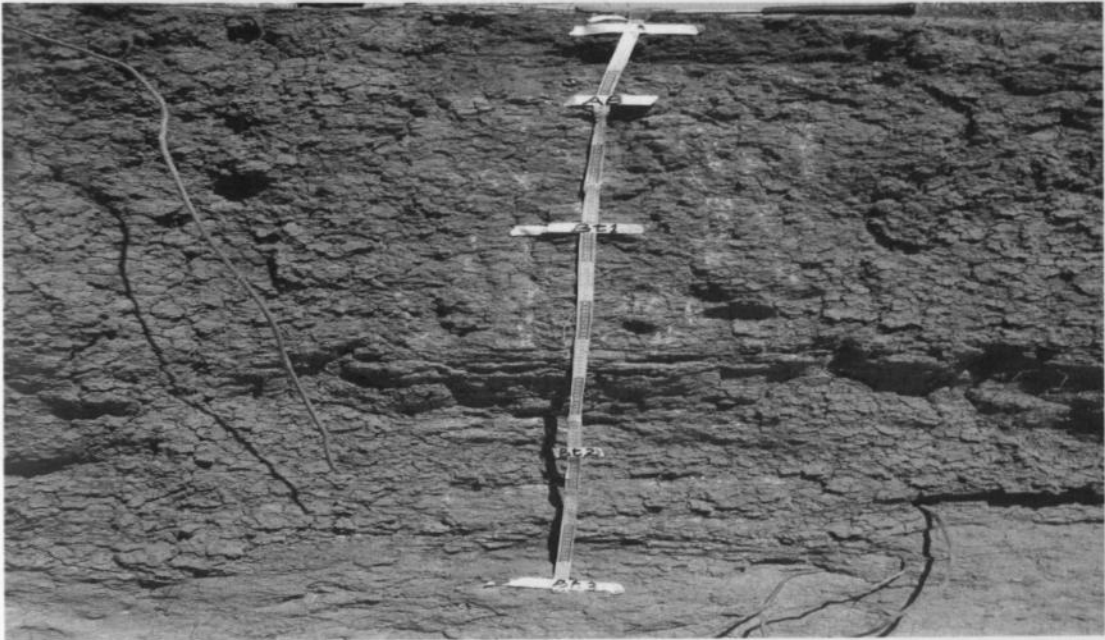


Plate 10.0: Soil profile pit at Endao

The following horizons were identified on the fresh erosion gully at Endao:

1. Horizon A 0 — 16 cm: This horizon had moist dark greyish brown (10YR 4/2) and dry very dark greyish brown (10YR 3/2) clay soil with fine crumb; slightly firm when dry, and friable, sticky and plastic when wet. The soil had medium and coarse pores, and a few medium and coarse roots. There was a clear and smooth transition to the next horizon.
2. Horizon AB 16 — 33 cm: This layer had dark brown (10 YR 3/3) moist and dry clay soil with moderate medium to coarse sub-angular blocky structure; slightly firm when dry, medium and coarse pores; medium and coarse roots. The soil was friable, sticky and plastic when wet. The horizon exhibited a gradual and wavy transition to the next layer.

3. Horizon Bt₁ 33 — 93 cm: The soils in this horizon were moist dark brown (10YR 3/3) and dry very dark greyish brown (10 YR 3/2) clay with a medium to coarse sub-angular blocky structure; medium and coarse pores; medium and coarse roots. The soils were slightly hard when dry, and friable, sticky and plastic when wet. Transition to the next horizon was gradual and wavy.
4. Horizon Bt₂ 93 — 150 cm: The soils in this layer were moist dark brown (10 YR 3/3) and dry clay with moderate medium to coarse angular blocky structure; medium and coarse pores, and coarse roots. They were slightly hard when dry, and friable, sticky and plastic when wet.

This profile was sited at a deep fresh erosion cut/gully with a deposition of stones at the floor of the gully. There was positive reaction with Hydrochloric acid from the second horizon, indicating presence of sodium and calcium (calcareous). The soils of the study area can generally be described as soils on piedmont plains. Soils developed on alluvium from tertiary/quaternary volcanic rocks (mainly basalts). They are moderately well drained, very deep, dark yellowish brown to strong brown, friable, slightly to moderately calcareous, moderately to strongly saline and often sodic. They are firm, fine sandy loam to clay loam, with stone surface (desert pavement).

10.3.2 Soil profile description at Kaplelchony

The following horizons were identified on the profile at Kaplelchony:

1. Horizon A 0 — 26 cm: Soils in this layer were moist reddish brown (5YR 5/4) and dry reddish brown (5YR 4/4) clay loam with fine crumb and sub-angular blocky structure; medium and coarse pores; fine, medium and coarse root loose dry. They were friable, sticky and plastic when wet. There was a clear and smooth transition to the horizon below.
2. Horizon AB 26 — 96 cm: This layer had moist reddish brown (5YR 4/4) and dry dark reddish brown (5YR 3/4) clay loam with sub-angular blocky structure; medium and

coarse pores; medium and coarse roots loose dry. They were friable, sticky and plastic when wet. This horizon exhibited a clear smooth transition to the next layer.

3. Horizon B — C 96 — 150 cm: Soils in this horizon were moist yellowish red (5YR5/6) and dry reddish brown (5YR 5/4) with stony and bouldery structure; coarse pores (very porous); medium and coarse root. They were loose, non-sticky and non-plastic when wet; gravely; stony and bouldery.

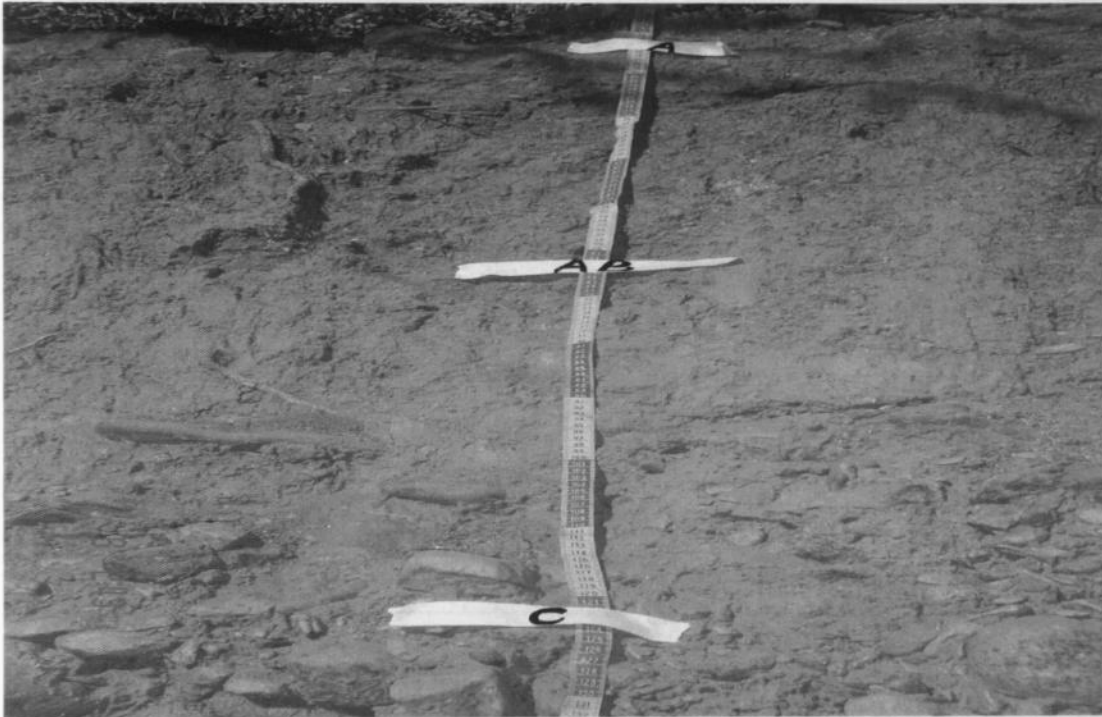


Plate 10.1: Soil profile pit at Kaplechony

There was positive reaction with Hydrochloric acid throughout the profile, therefore, indicating calcareous phase. These soils are on step-faulted floor of the Rift Valley (step-faulted plateaus) and developed on tertiary basic igneous rocks. They are well drained, moderately, deep, dark reddish brown to reddish brown, coarse, friable to firm and slightly smeary, smouldery and strong. They are clay loam to clay, and in some places calcareous.

10.4 APPENDIX IV: QUESTIONNAIRE FOR INVESTIGATION OF THE DETERMINANTS OF POVERTY IN THE NJEMPS FLATS

[Fill in blank space/tick appropriate code]

1.0 General information

- 1.1 Date of interview:...../...../.....
- 1.2 Season: (1) Dry (0) Wet
- 1.3 Questionnaire serial number:...../...../.....
- 1.4 Name of enumerator:.....
- 1.5 Division:.....Location:.....Sub-Loc:.....Village:.....
- 1.6 GPS: Altitude:.....Longitude:.....Latitude:.....
- 1.7 Site: (1) Marigat (0) Loruk

2.0 Respondent's information

- 2.2 Name of respondent:.....
- 2.3 Sex:(1) Male (0) Female
- 2.4 Age: (1) Under 30 years (2) Between 30 – 60 years (3) Over 60 years

3) Household's information

- 1.1 Household head: (1) Male (0) Female
- 1.2 Age: (1) Under 30 years (2) Between 31 – 60 years (3) Over 60 years

1.3 Household Size/ Composition

Adults		Children under 18		No. of children in School	Other dependants	Total No. of members
Husband and Wife(s)	Children over 18 years	Boys	Girls			

- 1.4 Education: (1) None (2) Primary (3) Secondary (4) Post Secondary
- 1.5 MAIN source of livelihood: (1) Livestock keeping (2) Crop cultivation (3) Bee-Formal employment (4) Business (5) Others (specify)
- 1.6 Land tenure system: (1) Group ranch (2) Clan/family ownership (3) Old titled private land (4) Newly titled private land (5) Squatter (6) Scheme settlement
- 1.7 Do you have an enclosure (*Shamba*)? (1)Yes (0) No. If yes:
 (i) What type of enclosure? (1) Pasture/Grass (0) Crop
 (ii) What is the size of your enclosure?.....
 (iii) Do you have a title deed? (1) Yes (0) No.
 (iv) What is your main reason for having an enclosure?.....
 (v) Do you consider yourself more food secure with than without one?.....
- 1.8 Do you ever migrate? (1) Yes (0) No. If yes, how many times in a year?.....

1.9 How many animals do you keep? Please fill the table below:

Species/Class	Number		
	Total	Own (also indicate who in the family owns which species)	Gifts
Cattle			
Calves			
Goats			
Kids			
Sheep			
Lambs			
Camel			
Chicken			
Donkey			

Codes for ownership: (1) Husband (2) Wife (3) Boys (4) Girls (5) Family

1.10 What is your main reason for keeping these animals? Please fill the table below:

Species	Rank the purposes for which the livestock is kept in order of importance (use the codes below)
Cattle	
Goats	
Sheep	
Camel	
Chicken	
Donkey	

Codes for the ranks: (1) Meat values (2) Milk (3) Income (for school fees etc) (4) Prestige (5) Draught power (6) Dowry/Other cultural (7) Others (specify)

3.11 How many animals have you.....this season?

Species	Sold		Bought		Slaughtered	Given out as gift	Received as gift	Lost/Died
	No.	Unit price (KSh.)	No.	Unit price (KSh.)				
Cattle								
Goats								
Sheep								
Camel								
Chicken								
Donkey								
Total								

3.12 If you sold any animals:

- (i) Who in your family sold them?.....
- (ii) Where did he/she sell them?.....
- (iii) What was the money used for?.....

3.13 How much milk do you get from.....? Fill the table below:

	No. of animals on milk	Litres/day
Cattle		
Goats		
Camel		

3.14 What do you do with your milk? Please write the correct response in relevant space provided below:

	Litres of milk consumed at home per day	Sold	
		Litres/day	Unit price (KSh./litre)
At the moment			
During the wet season			
During the dry season			

3.15 If you do sell milk?

- (i) Who in your family sells it?.....
- (ii) Why do you sell it?.....
- (iii) Where do you sel lit?.....

3.16 How do you handle your animals? Tick as appropriate

Tethering	
Herding	
Free ranging	
Paddocking	

3.17 If you herd your animals, how far from the main camp do you move on daily basis looking for pasture? Tick as appropriate

	Distance to pasture (Km)	Distance to water (Km)
At the moment		
During the wet season		
During the dry season		

3.18 What is your MAIN diet? Write the correct response in relevant space provided below:

Foodstuff	Rank (1,2,3,4.)	Gift/Donation (tick as appropriate)	Bought		Quantity Produced	Relief	
			Quantity	Unit price (KSh.)		Quantity	Type of relief (FFW, School feeding etc)
Milk							
Meat							
Maize & Beans							
Vegetables							
Wild fruits							
Uji							
Honey							
Others (specify)							

3.19 How much.....do you consume per day? Please fill the table below:

During dry season		During wet season	
Food item	Qty (Kg/litre/KSh. etc.)	Food item	Qty (Kg/litre/KSh. etc.)
Milk		Milk	
Meat		Meat	
Maize & Beans		Maize & Beans	
Ugali		Ugali	
Vegetables		Vegetables	
Wild fruits		Wild fruits	
Honey		Honey	
Others (specify)		Others (specify)	

3.20 How much do you spend on :
 (i) Food (Daily)?.....
 (ii) Medicine (Monthly)?.....
 (iii) School fees (yearly)?.....

3.21 Are there any member of your family who is employed elsewhere? (1) Yes (0) No. If yes,
 (i) How many are employed?.....
 (ii) Where are they employed ?.....
 (ii) Do you ever receive any money from them? (1) Yes (0) No. If yes, how much per month? KSh.....

3.22 How much do you get from.....in a month? Fill the table below:

Activity	Output (Kg/sacks/litres/Galons/KSh.)	Quantity used at home	Quantity sold	
			Quantity	Unit price (KSh.)
Crop cultivation				
Bee-keeping (Honey)				
Charcoal burning				
Trade/business				
Employment				
Cattle sales				
Goats sales				
Sheep sales				
Chicken sales				
Others (specify)				
Total income				

4.0 Government policy and services

4.1 Are you aware of any government policy/law that constraints pastoralism in your area? (1) Yes (0) No. If yes:
 (i) Which one?.....
 (ii) What is your opinion about it?.....

4.2 Have you or any member of your family got any training/extension services on land-use and management? If yes:
 (i) Describe the type of training and the government agency, which offered it.....

