AN ANALYSIS OF HUMAN-WILDLIFE CONFLICTS IN TSAVO WEST – AMBOSELI AGRO-ECOSYSTEM USING AN INTEGRATED GEOSPATIAL APPROACH: A CASE STUDY OF TAVETA DISTRICT.

MBAU JUDITH SYOMBUA

(BSc, MSc)

A THESIS SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN DRYLAND RESOURCE MANAGEMENT

UNIVERSITY OF NAIROBI.

2013

DECLARATION

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

Signature... Date ………………………………….

Mbau Judith Syombua

This thesis has been submitted with our approval as university supervisors

Signature... Date ………………………………

Dr Moses M. Nyangito, Department of Land Resource Management and Agricultural Technology (LARMAT)

Signature... Date ………………………………

Prof. Charles K.K. Gachene, Department of Department of Land Resource Management and Agricultural Technology (LARMAT)

DEDICATION

This work is dedicated to my family which was a great source of support during my entire study period. My sincere gratitude to my husband Eng. Ben Mutuku, and sons, Brian Kyalo and Sean Mulwa, and my brother, Martin Mbau who has always wanted the best in the world of academia.

ACKNOWLEDGMENT

I sincerely wish to appreciate my supervisors Dr. Moses Nyangito, and Prof Charles Gachene for their guidance through the entire study period. I also wish to appreciate Dr. Jeff Worden for his unrelenting guidance during my studies as well as organizing the research funds. My sincere gratitude to the District Commissioner of Taveta, the Deputy Director Research - Kenya Wildlife Service (Dr Samuel Kasiki) and the staff from the Tsavo Conservation Area (TCA). The support I got from all chiefs and their assistants from Taveta district was overwhelming and I take this opportunity to express my great indebtedness to them. Likewise I enjoyed working with the local community and wish them the best in life.

I also take this opportunity to thank my field assistants and local community interpreters who made my work substantially easier. In this connection, I remember Peter Kaimi, Clay Zuberi, Benson Kalunda, Issack Sakimba and Davies Mbele. Staff from Kenya Agricultural Research Institute (KARI) and the National Museums of Kenya (NMK) really encouraged me, in particular the librarians who generously availed a diversity of reference materials.

I sincerely thank the Director - Centre for Sustainable Dryland Ecosystems and Societies (CSDES) (Prof Jesse Njoka) for always assisting in mobilizing the much needed funds. I feel indebted to Prof Randall Boone who availed research funds through the Gnu Landscapes Program United States National Science Foundation (NSF) grant number 0919383. Thank you so much, you made it happen. I thank Dr. Vincent Kathumo for input and assistance during Landsat image analysis. Above all, I thank the Almighty God for the grace to handle this study.

ABSTRACT

Human-wildlife conflicts are a challenge to conservationists, researchers and local communities alike. The conflicts have become a serious issue of concern and are a threat to local community livelihoods, safety and wildlife conservation efforts especially in rangelands bordering protected areas. The primary aim of this study was to analyse Human – wildlife conflicts and assess the role of land use and land cover changes as key factors that influence the dynamics of Human-wildlife conflicts in Taveta district. The secondary aim was to evaluate the application of Participatory Geographic Information Systems (PGIS) tools and approaches for spatial-temporal analysis of resource changes and as tools for community engagement in the management of Human-wildlife conflicts. Questionnaires, area estimation techniques, direct and indirect observations were used to describe Human-wildlife conflicts. Supervised classification using EXELIS Visual Information Solutions (ENVI) 4.7 software was used for spatial-temporal analysis of land use and land cover change. PGIS tools and processes were used to assess local community awareness on resource changes and their implications on Human-wildlife conflicts. Descriptive statistics, Chi-square and regression analysis were applied at 95% confidence levels in describing and revealing significant effects in Human-wildlife conflicts, land use and land cover changes.

Eating and trampling on crops were the main forms of conflicts in Taveta district, followed by livestock depredation. These differed significantly between locations ($P < 0.05$). Elephants (*Loxodonta Africana*) and hyenas *(Crocuta crocuta*) led in crop destruction and livestock depredation respectively. Seasonality was a main factor driving conflicts in the rainfed agricultural zones. Maize was the preferred crop for the top three conflict causing species. Local community attitudes towards conflict causing species were negative. Between 1987-2011, significant changes ($p < 0.05$) in land use and land cover occurred in woodlands, sisal plantations, rainfed and irrigated agricultural areas. Land use and land cover changes were as result of agricultural expansion. Through PGIS; linkages between land use / land cover changes and Human-wildlife conflicts were clearly established with agricultural expansion found to be the primary determinant of the nature and spatial distribution of Human-wildlife conflicts. Participatory GIS approaches revealed significant ($p < 0.05$) cover changes in woodlands, rainfed and irrigated agricultural areas. Local communities were found to be significantly knowledgeable

($p < 0.05$) about changes in most of the resources and their causes. PGIS compared well to conventional GIS analysis and is an appropriate technology for analyzing land use and land cover changes. In addition, the technology was found to be appropriate for educating local communities on the implications of resource exploitation.

There is urgent need for redress of the Human-wildlife conflicts in Taveta district in order to safeguard local community livelihoods and enhance wildlife conservation. In this respect, proper land use planning, increased community awareness on the importance of wildlife and the implications of land use and land cover changes, as well as multi-stakeholder participation in conflict strategy setting, refinement and implementation are necessary. These efforts will benefit from using appropriate technologies such as PGIS to enhance multi-stakeholder participation and transparency. PGIS tools and process will be useful in delineating Zones of Interaction, implementing integrated monitoring and evaluation of trends in land use and land cover changes, identifying and strategizing for opportunities leading to sustainable wildlife utilization with the local communities and evaluating the efficacy of implemented approaches and strategies for Human-wildlife conflicts management. From this study, among the key strategies for Human-wildlife conflicts management were; compatible land use practices, fencing of homesteads and farms, rehabilitation of water sources, inter-sectoral coordination and compensation for crop and livestock losses and human injuries or death. Active engagement of local communities will be necessary for the success of Human-wildlife conflict management in the district.

TABLE OF CONTENTS

LIST OF FIGURES

LISTS OF TABLES

LIST OF PLATES

ABBREVIATION AND ACRONYMS

ASALs: Arid and Semi Arid Lands

AWF: African Wildlife Foundation

BC: Before Christ

CBD: Convention on Biological Diversity

CBS: Central Bureau of Statistics

CBNRM: Community- Based Natural Resource Management

ENVI: EXELIS Visual Information Solutions

ERMIS: Environmental Resource Mapping and Information Systems

ESRI: Environmental Systems Research Institute

ETM: Enhanced Thematic Mapper

FAO: Food and Agriculture Organization

FGLG: Forest Governance Learning Group

Gvt: Government

GIS: Geographic Information Systems

GIT: Geographic Information Technologies

GLS: Global Land Survey

GPS: Global Positioning System

iMAP: Information Mapping

IUCN: International Union for the Conservation of Nature

KFS: Kenya Forest Service

KNBS: Kenya National Bureau of Statistics

KWS: Kenya Wildlife Service

LC: Local Community

LULCC: Land Use and Land Cover Change

£: Sterling Pound

MEA: Millennium Ecosystem Assessment

MoA: Ministry of Agriculture

MoE Ministry of Energy

MoH: Ministry of Health

MoR: Ministry of Roads

NEMA:	National Environment Management Authority
NGOs:	Non-governmental Organizations
PGIS:	Participatory Geographic Information Systems
PM:	Policy Makers
ROK:	Republic of Kenya
SWOT:	Strengths, Weaknesses, Opportunities and Threats
SPSS:	Statistical Package for Social Scientists
TM:	Thematic Mapper
USAID:	United States Agency for International Development
USDA:	United States Department of Agriculture
USGS:	United States Geological Survey
UN/ECE:	United Nations Economic Commission for Europe
VIM:	Vertical Integration Model
WCED:	World Commission on Environment and Development.
WGS:	World Geodetic System
WWF:	World-Wide Fund for Nature
SARPO:	Southern African Regional Programme Office (SARPO)

DEFINITION OF OPERATIONAL TERMS

Climate change: Refers to the change in climate attributed directly/indirectly to human activities which in addition to natural climate variability is observed over comparable period.

Community participation: The involvement of local people in the identification, planning and implementation of projects and programmes. The members of a community commit themselves to contribute towards the evolution and development (Mwakima, 2005).

Ecotourism: Refers to low impact nature tourism, which contributes to the maintenance of species and habitats either through contribution to conservation and /or indirectly by providing revenue to local people sufficient for people to value, and therefore protect their wildlife heritage area as a source of income (Goodwin, 1996).

Geographic Information System: It is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

Global Positioning System: It is the only fully functional global navigation satellite system (GNSS). The GPS uses a collection of at least 24 medium earth orbit satellites that transmit precise microwave signals that enable GPS receivers to determine their location, speed, direction and time.

Human-Wildlife conflicts: Any and /or all disagreements or contentions relating to destruction, loss of life or property, and interference with rights of individuals or groups that are attributed directly or indirectly to wild animals (Kenya Wildlife Service, 1994).

Land use: Refers to what people do on the land surface, i.e., the manner in which human beings employ the land and its resources e.g., agriculture, settlement etc. (Turner and Mayer, 1994; Brandon, 2001).

Land cover: Defines the type of material present on the landscape, i.e. the ecological state and physical appearance of the land surface (e.g., water, crops, forest, human structures, shrubs etc) (Turner and Mayer, 1994; Geist and Lambin, 2002).

Local communities: People of the study area (Taveta district). In this thesis it has also been used to refer to people living near protected areas.

Participatory Geographic Information Systems: It is the integration of geospatial tools and community resource mapping, Indigenous Ecological Knowledge and Indigenous Knowledge and farmers experience in the resource base analysis and seeking solutions and laying strategies. It is a continuum starting from community mobilisation to project planning and design, choice of mapping methods and technologies, visualisation of different technologies in diverse ethno-cultural and agro-ecological environments and finally putting the maps to work in the domains of identity building, self determination, spatial planning and advocacy (Harris and Weiner 1998).

Remote Sensing: It is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation.

Sustainable development: The type of development which meets the needs of the current generation without compromising the ability of the future generations to meet their own needs (WCED, 1987).

Wildlife dispersal area: Those areas outside protected areas which are utilized by wildlife seasonally as grazing areas during the dry seasons or as breeding grounds for some wildlife species.

CHAPTER 1

INTRODUCTION

1.1 Underlying Causes and Management of Human-Wildlife conflicts

Although Human-wildlife conflicts have been found to impact on species conservation and jeopardize human livelihoods and safety (Campbell et al., 2003; Woodroffe et al., 2005; Baruch-Mordo et al., 2009), most of the research devoted to addressing the conflicts has tended to focus on managing the wildlife alone. However, there is an increasing recognition that solutions focused on wildlife alone limit managers' ability to effectively resolve conflicts (Baruch-Mordo et al., 2009, 2011). This has been witnessed in Kenya where Human-wildlife conflicts have persisted over the years despite efforts to manage the wildlife. In addition to this challenge, about 70% of Kenya's wildlife is found outside the protected areas network, land which also acts as dispersal areas or migration corridors for wildlife residing within the protected areas (Sindiga, 1995; Okello and D'Amour, 2008). Despite their importance, dispersal areas around the Tsavo-West and Amboseli National Parks are decreasing at an alarming rate as a result of changes in land use, institutional frameworks in the ranches (Okello, 2005a) and climate variability. While this is the scenario, the land outside the protected areas is largely under the control of private owners and local communities. Since majority of the land outside protected areas is subjected to a multiplicity of uses some of which conflict with wildlife conservation, the cooperation of communities is essential for the success of wildlife conservation.

Land use change within these rangelands has had a number of implications, among them being; agricultural intensification, decrease in grazing land and available water, and a decrease in the quantity and quality of wildlife habitats (Campbell et al., 2000; Githaiga et al., 2003; Okello, 2005a). The evolution of land use and land cover changes dates back to the 1970's, when government directive saw the establishment of group ranches in most of the rangelands around the Tsavo West – Amboseli ecosystem. As a result, the once expansive rangelands became fragmented into parcels of ranches, reducing the range available for the seasonal wildlife and livestock movement. Institutional frameworks within the ranches further saw the subdivision of ranches into individually owned parcels of land, further curtailing wildlife and livestock movement (Okello and Kioko, 2010). Agricultural intensification within individual lands on the other hand has been characterized in some cases by fencing of cultivated areas. These changes have created habitat mosaics within the rangelands that curtail wildlife movements and accessibility to feed resources while exacerbating Human-wildlife conflicts.

Predictions from the Intergovernmental Panel for Climate Change (IPCC) indicate that, some future impacts of climate change are already unavoidable even under stringent mitigation scenarios (Thornton et al., 2008). Among these include increased climate variability and uncertainty, decreased water availability and increased drought risk in the tropics and subtropics. These will lead to a decrease in feed and water resources in the rangelands exacerbating the direct effects of competition between livestock and wildlife for water and fodder. In general, climate change and the other factors explained above have the potential to heighten Human-wildlife conflicts in rangelands and therefore increased local community engagement to enhance environmental management is necessary to mitigate the conflicts.

From the above influences, the Tsavo West –Amboseli landscape has undergone considerable changes in land use and socio-economic characteristics that need to be understood in relation to wildlife conservation. Both subsistence and commercial farming have proliferated in the ecosystem over the years feeding not only the immediate markets of Taveta, Kimana and Loitokitok, but also the larger markets of Nairobi and Coast province. The demand for land has seen some of the local people lease their land to immigrant farmers while others have subdivided their land and sold it out. This transformation of predominantly wildlife lands for other purposes has heightened Human-wildlife conflicts within the agro-ecosystem.

As a case in point, the Taveta sub-ecosystem is telling. The sub-ecosystem has a population growth rate of 2.94 % p.a., which is slightly above the average Kenyan population growth rate of 2.9 % p.a. (Republic of Kenya, 2009). In tandem with population growth in the area, there has been a rise in settlements, agricultural intensification, infrastructural development and growth of the local markets, all leading to wildlife habitat fragmentation and increased resource competition. Due to the increased human developments within the crucial dispersal areas for wildlife, competition for natural resources in the form of Human–wildlife conflicts has greatly increased over the years while taking different dimensions over time (Kamande, 2008). Although conflicts are not a new problem, their apparent increase threatens the conservation of wildlife and local community livelihoods in affected areas. Recent reports from local communities point to an increasing trend in Human-wildlife conflicts, a situation which not only threatens their food security but also community livelihoods in the agro-ecosystem and thus exacerbating poverty.

Despite efforts to solve these conflicts, Human-wildlife conflicts have continued to increase in the country over the years. The approach has always been an effort to manage the wildlife with minimal involvement of communities concerned (Okello 2005a). For example, in its strategy for conservation and management of lions (*Panthera leo*) and spotted hyenas (*Crocuta crocuta*) for the period 2009-2014, Kenya's National Large Carnivore Task Force identified poor governance and the exclusion of local communities from policy-making frameworks as one of problems facing lions, hyena, cheetahs and wild dogs conservation (Kenya Wildlife Service, 2007, 2008). Likewise, in its efforts to reach out to the communities, the Kenya Wildlife Service, through the community enterprise department recognizes the need to enhance community involvement in conflict mitigation and that communities need to be encouraged to participate in wildlife conservation for profit enterprises and as a land use option. The departments' expectation is that, such attempts will significantly reduce the need for compensatory payments. In its strength and weaknesses, opportunities and threats (SWOT) analysis, the department indicates that a new strategic focus on community engagement outside the protected areas system is still being developed and refined. The department identifies community groups and individuals interacting with wildlife as primary customers, and that active participation in wildlife conservation and management is the behaviour they would like to see from them (Kenya Wildlife Service, 2011). This highlights the need for the contribution of local communities in wildlife management and appropriate approaches for community engagement.

Solving conflicts by addressing wildlife management alone only acts as a palliative to the conflicts, providing short term solutions and hence can lead to their persistence. Top-down approaches to natural resource management have been counterproductive in many situations. The participation of local communities in natural resource management has been found to be key in effective governance of natural resources. People's perception about Human-wildlife conflicts are also important in coming up with site specific and workable solutions to conflicts, an approach that has minimally prevailed in Kenya. In order to come up with workable solutions to Human-wildlife conflicts, it is important to fully investigate the underlying causes of these conflicts and integrate local community perceptions about the conflicts to appropriately inform efforts towards environmental resource use sustainability and conservation. Recently, one conflict management strategy that has been strongly advocated for is bringing together stakeholders in a forum that can share information, build collaboration and advocate new policies (Hoare, 2011). In recognition of this then, there is need to focus management solutions not only to the causes of the conflicts but also to humans as well; an integrated approach as envisaged in the draft wildlife policy (Republic of Kenya, 2011). This will however require a new strategic focus on community engagement outside the protected areas system (Kenya Wildlife Service, 2011) and the application of appropriate approaches and technologies to facilitate multi-stakeholder participation and knowledge sharing.

1.2 Integrated geospatial approaches for conflict management

Conventional GIS and RS technologies have always taken the centre stage in the analysis of land use and land cover changes (i.e., natural resource use change) as a means of understanding the underlying factors leading to resource use change. However, the products are mostly useful to policy makers and not easily understood by local communities due to technological and knowledge gaps. Information produced only from analysis of conventional GIS and RS may not represent the reality on the ground and therefore policies produced based on purely conventional GIS and RS data may be unattractive to local communities who may not then participate in all the steps required in the development process (Aynekulu et al., 2006). Linking conventional GIS and RS with Participatory Geographic Information Systems (PGIS) produces a hybrid methodology that strengthens the capacity of local knowledge in the multi-participant planning process.

In order to carry out informed and cost effective management decisions, a three-phase approach is needed; collection of information on Human-wildlife conflicts, analysis of information and decision making and lastly choice and implementation of management options (FAO, 2009). Thus, this research sought to analyze the nature and extent of Human-wildlife conflicts in Taveta district, evaluate the status of land use and land cover changes as one of the key factors that influences Human-wildlife conflicts using integrated geospatial approaches (Conventional GIS, RS and PGIS) and use the PGIS forums to propose management strategies for Human-wildlife conflicts in a multi-stakeholder/multi-participant process that can be owned by the local communities in Taveta district. The research also sought to evaluate the application of PGIS technology in analyzing resource use change while bringing on board local communities to participate in the formulation of Human-wildlife conflict management strategies. It is expected that outputs from this research will provide important information to inform Human-wildlife conflicts management approaches as well as inform policy for enhanced governance of natural resources in an ecosystem-based approach.

1.3 Problem Statement

Wildlife habitats in the South-western side of the Tsavo West - Amboseli ecosystem formerly used as pastoral grazing land have undergone tremendous changes in land use patterns (Campbell et al., 2000; Okello, 2005a). The situation has been characterized by diminishing resources and reduced accessibility to water resources, grazing land and adverse human-wildlife interactions. As resources become scarce, conflicts become inevitable as both wildlife and people strive to survive. In this ecosystem, Human-wildlife conflicts have been on the increase exacerbating food insecurity and negatively impacting on local community livelihood. However, Human-wildlife conflicts in the study area have received scanty research attention to unearth the underlying causes, conflicts dynamics and inform mitigation strategies. Also, managing Human-wildlife conflicts in Kenya has mainly focused on managing the wildlife with minimal involvement of local communities. This approach has always been viewed by local communities as purely top down; that is, management strategies are being imposed on them and thus building resentment by local communities on wildlife management strategies. There is need to involve communities in coming up with appropriate technologies for Human-wildlife conflict management.

One of the key factors escalating Human-wildlife conflicts and which communities need to understand clearly is land use change. Land use change influences habitat quality and quantity, and plays a push-pull effect on the conflicts. However, how land use change over time in the Taveta agro-ecosystem and resultant land use patterns affect the dynamics of conflicts is not yet fully understood. While this is the case, conventional GIS and RS tools and approaches are applied in the analysis of land use change. However, this does not offer local communities an opportunity to participate in analyzing the causes of problems that affect them (e.g., Human-wildlife conflicts) which is key in determining community's response to the implementation of proposed management strategies. Involving local communities in wildlife management requires appropriate technologies that bridge the technology gaps that exist between wildlife managers as experts and the local communities as custodians of resources on which wildlife ranging outside protected areas depend on. Therefore there is need to involve communities in mapping of natural resource changes and in coming up with strategies for conserving them using appropriate technologies. PGIS offers such an opportunity, however, little has been done on its application in natural resource management in Kenya and more so in Human-wildlife conflict management.

Given the above scenario, and acknowledging that land use planning has been recommended as the most sustainable approach to Human-wildlife conflict management in the long-term (Sitati et al., 2007; Hoare, 2011), and with local community participation being indispensable (Baruch-Mordo et al., 2011), this study aimed at analysing Human-wildlife conflicts and its key drivers, and applied both conventional GIS, RS and PGIS tools and processes in availing scientific data on the status of land use/cover and community understanding and participation in managing conflict in Taveta agro-ecosystem. PGIS was also evaluated as an information and communication technology for providing a forum for transparent communication for multi-stakeholder natural resource management process.

1.4 Conceptual framework

Human-wildlife conflicts still continue to challenge wildlife managers, researchers and conservationists todate. The problem has been compounded more by lack of a clear understanding of the linkages between the ecological and policy factors that drive conflicts and the integration of these factors with Indegenous Ecological Knowledge (IEK), Indegenous Knowledge (IK) and perceptions held within local community domains in influencing their dynamics. In addition to this is the lack of appropriate technologies for integrating different stakeholders in Human-wildlife conflict management. Research geared towards this integration is poorly understood, thus necessitating integrated studies to better understand what appropriate approaches can guide Human-wildlife conflict management.

This study incorporated integrated approaches for the analysis of land use and land cover change as a key driver of Human-wildlife conflicts, while testing the appropriateness of Participatory Geographic Informations Systems technology as a tool for enhancing local community engagement in the management of Human-wildlife conflicts. Through this approach key strategies and approaches of managing Human-wildlife conflicts can be formulated in addition to influencing natural resource management policies. The linkages between the key drivers of Human-wildlife conflicts mainly; land use and land cover change, local community perceptions, policies and wildlife species composition dynamics are shown in figure 1.1

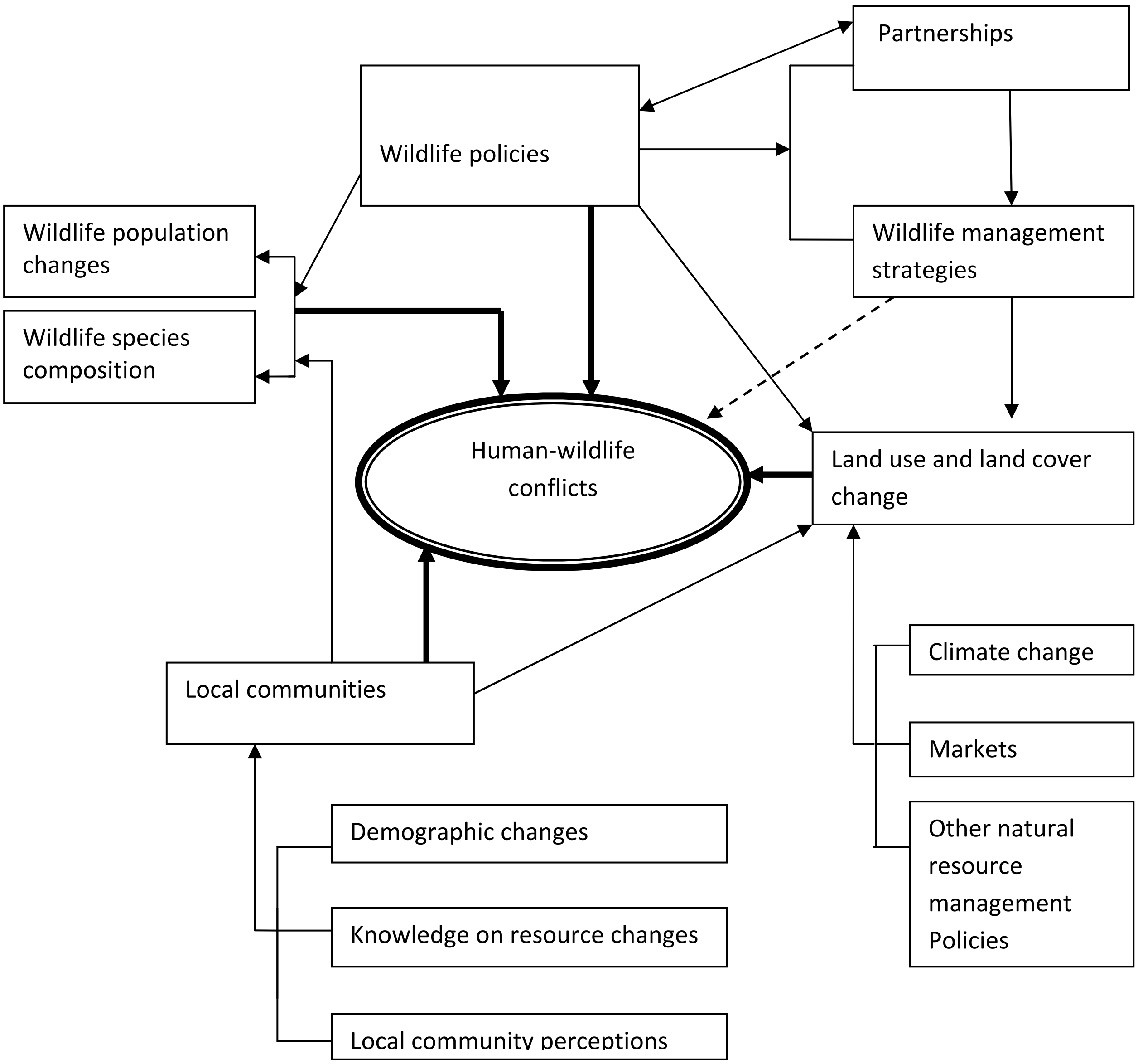


Figure 1.1: Linkages between Human – wildlife conflicts, land use and land cover changes, local communities, policies and wildlife population dynamics.

1.5 Objectives

General Objective

To identify the causal factors of human-wildlife conflicts and strengthen approaches for their management so as to enhance coexistence between human beings and wildlife in Taveta District.

Specific objectives

The specific objectives of the study were;

1. To establish the nature, extent and spatial distribution of Human-wildlife conflicts in Taveta district.
2. Assess land use and land cover changes (LULCC) in the study area for the last 24 years and its effects on Human-wildlife conflicts.
3. Evaluate the extent to which local community through mapping (PGIS) can communicate information and knowledge about resource changes and Human- wildlife conflicts.
4. To identify strategies to enhance land resources and Human-wildlife conflicts management in Taveta district.
5. To identify policy options for sustainable Human-wildlife conflict management.

1.6 Research questions

1. What is the nature, extent and spatial distribution of Human-wildlife conflicts in Taveta district?
2. How has land use and land cover changed in the study area in the last 24 years and affected Human-wildlife conflicts?
3. What is the status of local community knowledge on resource changes and Human-wildlife conflicts in the study area?

4. What strategies are applicable for Human-wildlife conflicts management in Taveta district?
5. What policy options are there for sustainable management of Human-wildlife conflicts?

1.7 Significance of the Study

Currently Kenya is facing one of its greatest challenges: hunger and malnutrition of a greater part of its population and more so in the arid and semi-arid lands (ASALs). As the country struggles with the challenges of recurrent droughts and food insecurity, efforts should be made to foster sustainability of the existing food resource base. Research focused towards finding solutions for sustainability of agro-ecosystems is quite timely especially when Human-wildlife conflicts for resources, threatens the achievement of sustainable development while increasing food insecurity.

The loss of wildlife habitats continues to challenge the co-existence of wildlife in human dominated landscapes. The consequences of anthropogenic land use have received little attention in addressing Human-wildlife conflicts. Continued high population growth rates, land use and cover changes, can lead to further escalation of Human-wildlife conflicts, which not only affects food security but can lead to increased levels of poverty among the local community. Moreover, Human-wildlife conflicts in the study area, can derail the areas contribution to achieving Kenya's Vision 2030 (Republic of Kenya, 2007), the Millennium Development Goals (MDGs) number 1 (Eradicate extreme poverty and hunger) and MDG number 7 (Ensure environmental sustainability) (MEA, 2005) as well as the first two objectives of the Convention on Biological Diversity (the conservation of biological diversity; sustainable use of its components) (CBD, 1992). Proposing strategies for mitigating Human-wildlife conflicts based on an "Ecosystem Approach" will go a long way in enhancing food security, reducing poverty and enhancing environmental sustainability in the study area and other areas.

Conflicts for resources seem to be an issue of concern even for the future under changing scenarios of land use and human population growth; factors which will inevitably influence mammalian resource gradients in ecosystems. Since most attempts to tackle cases of Human-wildlife conflicts have been searches for an effective palliative, mammals will always return unless long-term solutions are found by addressing the underlying causes of the problem and establishing the linkages between these causes. This research provides spatial-temporal data on land use and land cover changes as a known underlying cause of Human-wildlife conflicts, status of community knowledge about resources changes and their ability to link land use and land cover changes to Human-wildlife conflicts using PGIS approaches whose application on wildlife management has not been tested before in Kenya. Integrating such information is important in setting appropriate strategies for mitigating Human-wildlife conflicts while informing policy.

In many African governments including Kenya, the necessary institutional links between local, provincial or regional, and national entities are too diffuse and poorly integrated to address the complexities of Human-wildlife conflicts. In order to harmonize wildlife management issues, there is need to overcome the disconnect between all levels of Human-wildlife conflicts governance and fixed policies and hierarchical government decisions outside the conflict zone. From this point of view, a recent vertical integration model (VIM) has been proposed, which places local communities at the bottom of the model. The recommendations are that communities need to participate in setting community-based conflict mitigation initiatives and contribute to policy development and review. It is emphasized that there is need for more devolution of centralized authority to community-based natural resource management (CBNRM) to resolve lags and address inactivity in natural resource governance. In this approach, PGIS can play a central role. However, little has been done on the application of PGIS in addressing natural resource management in Kenya including its application in addressing Human-wildlife conflicts. Therefore results generated from this study provide an additional opportunity for a better understanding of the need for an integrated approach in Human-wildlife conflict management, the application of PGIS tools and processes in bridging the technology gaps between wildlife managers and local communities as well as creating a forum for knowledge exchange, learning and strategy development for mitigating Human-wildlife conflicts. Technically, the results serve as a guideline in choosing the appropriate tools and approaches for community engagement and development of Human-wildlife conflict management strategies hence contribute to KWS's solution for search for new ways of community engagement outside protected areas. The results obtained will also provide important information to guide policy in wildlife management approaches.

1.8 Scope of the Study

This study analyses the nature of Human-wildlife conflicts in Taveta district, detailing the species involved, where, the extent of farm damage and spatial distribution of the conflicts. Effects of seasonality on conflicts and intensity are analysed in addition to crop preference and farm characteristics that enhanced conflicts. Local community attitudes towards wildlife are discussed. Land use and land cover changes are analysed using remote sensing, conventional and participatory GIS tools. Local community knowledge on resource changes and its implications is established and strategies for land resource and Human-wildlife conflicts management proposed in a multi-stakeholder process. The study also establishes the application of PGIS tools and processes for Human-wildlife conflicts management. Policy implications of the research are discussed.

1.9 Organization of Thesis

In this thesis, chapter one diagnoses the problem and its current status. It explores the development of Human-wildlife conflicts in Taveta district and their implications and why it is necessary to address the problem. In addition, the chapter states the objectives and research questions. Chapter two details the state of knowledge on Human-wildlife conflicts and the causes. It also discusses the Kenyan scenarios of wildlife management and implications to conflicts, and details the Kenyan experience with Human-wildlife conflicts. The chapter also discusses land use and land cover change, and the driving factors in addition to describing GIS and PGIS and their applications in natural resource management. The chapter culminates with a synopsis of cases of PGIS application in Kenya. Chapter three details the research methodology used.

The nature and extent of Human-wildlife conflicts in Taveta district, their spatial distribution, and species involved and farm characteristics that enhance conflicts are described in chapter four. The chapter also provides scientific information on conflicts which have not been studied in details in this study area. Chapter five describes the spatial-temporal changes in LULCC in Taveta district from 1987 to 2011. In addition, their implications to Human-wildlife conflicts are discussed and the role of the data in informing spatial planning in the district. Chapter six explores the application of PGIS technology as a tool for winning allies for Human-wildlife conflicts management through problem analysis, building collaborations, strategy setting and advocacy for sustainable mitigation of Human-wildlife conflicts. The thesis concludes with a synthesis of the research findings and recommendations as chapter seven, which also highlights how PGIS can be applied in future as a tool in Human-wildlife conflicts management.

CHAPTER 2

LITERATURE REVIEW

2.1 An Overview of Human-Wildlife Conflicts

2.1.1 The history of Human –wildlife conflicts

Human-wildlife conflicts have occurred across the globe for many centuries when humans and wild animals shared the same landscape and resources. Studies from fossil records have linked conflicts between humans and wildlife to ancient times. For example., Berger and Clarke (1995) and Berger (2006) showed that the "Taung Skull'' which is one of the most famous hominid fossils discovered in South Africa in 1924, belonged to a child who was killed by an eagle two million years ago. According to Egyptian historical records, hippopotamus in the Nile Delta are known to have fed on crops, while livestock and humans fell prey to crocodiles by 2000BC. Barnes (1996) and Treves and Naughton-Treves (1999) described human-elephant conflicts in Africa to be as old as agriculture started in the continent. Although the eighteenth and mid-twentieth century's saw exploitation of large mammals for commercial gains (ivory, rhino horns, meat, skins and hides), Human-wildlife interactions in the twentieth century have come to be increasingly characterized by conflicts. This has largely been blamed on modern agricultural development and expansion (FAO, 2009).

2.1.2 Global outlook of Human-wildlife conflicts and trends

All continents and countries are affected by Human-wildlife conflicts. The problem varies depending on the prevailing environment and the people's way of life. Human-wildlife conflicts occur when wildlife requirements encroach on those of human populations (IUCN, 2005; FAO, 2009). However, the level of vulnerability varies between developed and under-developed countries; for example, the vulnerability of agro-pastoralists mainly in developing countries is different from that of nationalities from developed countries that tend to be more economically better off. Globally Human-wildlife conflicts vary; e.g., in northern United States of America, deer collisions injure an estimated twenty nine thousand people annually while at the same time causing more than US$1 billion in damages (USDA, 2006). Musian et al. (2003) showed that between 1987 to 2001, wolves killed 728 animals in Idaho, Montana and Wyoming in the United States. In Europe, wild boar, hare and the wood pigeon are known to cause crop damage while red deer and roe deer are known to negatively influence forest regeneration. Other forms of damage caused by wild animals in Europe include livestock predation mainly by bears, wolves or lynx and disease transmission such as bovine tuberculosis to dairy cattle (Wilkinson et al., 2004). In Asia, large feline predators such as tiger, leopards and lions as well as elephants are key conflict causing species. While elephant crop damage accounted for an average annual loss of 14% of the total annual production, the overall annual damage caused by tigers and leopards around the Bhadra Tiger Reserve is estimated at 12 % of total family livestock holding in the southern state of Karnatake (Madhusudan, 2003).

Generally the smaller animals which also exist in larger numbers have been known to have greater impact than the larger animals (Lahm, 1996), although variations can exist depending on species compositions in the different localities (FAO, 2009). Traditionally, the larger herbivores (buffalo, elephants and hippopotamus) as well as the large mammalian carnivores (leopards, cheetah, lions, wild dogs and hyenas) and crocodiles have been considered as the animals responsible for most of the Human-wildlife conflicts. The notion has been attributed to local community perceptions about wildlife, which is normally viewed as government property (WWF SARPO, 2005; Okello and Kioko, 2010). Among the main issues surrounding Human-wildlife conflicts include., death and/or injury to people, destruction of crops, attacks on domestic animals, transmission of diseases to livestock and/or humans and adverse interaction with other species e.g., through habitat degradation leading to competition. Some of these impacts are shown in Table 2.1 and 2.2. The conflicts have had negative effects on people leading to increased community outcry in the past decades especially due to crop destruction, disruption of livelihood systems and killing of people, thus necessitating the need for action by governments (FAO, 2009).

Table 2.1: Cost of damage caused by bears and wolves in Western Europe in 1997 (£)

	Bears		**Wolves**	
Country	Total cost	Cost per bear	Total cost	Cost per wolf
Austria	8640	346	-	-
France	31 540	3 501	151 690	3 792
Greece	130 870	1 091	708 330	2833
Italy	33 600	448	1 095 164	2 434
Portugal	-	-	407 010	1 163
Spain	70 562	882	173 970	1 160

Source: Fourli, 1999.

Table 2.2: Percentage of total agricultural output reported lost as a result of elephant crop-raiding in some African countries

Country	Zone	Year of study	% lost
Gabon	Gamba	1996	0.75
		1998	0.3-6.2
Ghana	Red Volta	1996	8.6
Malawi	Kasungu	1981	6.3
	Liwonde	1997	8.8
Mozambique	Maputo	1996	10.2
Uganda	Kibale	1996	21
Zimbabwe	Binga	1994	11.6

Source: Hoare, 1999.

2.1.3 Causes of Human-wildlife conflicts

Human-wildlife interactions occur across a variety of social and landscape contexts (Hoare, 1999; Woodroffe et al., 2005). The locations of human-wildlife interactions are highly influenced by landscape characteristics and configuration, which in turn influences animal habitat selection (Hoare, 1999; Treves et al., 2004; Kretser et al., 2009; Shota and Takuhiko, 2011). In some instances, resource acquisition has been characterized by conflicts especially when resources are minimal or mammals in their normal foraging behaviour select the “good” patches leaving “poor” patches (Pretorius et al., 2011). However, social characteristics drive emotional responses to wildlife (Kellert, 1980a, 1980b; Ebua et al., 2011), e.g., attitudes towards wildlife are in most cases related to more recent experiences and are influenced by beliefs (Kretser, 2008). Tsi et al. (2008) demonstrated that in Northern Cameroon, idle and less educated people who inhabit areas surrounding national park territories are more prone to wildlife crimes.

The main causes of Human-wildlife conflicts include;

2.1.3.1 Human factors

2.1.3.1.1 The requirements for human development

Competition between growing human populations and wildlife for the same declining resources and living spaces has been considered as the main cause of Human-wildlife conflicts. This has been occasioned by land use change which has seen transformation of forests, savannah and other ecosystems into agricultural, settlement and urban areas due to increased demand for land, food production, raw material and energy (Kagiri, 2004; Sitati et al., 2005; FAO, 2009; Kioko and Okello, 2010). In Africa for example, by the year 2000, human population tripled since 1960. This has seen the spread of agriculture leading into encroachment of more marginal lands which have been acting as wildlife habitats (Campbell et al., 2003; Okello, 2005a; Muruthi, 2005; Okello and Kioko, 2010). The settlement of people into new habitats leads to increased demand for resources that are also a necessity for wildlife, e.g., water and pasture for their livestock. Setting permanent residence near water resources prevents wildlife from accessing water, thus setting scenarios for conflicts (Fergusson, 2002).

2.1.3.1.2 Local in-migration for security and food safety

The migration of local people from one area to another has been associated with destruction of wildlife habitats. This migration has been occasioned by a number of factors *interalia*; droughts, civil unrest, natural disasters, floods, and war. These phenomena which are on the increase tend to disrupt normal production and distribution of food resulting into famines. Local communities under such pressures tend to migrate into other areas where resources could be obtained, which unfortunately and often happen to be occupied by wildlife, a precursor for conflicts. For example; in Mozambique, war and civil unrest forced people to seek refuge in protected areas while in Kenya, the human population growth rate into the southern rangelands of the Amboseli ecosystem was estimated about 4%, way above the country's growth rate of 2.9% (Government of Mozambique, 2006; McCarthy, 2006; Republic of Kenya, 2009; Okello and Kioko, 2010). The challenges of droughts and desertification have also seen people migrate to rangelands in Kenya. The migrants tend to settle near the remaining pockets of natural resources within or around protected areas thus exposing themselves to Human-wildlife conflicts, e.g., the Tsavo National Parks buffer zone of about 20000km^2 supports almost 250 000 people. In such areas a wide range of species co-exist with a high density of human population precipitating conflicts (Ogada et al., 2003; Patterson et al., 2004).

2.1.3.1.3 Attitudes and perceptions

Rural communities especially in Africa consider wildlife, especially large mammals as threat to their safety and food security. This is more so for local communities that inhabit areas surrounding protected areas where wildlife are frequently responsible for adverse consequences , e.g., crop and livestock damage, death or injury. In other instances, wildlife is viewed as a source of hardship through increased competition for food and water resources. Such association of wildlife with damage influences local community tolerance to wildlife and their response to conservation initiatives/efforts (McGregor, 2004; Hamissou and di Silvestre, 2008). Local community beliefs in some instances are associated with occurrence of conflicts, e.g., crocodile attacks to humans are often ascribed to witchcraft. This has been linked to the apparent lack of concern shown by local communities to exposure to crocodiles often described as "carelessness" (Sichali, 2000; Wanjau, 2002).

2.1.3.1.4 Human specific activities

Some activities are known to expose local communities to wildlife attacks. These activities which tend to show gender bias with more men affected include protecting crops, herding cattle, walking at night, drunkenness and snatching prey from large felines as well as retaliation against man-eating lions (Treves and Naughton-Treves, 1999; Parker et al., 2006). In addition, the inability to invest in mitigation measures affects more of the women headed families than male headed families (Muruthi, 2005). The increasing interest in ecotourism and increased presence of people in protected areas tends to exacerbate conflicts between humans and wildlife (Vasagar, 2007).

2.1.3.2 Habitat factors

The availability and quality of habitats influences animal foraging behaviour both at temporal and spatial scales. Within wildlife ranges, habitats have gradually decreased and increasingly become fragmented leaving wildlife confined into smaller pockets of suitable habitats. Due to intensification of human activities around these protected areas, Human-wildlife conflicts have become prevalent within the protected areas buffer zones, as wildlife stray into the adjacent cultivated fields or grazing areas normally considered as wildlife population sinks. The situation has led to humans and wildlife increasingly coming into contact thus increasing incidences of conflicts between them (Woodroffe and Ginsberg, 1998; Kagiri, 2004; Okello, 2005a).

The quality and quantity of wildlife habitats is influenced by human activities and natural factors. These human activities include agriculture, infrastructural development, fishing, tourism development and wildlife protection. For example, in efforts to protect farms from wildlife, fencing of farms to keep wildlife away has been advocated for in several occasions. While this is a noble action to guard farms, in some situations it creates physical barriers for migratory wildlife species. In a bid to reclaim their migratory routes, migratory species such as elephants, wildebeest's, zebras etc break such fences leading to conflicts. Likewise, subdivision of state trust lands and ranches and the subsequent cultivation creates scenarios for conflicts. In many areas where wildlife is abundant such as the Samburu, Trans-Mara, Kwale, Mt Kenya and Taita-Taveta areas of Kenya, land fragmentation through small scale farming has precipitated intensification of Human-wildlife conflicts (Kenya Wildlife Service, 1996, 2012). Sharing of resources between wildlife and livestock leading to direct and sometimes indirect contact as is the case with water and pasture resource, has been considered as recipe for disease transmission (Bengis et al., 2002). The demand for fish for subsistence and commercial purposes has led to increasing exposure to crocodile attacks in most of African waters. This also deprives crocodiles their primary food source (FAO, 2005). Wildlife management and protection has seen the successful recovery of declining or near extinct species such as elephants. This in some areas, e.g., in Kakum National Park of Ghana and Zimbabwe has lead to increased elephant populations with resultant concomitant increase in conflicts in the surrounding villages (Fergusson, 2002).

On the other hand natural factors such as droughts, bush fires, and climate change can lead to a decrease in suitable wildlife habitats, thus influencing the occurrence and extent of Human-wildlife conflicts. As observed by Patterson et al. (2004) in Tsavo National Parks, Bauer (2003b) around Waza National Park in Cameroon, and in Niger by Hamissou and di Silvestre (2008) seasonal modification of habitats influenced Human-wildlife conflicts. Lions were found to have a high preference of attacking livestock during the rainy season. Seasonality was also found to drive lion attacks in Tanzania with most cases occurring within the harvest season of March, April and May. The attacks were meted on people found sleeping in makeshift huts protecting nocturnal crop raiding pests mainly bush pigs (Parker and Osborn, 2006). However, to the contrary, wild predators were found to attack livestock during the dry season near Sengwa Wildlife Research Area of Zimbabwe (Butler, 2000).

2.1.3.3 Natural characteristics of wildlife

Among the characteristics of wild animals that influence conflicts is the animal's food preference, predation behaviour and migration patterns. Previous studies have confirmed such associations, e.g., maize and cassava were found to attract elephants to farms around Kakum National Park (Barnes et al., 2003). Similarly around Djona hunting zone in Northern Benin, Alfa-Gambari Imorou et al. (2004) observed that elephants raided maize twice as much as cotton and more frequently than ground nuts. In Burkina Faso, Mama (2000) observed that mature wild fruits such as shea nuts (*Vitellaria paradoxa*) and *Parkia biglobosa* pods growing in Maize and ground nut farms were found to attract elephants to the farms. Likewise, Packer et al. (2005) observed that the number of lion attacks on humans in Tanzania increased with scarcity of the normal prey.

Villages located along habitual migration routes of migratory wild animals (such as elephants, wildebeests, zebras) experience increased levels of wild animal attack and more so when farming is practiced in these village. Such scenarios were observed in Mali and Togo where elephant crop raiding occurred more frequently on farms located along migratory routes of elephants (Maiga, 1999; Okoumassou et al., 2004). The "surplus killing" behaviour of some carnivores tends to exacerbate conflicts as livestock owners take offence of the unwarranted killings of their livestock (Frank, 2006). The health status of wild animals can exacerbate attacks, e.g., injured; sick or old age in wild animals can leave animals vulnerable to attack prey hence opting for weaker preys such as humans (Patterson and Neiburger, 2000). From the foregoing, factors causing Human-wildlife conflicts are established. However, proper conflicts management approaches and strategies that are responsive to local circumstances have not been fully established. In addition the status of land use and land covers changes in Taveta district, which leads to competition for declining resources between wild animals and local communities, has also not been well documented.

2.2 Wildlife Conservation in Kenya

2.2.1 Wildlife conservation approach in Kenya

The conservation of wildlife in Kenya has largely been based on the IUCN category 11 Park Models. This system of management involves the displacement of local people from the area, outlawing of human settlement and designating the resource as protected. Normally, there is no compensation for the alienated land, and even traditional uses of the area by local communities are totally banned or are severely restricted (Gakahu and Goode, 1992). While this is the case, most of the land surrounding the protected areas acts as wildlife dispersal areas providing key resources that enhance the ecological integrity and breeding grounds of wildlife. However, in most cases, such land is under private land tenure systems and their utilization by free roaming wildlife depends heavily on community's good will. As observed by McKinnon et al. (1986) and Okello (2005a) such scenarios can lead to local community resentment for conservation efforts. For example, Okello (2005a) working in Kuku Group Ranch in Kajiado observed that opinions of most local people on wildlife resources and conservation were negative. Local communities did not appreciate wildlife residing or ranging freely on their group ranch despite the fact that most of them considered wildlife conservation important. This was based on people's opinion that most of the benefits derived from wildlife tourism benefited the government and tourism investors.

Local community involvement in wildlife conservation fulfills the important requirement of a protected area being managed through other effective means and not necessarily through legal means (Beresford and Phillips, 2000). Baruch-Mordo et al. (2009) evaluating approaches to wildlife conservation, observed that, for effective wildlife conservation there is need to focus management solutions on humans as well. Likewise, Okello (2005a) observed that support for wildlife conservation was dependent on benefits received. Losses from problem animals, lack of compensation for these losses, and lack of community involvement in wildlife conservation were major sources of local community resentment for wildlife. Thus without urgent redress to this situation, wildlife may be excluded from land surrounding protected areas either by direct persecution or incompatible land use changes. Both Manfredo (2008) and Baruch-Mordo et al. (2011) again stress the need for involving and understanding local communities by arguing that understanding people's attitudes provides valuable knowledge of constituencies and management alternatives. The participation of local communities in enhancing the co-existence of wildlife in human dominated landscapes is indispensable if wildlife will have to survive. Hoare (2011) evaluating the lessons learned from 15 years of human-elephant conflicts mitigation observed that in many African governments, the necessary institutional links between local, provincial or regional and national entities are too diffuse and poorly integrated to address the complexities of effective human-elephant conflicts. In order to harmonize wildlife management issues, there is need to overcome the disconnect between local, more consensual decisions that can be made by consultation and negotiations at the conflict zone level, and fixed policies and hierarchical government decisions outside the conflict zone. From this point of view, a recent vertical integration model (VIM) has been proposed, which places local communities at the bottom of the model. The recommendations are that communities need to participate in setting Pilot community-based conflict mitigation initiatives. It is emphasized that there is need for more devolution of centralized authority to community-based natural resource management (CBNRM) to resolve lags and address inactivity in natural resource governance (AfESG, 2010).

2.2.2 Future wildlife conservation outlook in Kenya

The current draft Wildlife Policy (Republic of Kenya, 2011) and the draft Wildlife and Conservation Bill (Republic of Kenya, 2012) seeks to employ the ecosystem approach for wildlife conservation, an approach that is expected to be beneficial to both local communities and wildlife alike, a departure from the past Top-down approach. The ecosystem approach is a strategy for integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on the levels of biological organization, which encompasses the essential structure, processes, functions and interactions among organisms and their environment. The approach recognizes that humans with their cultural diversity are an integral component of many ecosystems and thus acknowledges that management should be scaled down to the local level. In addition, communities are considered to be central in managing natural resources (MEA, 2005).

The implementation of the policy in addressing Human-wildlife conflicts management will however rely on appropriate approaches that enhance the principles of the ecosystem approach of managing wildlife resources and counteracting negative attitudes of local communities as key stakeholders in the wildlife conservation process outside protected areas. It is expected that such approaches will enhance the co-existence of wildlife and people through mitigation of Human-wildlife conflicts. Information and communication technologies that enhance such approaches will thus be necessary.

2.3 Human-Wildlife Conflicts: the Kenyan Experience

Omondi et al. (2004) documented through literature review that, in Kenya Human-wildlife conflicts were as a result of competition for limited resources occasioned by changes in land use due to occupation of previous wildlife dispersal areas, collapse of the agriculture sector especially of commercial livestock farms and the subsequent subdivision of the rangelands (commercial ranches), climate change as well as the political and socio-economic environments. As a result of these factors, the Kenya Wildlife Service has documented six Human- wildlife conflicts hotspots as shown in Figure 2.1. The Human-wildlife conflicts hotspots are areas around protected areas mainly the Tsavo National Parks, Maasai Mara National Reserve, Hell's Gate National Park, Mt. Kenya National Park, Ol Doinyo Sabuk National Park and Tana-River Primate National Reserve, areas which are part of Kenya's rangelands. In some of these rangelands, the lack of sustainability of the pastoral systems has seen a large population of the pastoral communities settle down to agro-pastoral lifestyles (Thompson and Homewood, 2002). Agricultural intensification has also been fuelled by the presence of permanent water sources for irrigation thus adding to the conservation crisis. Cultivation along wetlands and swamps destroys valuable habitats suitable as livestock and wildlife refugia in the dry season (Okello, 2005a). Habitat degradation outside protected areas has seen more wildlife habitats become more isolated and others insularized thus reducing the effective size of a protected area by limiting the movement of species within and between dispersal areas (Okello and D' Amour, 2008). In most of these areas, habitat fragmentation is also on the increase. This has been attributed to infrastructural development, agricultural intensification, erection of fences, influx of people from other parts of the country especially due to safety and food insecurity factors (Burkey, 1994) and government policies.

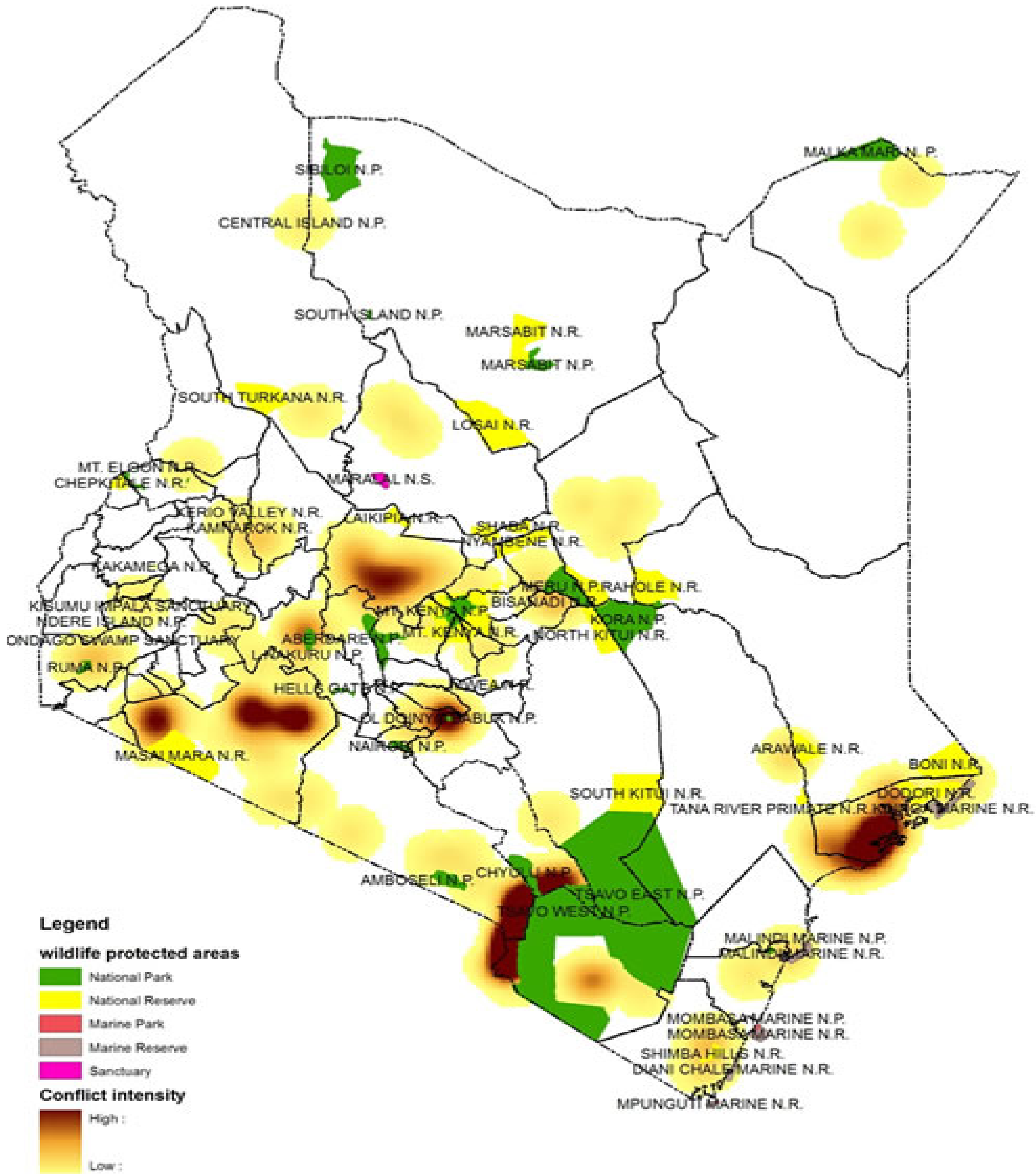


Figure 2.1: Human-wildlife conflict hotspots in Kenya.

Source: Kenya Wildlife Service, 2012.

Some studies have given insights into Human-wildlife conflicts in Kenya. Among these include studies conducted in Samburu by Ogada and Ogada (2004), Tsavo National Park (Bruce et al., 2003), Laikipia (Kagiri, 2004), Maasai Mara (Sitati, 2003; Kamonjo et al., 2007; Sitati et al., 2012; Sitati and Ipara, 2012) and Taveta district (Kamande, 2008). Figure 2.2, 2.3 and 2.4 show the results obtained from Samburu and Taveta areas of Kenya.

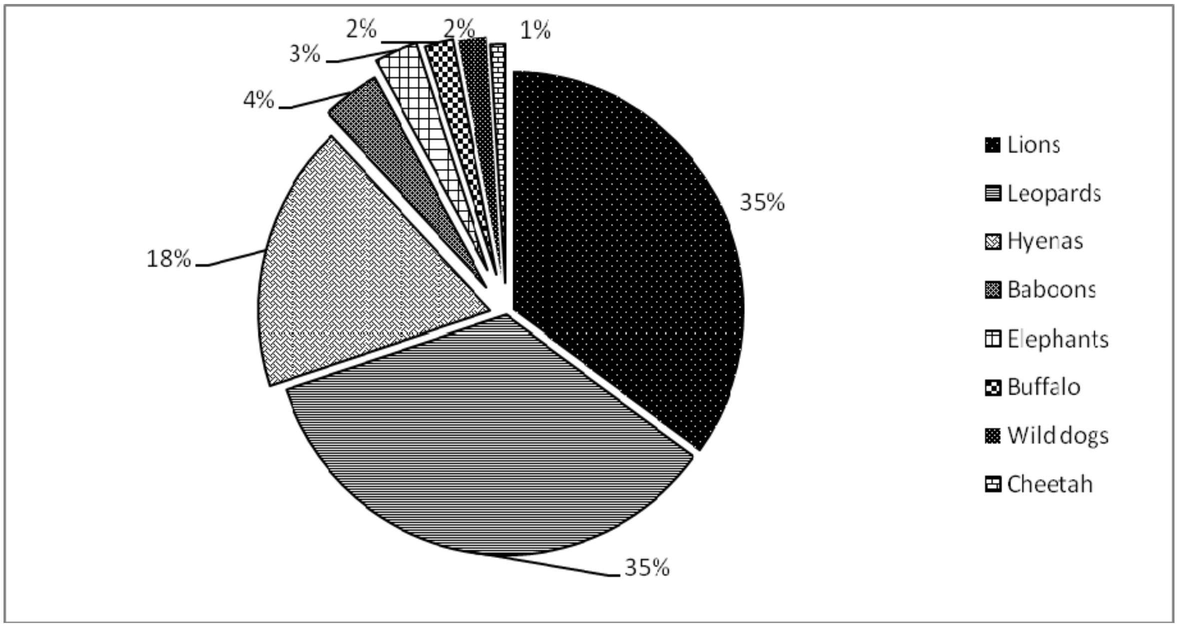


Figure 2.2: Domestic animals killed by wild predators in the AWF Samburu Heartland, Kenya (% of reported deaths). Source: Ogada and Ogada, 2004.

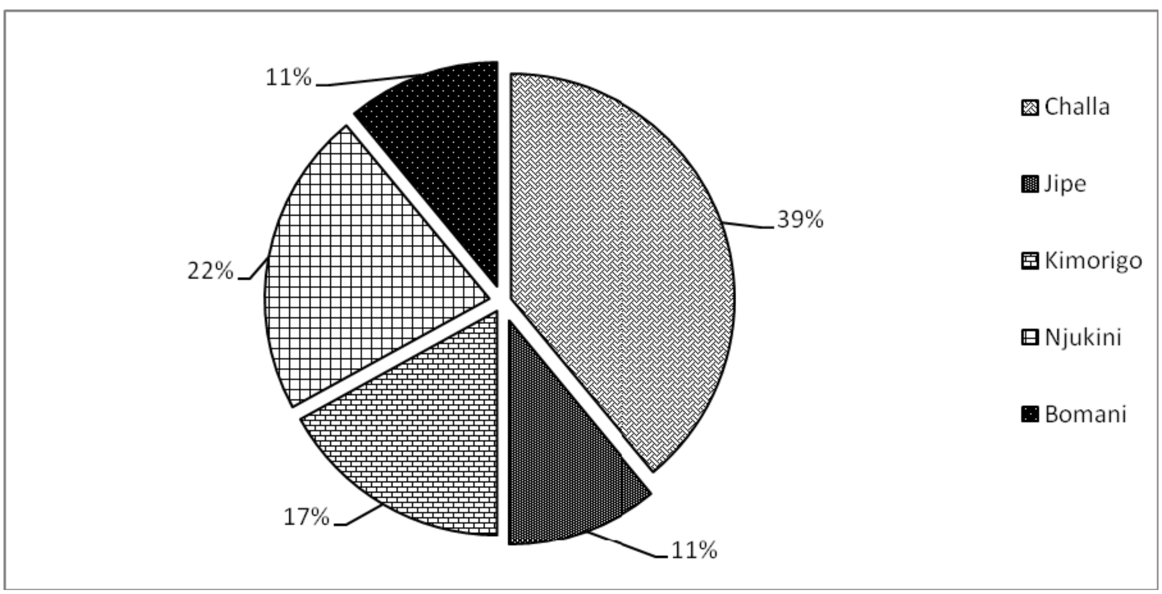


Figure 2.3: Percentage crop losses incurred as a result of wildlife damage in different locations in Taveta district in 2008. Source: Kamande, 2008.

The notorious wildlife species in Taveta district associated with above losses were; elephants (60%), Monkeys/ baboons (18%), hyenas (16%), buffalos (16%), bush pigs (14%), hippopotamus (11%), lions (9%), leopards and crocodile's 5% each. In Laikipia district, hyenas were also observed to be a key species for livestock depredations with goats being most affected (Kagiri, 2004). Figure 2.4 shows the trends in Human-wildlife conflicts in Taveta district.

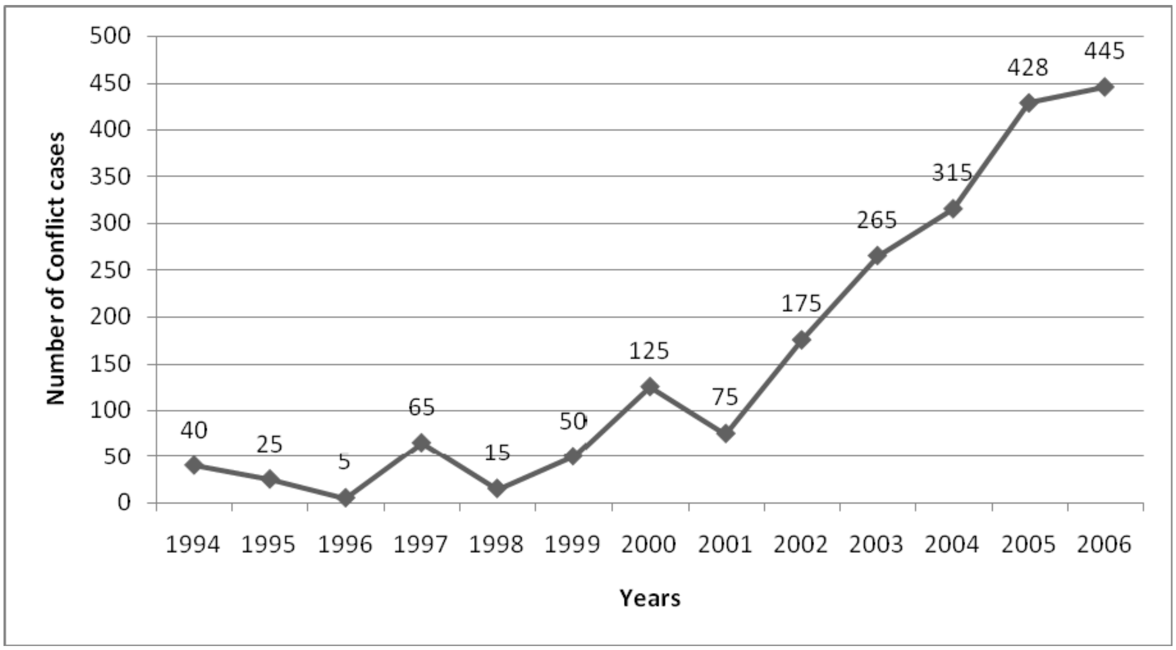


Figure 2.4: Trends of Human-wildlife conflicts in Taveta district between 1994 to 2006
Source: Kenya Wildlife Service

Human-wildlife conflicts have also been criticized on their impact on education. For example in Taita-Taveta County, politicians have related the low student performance to human-elephant conflicts (Appendix 4). Although studies by Sitati et al. (2012) in Maasai Mara showed that the mean pupil scores within elephant range were significantly lower than mean scores outside elephant range, it was worth noting that factors such as distance traveled to school and ethnic background may influence performance more strongly than human-elephant conflicts. On assessing the economic costs and benefits of maize farming within the Maasai Mara National Reserve, Kamonjo et al. (2007) observed that, farmers bordering the Reserve incurred lower input and mitigation costs than farmers within the elephant range who were further away from the reserve boundary. This points to the intricate nature of conflicts as driven by landscape characteristics.

2.4 Managing Human-Wildlife Conflicts

In Kenya, Human-wildlife conflicts challenge conservation efforts, and more so where wildlife highly depends on the dispersal areas outside the parks and confront local communities (Okello and D'Amour, 2008). Despite efforts to solve the problem, Human-wildlife conflicts have increased over the years. The main methods that have been used for managing Human-wildlife conflicts in Kenya include physical barriers (Electric fencing, game moats, vegetation barriers, ditches, stone walls and high tensile fences), translocation, establishment of sanctuaries, problem animal control, conducting animal drives especially for elephants and community sensitization in addition to traditional deterrents and mitigation approaches (Omondi et al., 2004). The approach has in most cases tended towards managing the wildlife. Unfortunately most of these traditional and short term measures applied locally within the conflict zone have not proven adequate or sustainable to effectively contain the problems leaving longer-term but far more complicated and difficult measures necessary at a larger national scale as the right options to apply (Hoare, 2011). Some of the traditional means like poisoning are a threat to biodiversity conservation. There have been progressive calls and an indication of the need for active community involvement and participation in managing wildlife and conflicts (Hoare, 2011; Kenya wildlife service, 2008; 2011; 2012). Hoare (2011), strongly advocates for bringing together stakeholders (at the different levels) in a forum that can share information, build collaboration and advocate new policies as one of the key activities necessary for managing human-elephant conflicts. Similar approaches were found to be successful in other sectors such as forestry and lands in Tanzania and Mozambique (AfESG, 2010).

Another approach to managing conflicts is through compensation schemes. These, have, however received a lot of criticism in their inability to address the root causes of conflicts and have been considered as a "Flawed concept" that only treats the symptoms of the problem

(AfESG, 2000a). The main bone of contention is that most of the compensation schemes have failed in the past, and thus tend to damage the relationship between wildlife authorities and the local farming communities, and are only being applied for good public relations as is the case with Botswana (Hoare, 2011). It is important to understand stakeholders and the root causes of the conflicts in developing effective Human-wildlife conflict management strategies (Kretser et al., 2009). As observed by Baruch-Mordo et al. (2011), evidence-based decision-making is critical for implementing conservation actions, especially for Human-wildlife conflicts. Local people's opinions are known to influence conservation efforts, and thus understanding local communities concerns in relation to conservation and wildlife resources can provide a foundation for effective decision making that mitigates wildlife impacts (Kretser et al., 2009). To effectively manage human-wildlife impacts and minimize conflicts involves knowing where interactions take place and how they are perceived (Kretser et al., 2009). The success of wildlife conservation depends on the attitudes of people towards conservation (Katrina, 1995; Baruch-Mordo et al., 2009; 2011) and therefore the assessment of peoples' attitudes and perceptions towards conservation has become an important aspect in many studies of wildlife conservation (Baruch-Mordo et al., 2011). Equally, understanding factors which influence attitudes is important to enable wildlife managers to implement approaches that attract support of stakeholders and the general public. Therefore putting into consideration local community perspectives on Human-wildlife conflicts in addition to understanding the ecological factors leading to conflicts is key in coming up with workable solutions/strategies to solve the conflicts.

2.5 Land Use and Land Cover Change

Worldwide, land cover change has been occasioned by changes in the way people use and manage land (Millennium Ecosystem Assessment (MEA), 2005a). This arises mainly from the direct effects of population growth such as agricultural expansion, grazing and land for settlement as well as indirect effects of pollution (UN/ECE, 2002; MEA, 2005b). Land use and land cover changes (LULCC) are a central component of global environmental change with direct implications for the Earth's climate, ecology, and human societies. It is of great concern to national and international policymakers. Policymakers seek from scientists information on the root causes of LULCC in order that policy may focus not on symptoms, but upon the fundamental processes that require remedial action. However, processes that drive LULCC are complex and require the use of multiple methods of analysis and critical interpretation of social data in order to understand the drivers and impacts of change through time and across spatial scales (Campbell et al., 2005).

2.5.1 Factors that influence land use and land cover change

2.5.1.1 Economic factors

Economic factors both local and international account for 81% of the cases underlying the causes of land use and land cover change (Sherbinin, 2002). For example, observed changes in land use in the Maasai Mara ecosystem have been attributed to an increase in tourism in the area, which led to development of tourist facilities within the ecosystems and it's surrounding. This also led to land fragmentation (Mundia and Murayama, 2009). Likewise, Lorent et al. (2009) observed that viable timber markets are known to drive land use change through deforestation.

2.5.1.2 Institutional factors

Policies are known to either directly or indirectly enhance resource utilization. As observed by Sherbinin (2002), policies account for 78% of land use change. For example, policies that promote access to credit facilities and subsidies tend to enhance the housing industry leading to land use change (Zondag and Borsboom, 2009). Also Mundia and Murayama (2009) observed that government policies that tended to discourage nomadic pastoralism led to proliferation of agricultural activities and settlements within the Maasai Mara ecosystem which was initially utilized for livestock and wildlife grazing. Similar observations were made within the rangelands of southern Kenya. Traditionally, the arid and semi-arid areas (ASAL) of southern Kenya were inhabited by the Maasai community. Their pastoral lifestyle which encompassed mobility was in tandem with wildlife conservation. In the 1940's, government policy directives saw the seizure of pastoral grazing lands for the creation of wildlife conservation areas thus legally restricting access to these areas for grazing and water resources by the pastoral Maasai community. In a final bid to replace nomadic pastoralism with a sedentary agricultural lifestyle and salvage the remaining natural resources for the Maasai, the government in the 1960's created group ranches (Campbell et al., 2000, 2003). The subsequent subdivision and privatization of group ranches has seen proliferation of agricultural activities as individuals attained land ownership rights hence gained the freedom to even sell or lease their land to outsiders who mainly practiced farming. This saw the once expansive grazing areas reduced to fragmented landscapes of farmlands and grasslands/shrubland and woodlands.

2.5.1.3 Cultural factors

Cultural factors such as attitudes, beliefs, values and perceptions influence decisions made on land use (Vien, 2009). This influences people's lifestyle which affects their consumption patterns and housing preference (Zondag and Borsboom, 2009). Likewise some cultural perceptions e.g., for sacred places can lead to preservation of such landscapes hence remaining in their undisturbed state. For example, the preservation of the coastal Kayas by the Mijikenda community. Similarly, among the pastoral communities, some land is always preserved as dry season grazing refugia as a matter of cultural practice (Mortimore, 2006).

2.5.1.4 Technological factors

The development of technologies especially in the agricultural sector is a major cause of land use change. Zondag and Borsboom (2009) observed that mechanization of agriculture together with farming technologies were key in influencing the future direction in land use change. Among the farming technologies include both agricultural intensification and extensification.

2.5.1.5 Demographic factors

Both natural increase and in-migration of people which affects the size and composition of populations and households influence the direction of land use change. Campbell et al. (2003) observed that, in-migration led to the changes of pastoral grazing lands to farmlands within the rangelands of southern Kenya for the past decades. Similar observations were made by Mundia and Murayama (2009), whereby, conversion of grasslands into mechanized and smallholder agriculture and settlements was occasioned by increased population density due to natural population increase and in-migration. The Millennium Ecosystem Assessment (2005b) attributed human population growth to habitats destruction due to forest clearing and human settlement.

2.6 Geographic Information Systems and its Implications

Remote sensing and Geographic information systems are increasingly being used worldwide to assist in gathering and analyzing images acquired from aircrafts, satellites and even balloons (Aschbacher et al., 1995; Blasco et al., 1998; Dahdouh-Guebas et al., 2000b). A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. It is a relational database whose main feature is the use of a common coordinate system for accessing both spatial and descriptive or attribute information defining the objects under investigation (Mbile et al., 2003). The notable advantages of using GIS include the ability to update the information rapidly, to undertake comparative analytical work and making this information available as required (Long and Skewes, 1994). GIS in addition to providing efficient data storage and retrieval facilities also offers a cheaper option for monitoring landscape change over time (Long and Skewes, 1996). However, information produced only from analysis of conventional GIS may not represent the reality on the ground, and therefore policies produced based on purely conventional GIS data may be unattractive to local communities who may not then participate in all the steps required in development. In his study, Campbell et al. (2005) recommended that, the use of multiple methods is important in describing changes in land use and land cover patterns and for identifying the driving forces of these changes. No previous studies have detailed land use and land cover changes in Taveta district. Such data would be necessary to guide land use planning and management of land use resources in the district.

2.7 Participatory Geographic Information Systems (PGIS)

In order to facilitate local community participation in natural resource management, people need to understand variations in land, their causal attributes and the linkages between them. For this to be achieved, these variations must be identified, characterized and information communicated via the most inclusive and cost effective means. Resource managers need to understand the underlying social and ecological drivers of natural resource changes (Campbell et al., 2003; Aynekulu et al., 2006). In order to fully develop the knowledge portfolio required to design and implement natural resource management strategies in remote areas, an adaptable, robust and credible system of ethno-ecological knowledge representation, analysis and communication is required (Aynekulu et al., 2006). A more recent and plausible approach that not only gathers information from local communities but also enhances participation, empowerment, development of local skills in graphically representing ideas and problems (maps) is the use of Participatory Geographic Information Systems (PGIS). The approach allows communities not only to better analyze and communicate ideas of changes but also implement more sustainable projects (Aynekulu et al., 2006; Kathumo and Gachene, 2012). This bridges the technological gap between the rural communities and natural resource managers as well as facilitates the representation and integration of both temporally and spatially explicit historical and "real time" knowledge held within rural environments.

Over the years, it has emerged that, participatory approaches are needed to better understand the socio-cultural contexts of natural resource change. Such approaches not only represent local knowledge of realities prevailing on the ground but also capture historical perspectives crucial in understanding present and past dynamics and potential mitigation actions. Among the initial approaches to community participation was the use of participatory rural appraisal methods, which were aimed at understanding the real situation occurring on the ground and developing adequate policies aimed at ensuring the sustainability of any plans and techniques implemented (Perez, 2003; Aynekulu et al., 2006; FGLG, 2008). Participatory Geographic Information Systems has been considered to be more appropriate in addressing natural resource challenges facing local communities.

Conventional GIS uses conventional GIS tools. However, this may not always produce promising results unless the communities in question participate fully in the process. This is attributed to the fact that the data used excludes local knowledge. Such analyses produce information that does not represent the reality on the ground and policies produced from such analysis may be unattractive to local communities who may not participate fully in development processes (Perez, 2003; Eynekulu et al., 2006; Kyem and Saku, 2009). Linking conventional GIS and PGIS produces a hybrid methodology that strengthens the capacity of local knowledge in the multi-participant planning process. In addition it reduces the drawbacks associated with top-down approaches that are deemed to impose opinions on people; approaches that have been deemed to be counterproductive in the past. PGIS encourages multi-stakeholder participation in participatory development thus enhancing good governance of resources (Kyem and Saku, 2009). The differences between conventional GIS and PGIS are;

Conventional GIS

- Information is gathered through remote sensing
- Focuses more on gathering and computerized analysis of data resulting in the production of maps
- Not participatory i.e., it is for GIS experts only
- A tool used for producing maps
- Spatial analysis done by soft wares

Participatory GIS

- Information gathered from both geospatial data and mapping
- Focuses more on the process itself
- Is participatory including the formation of adequate and the selection of management tools for geospatial information
- Empowers ordinary people in adding value and authority

- Considered as operational practice rather than a tool to produce maps
- In most cases, it is a multi-disciplinary process in nature
- Integrates several tools and methods while relying on a combination of "expert" skills with socially differentiated local knowledge
- Promotes interactive participation of stakeholders in generating and managing spatial information
- Uses information about specific landscape to facilitate broad based decision making processes that support effective communication and community advocacy
- Promotes an effective/ interactive participation of all actors, producers and managers of the geographical information
- May use GIS technologies in the process although this is not a must
- Spatial analysis is done by the people
- Results from merging of Participatory Learning and Action (PLA) and geospatial information technologies
- Embraces low and high tech GIT e.g., ground mapping (drawing on the sand) etc

With the foregoing, then PGIS has worthy advantages to offer in enhancing the ecosystem approach which seeks to decentralize natural resource management to the local level while embracing multi-stakeholder participation processes in managing natural resources.

2.8 The Application of GIS and PGIS in Natural Resource Management

Due to the increasing complexity in resource policy decision-making, managers have found a need for new approaches, information and new analytical tools to integrate the multiple interests and viewpoints of stakeholders in official decision making (Walker, 2002). The need for collaboration between the different stakeholders has been occasioned by the lack of consensus on resource policy decisions. Purnomo et al. (2004) observed that partnerships between statutory and customary 'owners' of the resources are critical for achieving peaceful and effective resource management in the communities. Public participation has therefore undergone revitalization in resource management institutions. For example, in its quest to reach the local communities, the Kenya Wildlife Service identifies as one of its needs, the development of a new strategic focus on community engagement outside the protected areas system to achieve its mandate (Kenya Wildlife Service, 2011). Likewise the Environmental Management and Co-ordination Act (EMCA) (Republic of Kenya, 1999) (no. 8 of 1999) as reviewed by December 2006, includes new regulations that require access permits to genetic resources in Kenya, whose approval requires a prior informed consent from interested persons and relevant lead agencies, and a research clearance certificate from the National Council for Science and Technology. This includes consent from local communities who are the custodians of natural resources within their jurisdiction.

Within the context of GIS applications, the revival in public participation has taken the form of a movement known generally as Participatory GIS. In this context, PGIS is aimed at developing a system that is "adaptable to inputs from ordinary citizens" and other non-official sources (Kyem and Saku, 2009). Among the range of issues that have adopted the use of Participatory GIS tools successfully include; integrating indigenous local knowledge for natural resource management in developing countries (Tripathi and Bhattarya, 2004; McCall and Minang, 2005; Aynekulu et al., 2006; Kathumo and Gachene, 2012; USAID, 2012), increasing community access to information and resources (Elwood, 2002; Laituri, 2002), incorporating local knowledge into national land reforms (Harris and Weiner, 2002) and enabling a broader and more effective participation of marginalized groups in the decision making process (Smith and Craglia, 2003). In addition, community mapping of local knowledge regarding air pollution in the UK (Cinderby and Forrester, 2005), integrating expert knowledge into habitat suitability mapping (Yamada et al., 2003), mitigating resource conflicts among communities (Kyem, 2006) and mapping areas for conservation (Bojorquez-Tapia et al., 2003; Brown et al., 2004).

Vernooy et al. (2000) observed that mental maps graphically represent the community's perception on how they view and use their environment. Participatory resource mapping was found to make access to information and transparency in local governance a reality. In addition, the process of making the maps and the questions raised and features chosen to be included on the maps provided information on community use, ownership and access to the resources. As observed by Nabwire and Nyabenge (2006) and Kathumo and Gachene (2012), through participatory mapping, spatial inventories of natural resources, land use rights and perceived problems can be created for more equitable and sustainable natural resource management. However, the need to transfer decision making power to local communities and governments is necessary. Hoare (2011) demonstrated that one of the most important activities for managing human-elephant conflicts is to bring stakeholders in a forum that can share information, build collaboration and advocate for new policies.

Nabwire and Nyabenge (2006) working in Kyantobi watershed of south western Uganda observed that the integration of geospatial tools together with community resource mapping methodologies can provide the local community, natural resource managers and Non-Governmental organizations and Community Based Organizations with the necessary basic information for research, analysis and planning and better informed policy-making on the resource base as well as giving support to local community development efforts. They also observed that, integrating farmers' experiences in the resource base analysis, seeking solutions to problems and laying intervention strategies empowers communities to have involvement and ownership of both information and decision–making processes. Likewise Kyem and Saku (2009) observed that besides mapping, Participatory GIS (PGIS) projects create a peaceful medium for community groups and public officials to meet, exchange views and also learn to develop trust for each other.

Scanty information exists on the application of PGIS in wildlife management. However, Austin et al. (2009) illustrated the use of participatory GIS as a methodological framework for actively involving local stakeholders to enhance the knowledge base underpinning research and policy decisions on the management of wildlife resources in East of England, United Kingdom. The contextual basis of the research was that, some species that are perceived by certain stakeholders as a valuable resource can also cause ecological or economic damage, leading to contrasting management objectives and subsequent conflict between stakeholder groups. In addition, there is increasing recognition that the integration of stakeholder knowledge with formal scientific data can enhance the information available for use in management. This is especially true where scientific understanding is incomplete, as is frequently the case for wide-ranging species, which can be difficult to monitor directly at the landscape scale. Stakeholder involvement resulted in modifications to modeled abundance patterns for all wild deer species present in East England.

2.8.1 Participatory GIS in Kenya

In Kenya participatory GIS has been applied in a number of ways, e.g., among the most recent studies is the assessment of forest cover changes in Lower Tana River complex (Kathumo and Gachene, 2012). In this study PGIS was found useful in community land resources mapping especially for empowering the community and convincing them on the importance of conserving the forest and its resources. In addition, PGIS was found to compare well with conventional GIS in the analysis of resource changes. USAID (2012) used PGIS in the assessment of natural resource utilization by local communities in the Boni–Lungi-Dodori forest areas of Lamu County. In conclusion, it was observed that, by translating the traditional knowledge and history of the community into pictorial image, the map showed the dependent relationship and coexistence between the Aweer community and their environment. Through the mapping exercise, it was observed that the forests of Boni-Lungi-Dodori were particularly vulnerable to the increasing direct and indirect external threats from illegal logging, poaching, slash and burn and shifting agricultural practices, irregular land acquisition and large scale development projects. Such information is key in informing policy and management practices.

iMAP Africa (2009) influenced Urban planning in Kibera slums through PGIS. Among the findings made by iMAP was that PGIS, if appropriately utilized, could exert profound impacts on community empowerment, innovation and social change by enabling communities to demand the provision of public facilities and amenities. In addition, ERMIS Africa (2007) used PGIS for mapping resource rights of the Ogiek, Sengwer and Yiaku communities which are threatened with extinction. Its major finding was that the three communities differed significantly in their cultural backgrounds including places of worship, ancestral origin, and traditions making them distinct tribes. VACID-Africa (2010) also used PGIS to map farmers growing *Melia volkensii* in Kibwezi district of Makueni County in Kenya. This specific study also aimed at promoting natural resource management in Kibwezi area. Among the findings of the study was that there is still a major skill gap in the use of PGIS. No studies have applied PGIS technologies in managing Human-wildlife conflicts in Kenya.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Description of the study area

The study was conducted in the semi-arid rangelands of Taveta district bordered by Tsavo-West National Park to the East, Kenya -Tanzania Border to the west and south Kajiado district to the north. The district covers an area of 645.4Km^2 and located between longitudes 37^0 25'E and 38^0 17'E, latitudes 3^0 15'S and 3^0 62 S (Figure 3.1). It was formerly composed of eight locations which were recently subdivided into eleven locations and 23 sub-locations. The locations include, Njukini, Challa, Nakruto, Timbila, Ngarigashi, Kimala, Mata, Kimorigo, Kitobo, Mboghoni and Mahoo. The population growth rate of the district is high standing at 2.94% p.a (Republic of Kenya, 2009). Historically, the area was occupied by Taveta and Pastoral Maasai communities; however, currently the population is multi-ethnic composed of people from other parts of Kenya and Tanzania. The immigrants mainly engage in crop production. However, the Maasai's have also changed their lifestyle and are now engaged in agro-pastoralism. The area acts as a dispersal area for wildlife from Tsavo West National park.

3.1.2 Climate

The mean annual rainfall ranges between 200 mm from the Tsavo West National Park and increases gradually to about 800 mm towards the foothills of Mt Kilimanjaro. The long rains occur between March and May while the short rains occur between November and December. The district is largely a semi-arid area unsuitable for agriculture except the region towards Mt. Kilimanjaro and the lowlands where irrigated agriculture is possible. Mean annual temperature ranges from 21.2^{0}C to 31.0^{0}C (Jaetzold and Schmidt, 2005).

3.1.3 Drainage

The area is drained by Rivers Lumi, Tsavo, Kitobo and Njoro. Rivers Lumi and Tsavo originate from Njukini Location. River Lumi is the main water source for Lake Jipe, while the Tsavo River drains to Tsavo West National Park.

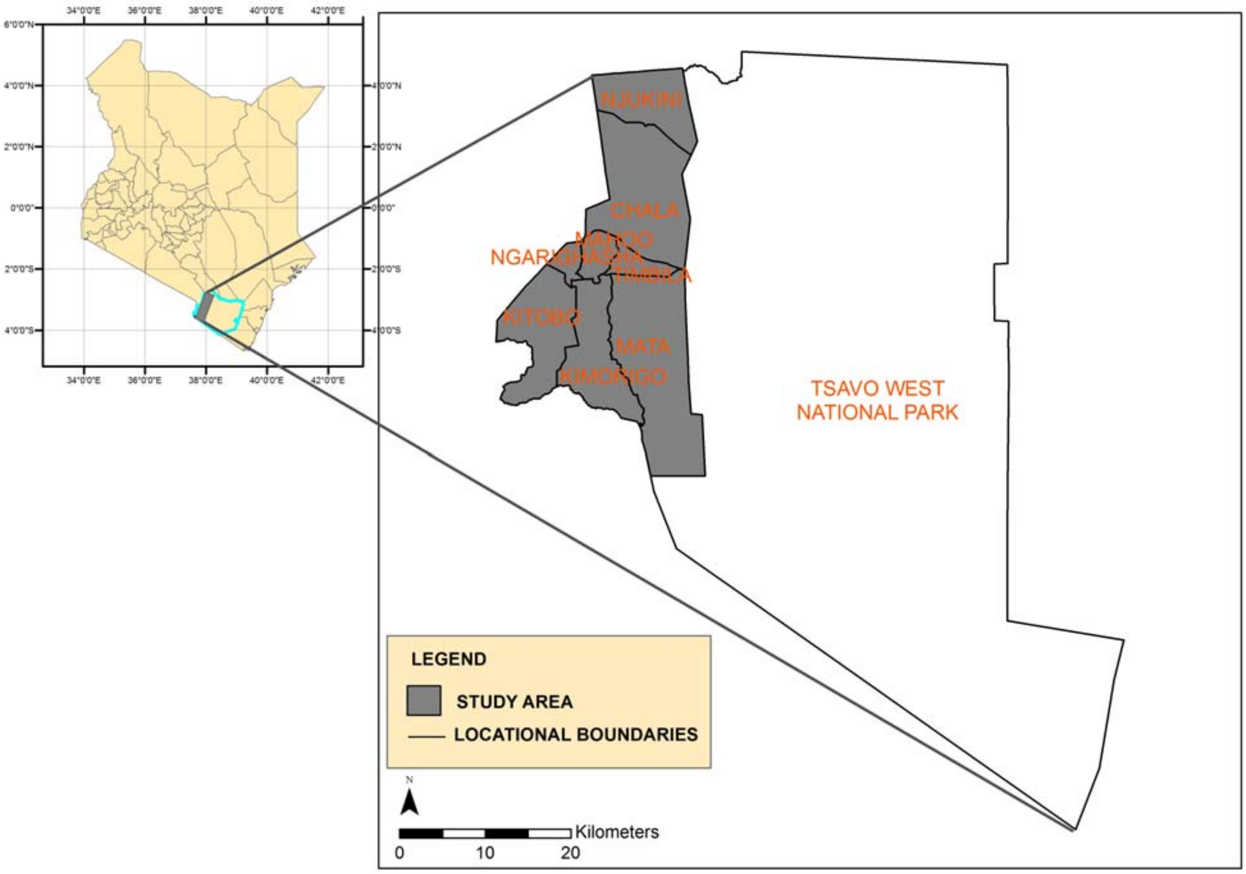


Figure 3.1: Map of Kenya showing the study area

3.1.4 Agro-ecological zonation of the study area

The study area which lies along the Mt Kilimanjaro ecological gradient covers five agro-ecological zones, LM4, LM5, L5, L6 and LM6 (Table 3.1). In the tropics, agro-ecological zones are defined by moisture supply and differentiated by soil types in order to provide a framework for the ecological land use potential of an area. As described by Jaetzold and Schmidt (2005), the letter part of the agro-ecological zone names represents temperature belts. In Kenya, these are defined by the temperature limits of the main crops. The main zone is represented by the number, and describes the combination of precipitation and evaporative demand of the atmosphere taking into consideration the length and intensity of arid periods.

Table 3.1: Characteristics of the Agro-ecological zones of Taveta district.

Agro-ecological zone	Description	Rainfall (mm)	Ecological potential	Actual land use and land cover (2011)
LM4	Lower Midland (Transitional)	600-800	Marginal cotton zone or sisal zone	Maize, beans, tomatoes, bananas, livestock(Stall-fed and free ranging), sisal
LM5	Lower Midland (Semi-arid)	480- 620	Livestock- millet zone	Maize, beans, tomatoes, bananas, livestock, sisal, shrublands
LM6	Lower Midland (Arid)	200	Ranching Zone	Sisal, livestock (free ranging), shrublands
L5	Lowland (Semi-arid)	550 – 680	Livestock–millet zone or marginal lower sisal zone	Bananas, maize, beans, tomatoes, mangoes, citrus fruits, water bodies, wetland vegetation, cotton (Small patch), sisal, forest.
L6	Lowland (Arid)	200	Ranching zone	Livestock (Free-ranging), wildlife, fishing.

Compiled from Jaetzold and Schmidt (2005) and field survey conducted in 2011.

3.1.5 Soils

The soils are mainly Cambisols, Luvisols, Ferrasols and Vertisols of variable fertility (Jaetzold and Schmidt, 2005). Taveta district has an ecological potential for millet, cotton, livestock and sisal production as well as ranching. Soil fertility ranges from high to low. Almost 75% of the district is covered by agro ecological zones LM4 and LM5. These are areas suited for cotton, sisal, and millet and livestock production.

3.1.6 Livelihood zones

The main livelihood zones are mixed farming (Food crops and livestock), irrigated agriculture, fishing and formal employment. Food security is precarious and deteriorating in the mixed farming (rainfed crops and livestock) zone, while in the irrigated zones the situation is stable. This is influenced by poor rains, high food prices, Human-wildlife conflicts and postharvest losses (Republic of Kenya, 2011).

3.1.7 Wildlife population trends in the Tsavo West National Park

Tsavo West National Park occupies the largest area of Taveta district. The district is home to a variety of wildlife species most of them found in the park and in Kitobo forest. Among these are the Leopard, Cheetah, Wild dogs, Buffalo, Rhinoceros, Elephant, Giraffe, Zebra, Lion, Crocodile, Mongoose, Hyrax, Dik dik, Lesser Kudu, bushpigs and Porcupine and over 600 bird species found in Tsavo West National Park. Of the wildlife, the Elephant, Rhino and Wild dogs are threatened species (IUCN, 2013). Figure 3.2 gives an overview of wildlife trends of some selected species based on available aerial census data (Kenya Wildlife Service, 2011).

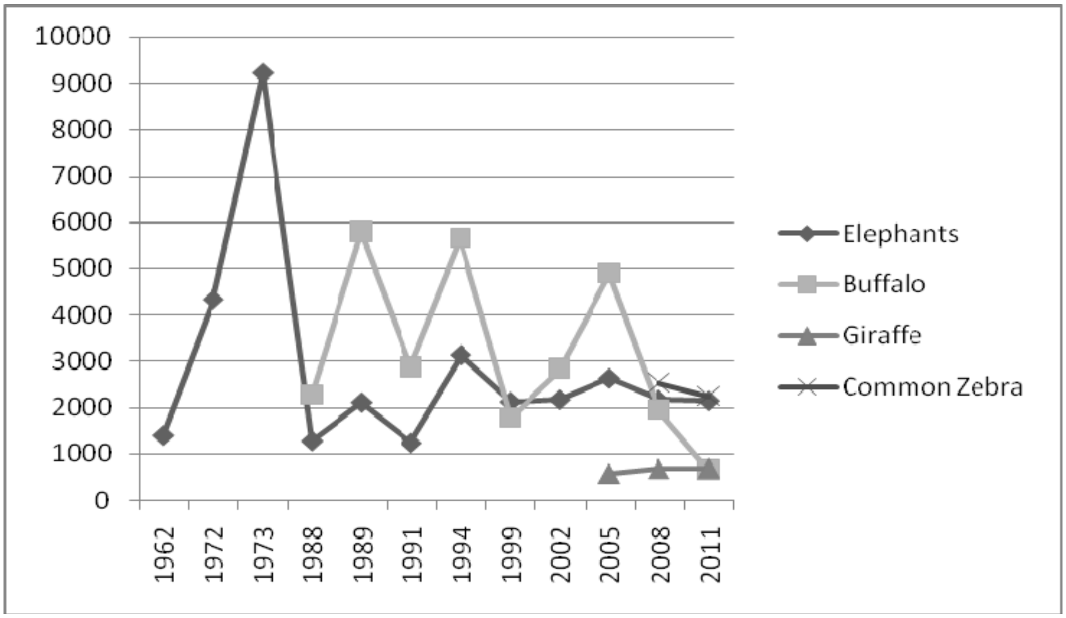


Figure 3.2: Wildlife population trends of Tsavo West National Park between 1962 and 2011 Source: Ngene et al. (2011)

3.2 Materials and Methods

3.2.1 Socio-economic and farm characterization approaches

In order to determine the nature and extent of Human-wildlife conflicts in Taveta district, the following activities, i.e., project sensitization to government administrators (Provincial commissioner, District commissioner, chiefs and assistant chiefs), community sensitization, training of field assistants, and pre-testing of questionnaires were undertaken before the actual examination of farms and administration of questionnaires to farmers. A preliminary survey was also undertaken.

3.2.1.1 Project sensitization

Official discussions were held with the provincial commissioner and the district officer on 9th and 10th February 2012 respectively. A subsequent meeting was held with nine chiefs on 13th February 2012. The aim was to enhance team building for the project through discussions around the intended project, the reasons behind the project and the expectations from the project. Benefits of the project to the district and how the project findings will be disseminated were discussed as well. It was expected that each chief discussed the project to their community.

3.2.1.2 Community sensitization

The project was also discussed during community gatherings organized by chiefs within the month of February and March 2012 (Plate 3.1). The aim was to highlight to the local community more about the project and enhance the information from the administrators. Dissemination of project findings was also discussed during the forum.

Plate 3.1: Community sensitization during one of the gatherings at Kimala location

3.2.1.3 Development of questionnaire

The aspects that were highlighted in the questionnaire developed were aimed at capturing the following; demographic data, Impacts of wildlife, community perceptions/attitudes about wildlife and farm characteristics (Appendix 3).

3.2.1.4 Training of enumerators

A two days training was done for the enumerators to; discuss the research agenda to the enumerators, discuss the questionnaire in details, practice questionnaires trials among themselves, strengthen their communication skills and train them on basic operations of the Geographic Positioning System (GPS) equipment. This was based on the fact that administering questionnaires to local communities requires a thorough understanding of the research agenda and the necessary skills to communicate clearly to the local communities. The enumerators were drawn from the various locations within Taveta district namely Kitobo, Mata, Njukini, Kimala, Chala, and Mboghoni. They were selected on the basis of prior experience, minimum education being form four with tertiary training as an added advantage and ethnicity to represent the different ethnic groups in Taveta District. They were selected in a meeting by the community headmen in consultation with the chiefs.

3.2.1.5 Questionnaire pre-testing

Pre-testing was aimed at ensuring that the questionnaire was well understood by farmers and field assistants for ease of capturing the information. A total of twenty farmers were interviewed and farms characterized for damages i.e., measurements for acreage under the various crops and damages, and foot prints and scats examined. Challenges observed during the pre-test were used to review the questionnaire before the actual survey.

3.2.2 Preliminary survey

The district was traversed to familiarize with the proposed livelihood zonation, local topography of the area, meet local community elders and talk to individual farmers. This was also aimed at building more rapport with the local community and to better understand the situation with regards to Human-wildlife conflicts.

3.2.3 The nature and spatial distribution of Human-wildlife conflicts

A multi-level collection sampling technique (de Vaus, 1996; Ebua, 2011) using structured interviews based on a questionnaire (opened and closed), were used to collect information from the community. Farm characterization was also undertaken to establish predictors of damage and crop raiding behaviour of wildlife species. The district was divided into 11 smaller areas based on the administrative boundaries of locations. To reduce sampling error, locations bordering protected areas which were more prone to Human-wildlife conflicts were included. The remaining locations were selected by allocating them two digit random numbers beginning 01 to 05. Out of these, 2 locations were selected. Therefore; a total of 8 out of the 11 locations were used in establishing transects. The first household to be sampled was picked randomly, while the subsequent households were picked systematically. In locations lying adjacent to the protected areas the first households were randomly selected within 200m from the wildlife concentrations. Sampling transects were laid perpendicular to the wildlife concentrations mainly Tsavo West National Park and Kitobo forest. Fifteen sampling transects were covered. Twelve transects were established perpendicular to Tsavo West National Park and three were established perpendicular to Kitobo forest. Sampled households were then allocated into their respective locations. Transects were established such that in each of the eight locations no less than 35 households were sampled taking into account the statistical requirement to have a minimum sample size of 30 per sampling unit (Zar, 1996) and the possibility of non-response. Both immigrants and residents from the various ethnic groups were interviewed (Campbell et al., 2005; Moses et al., 2005), crop and livestock damages assessed and species involved established.

People's perceptions towards wildlife interactions were described by how people perceived experiences with a range of wildlife impacts and the factors underlying attitudes, as a result of conflicts (Kretser et al., 2009). The information collected included overall perceptions by the community towards wildlife interactions as influenced by age, attitudes, experience with wildlife and type of farmer (resident and immigrants). Key informant interviews were conducted for land and wildlife managers from Kenya Wildlife Service (KWS), Ministry of Agriculture (MoA), Kenya Forest Service (KFS-Kitobo Forest), local community representatives, Government administrators (Chiefs/assistant Chiefs) and representatives from local Non-Governmental Organizations.

3.2.4 Land use and land cover change (LULCC) analysis

Standard procedures of developing land use and land cover maps using satellite imagery that involves defining spectral classes by clustering the image data and assigning pixels into classes was used (Mwavu and Witkowski, 2008). Space-borne satellite imagery was used for classifying and characterizing land use/cover changes over the last 24 years. These were analysed from multi-temporal Landsat images for the years 1987, 2001 and 2011 using ENVI 4.7 software. The ENVI 4.7 is a robust suite of image processing and analysis tools that supports image exploitation workflows and integration with GIS softwares. The software being robust allows for preparation of images (image calibration and correction for atmospheric distortion), image classification using supervised and unsupervised methods, identification of spectral signatures using robust libraries, detection and identification of targets and features of interest, analysis and mapping of materials of interest, as well as undertaking whole-pixel and sub-pixel analyses. The software also allows for change detection, calculation of image statistics such as mean, minimum/maximum and standard deviation, extraction of linear features and modeling of topographic characteristic (ESRI, 2009; EXELIS, 2012). The selected images were within the same dry season of the years. Images were classified into different land use/cover types using supervised classification where ground-truthing of the major land uses within the study area was done according to Chakraborty (2001). Within the study area, ground truthing points were geo-referenced for each available land use/cover in all the locations. A minimum of five points were geo-referenced for each land use and land cover in each location. Spatial-temporal changes in water resources, irrigated agriculture, rainfed agriculture, forests, woodlands, sisal plantations and shrublands were determined.

3.2.4.1 Characteristics of land sat images

The details of the Landsat images used for the analysis of land use and land cover are shown in table 3.2.

Table: 3.2. Characteristics of the satellite images in the study area

Year	**1987**	**2001**	**2011**
SENSOR_ID	LANDSAT 5 TM	LANDSAT 7 ETM+	LANDSAT 7 ETM+
Datum	WGS84	WGS84	WGS84
Path - row	167-62	167-62	167-62
Elevation source	GLS 2000	GLS 2000	GLS 2000
Spatial resolution	30m	30m	30m

3.2.4.2 Image classification

Multi-temporal Landsat data processing was done using ENVI 4.7 software (ESRI, 2009). Supervised classification was used with false colour composite bands (Bands 4, 3, 2). Mahalanobis distance classification methods were then used to classify the images to the various land use and land cover types.

3.2.5 Participatory geographic information systems (PGIS) approach for resource change mapping

3.2.5.1 Introduction of PGIS technology

To facilitate effective participation by local communities, participants were taken through the tools to be used for the PGIS exercise. These included Geographic Positioning Systems (GPS), manila papers and the colour schemes for the various land use and land cover types agreed upon. The purpose of the classified land use and land cover maps and at what point they were to be used was discussed. The reasons behind the project and the PGIS exercise were also discussed. The roles of the different age groups were assigned and participants made aware of the sketching details. The objectives of the PGIS sessions were discussed with the participants.

3.2.5.2 Resource change mapping

Resource mapping involved drawing sketch maps indicating the resources for the area at different times of settlement with the aim of reflecting on how resources in the area have changed over time. This was expected to give a visual representation of what the community perceived as valued assets, how the community has been exploiting resources (land use) and link the use to either as a negative or positive influence to the dynamics of Human-wildlife conflicts in the area. Key people mainly the elderly were used to indicate the resources as they were when they first settled in the area while those who settled after a certain time period drew a map of the current status of resources. Maps for different time periods were used to compare spatial-temporal changes in resource use as perceived by the local communities. PGIS mapping of resources was undertaken by communities living within the three main livelihood zones i.e., irrigated agricultural zone, rainfed agricultural zone and pastoral livestock production zone as described by Githae (2009). These were conducted in Mboghoni, Kitobo, Njukini and Njoro locations. In each PGIS session of 20 participants, 10 were individuals between 18-35 years and another 10 individuals of 50 years and above. Gender balance was observed whereby the 20 participants were composed of 10 women and 10 men. Both present and past land use practices were drawn. Developed maps were used for evaluating resource changes over the years. Resource change maps were drawn for 20 year periods representing 1970's, 1990's, and 2012. Of importance were resource changes in numbers and extent. Development of maps started with the most recent, i.e., for the year 2012, then worked backwards to finish with maps of 1970's. Once the maps were drawn, discussions were carried out focusing on the accuracy of the maps and modifications made until participants come to an agreement (Aynekulu et al., 2006).

The main land use types that were presented in the maps included rainfed agriculture, irrigated agriculture, forests, grazing lands (shrublands and woodlands), water resources and settlements. A field survey with representatives of the group was undertaken to geo-reference mental maps drawn using Global Positioning System (GPS). The GPS data collected was introduced into a Geographic Information System using program ArcView GIS, 3.2 for geo-referencing the mental maps of 2012. The geo-referenced maps were used for calculating the area under each of the land uses/ land cover types as represented by local communities. Statistics for both land use change analysis approaches were then compared.

3.2.5.3 Participatory GIS community forums

Once the visualization of the resource changes was completed, group discussions were held with the four groups of the local communities who participated in the PGIS exercises. The group discussions were to assess the major causes of land use change in the study area and gather more information and recommendations on strategies for sustainable resource use and for mitigation of Human-wildlife conflicts. Participants also discussed the negative effects of the land use and land cover changes. Participants presented their views on how Human-wildlife conflicts have changed in the study area over the years in terms of form and magnitude. This was linked to the resource change maps to evaluate if participants were able to link resource use changes and the dynamics of Human-wildlife conflicts.

3.2.6 Secondary data

This included three types of data; human demographic changes for the district, wildlife population data for the Tsavo Conservation Area and spatial-temporal data on Human-wildlife conflict incidences collated from Kenya Wildlife Service.

3.2.7 Data Analysis

a) Questionnaires

Questionnaire data was subjected to statistical analyses using Statistical Software for Social Scientists (SPSS vs. 20SPSS Inc., Chicago, USA). Descriptive statistics were used for describing relative frequencies for the various categories of data collected. The types of conflicts, their spatial distribution, affected crops, seasonality of attacks, conflict hotspots, crop preference, preferred parts of crop eaten and preferred time of attacks were summarized using tables and figures. Percentages of data collected and arithmetic mean were used as a means of comparing variables. Chi-square goodness of fit test was used to assess changes in response patterns by farmers between the eleven sampled locations. Regression analysis was used to determine the relationship between the probability of a farm being raided as a factor of the number of crop types grown and relationship between population growth and time (Zar, 1996).

b) Land use and land cover change

ENVI 4.7 and ENVI EX Software (ESRI, 2009) were used for image classification and thematic change detection respectively by comparing images taken at different times (1987, 2001 and 2011). Statistics on image changes were examined and analyzed for land use and land cover changes and their percentage changes calculated. Chi-square goodness of fit tests were done to determine significant changes in land use and land cover over the years for each of the cover types described from the Landsat images.

c) Participatory Geographic Information Systems (PGIS) mental maps

Changes in resource use were determined from the PGIS maps. The maps were geo-referenced and transferred into a Geographic Information System for analysis of resource changes as envisaged by the local community. Chi-square goodness of fit was used to determine how effective communities were in estimating spatial-temporal changes in land use and land cover, hence their ability to communicate knowledge and information on resources changes. Statistics for resource changes from conventional GIS were used to benchmark and evaluate the extent to which local communities effectively analyzed resource changes using PGIS.

CHAPTER 4

4.0 THE NATURE, EXTENT AND SPATIAL DISTRIBUTION OF HUMAN-WILDLIFE CONFLICTS IN TAVETA DISTRICT, SOUTHERN KENYA

4.1 Abstract

Human-wildlife conflicts have been on the increase and challenge both wildlife managers and conservationists. The conflicts are a significant problem in Africa and influences local communities' food security, safety and well-being as well as the country's economy. To manage the conflicts, site specific data is required for a particular locality. In this study, both farm characterization techniques and questionnaires were used to collect data to describe the conflicts in Taveta district. Eating of and trampling on crops were the main forms of conflicts in Taveta, followed by livestock depredation. These differed significantly between locations ($P < 0.05$). The key wildlife species involved were elephants, primates, bushpigs, hippopotamus and hyenas. The effects of each species differed significantly between the locations ($P < 0.05$). Seasonality was the main factor driving conflicts in the rainfed areas but had no effect in the irrigated zones. Elephants and Hyenas led in crop destruction and livestock depredation respectively. Most of the wildlife attacks occurred at night. Maize was the preferred crop for the top three conflict causing species. Animals preferred farms with 3-4 types of crops. Local community attitude towards conflicts causing wildlife species weighed more heavily on the negative and very negative sides. The conflicts are a real challenge that requires urgent redress to safeguard local community livelihoods and enhance wildlife conservation in the district. This can partly be achieved through raising community awareness on the importance of wildlife, identifying and encouraging alternative livelihoods to farming, especially in buffer zones where conflicts are high and inculcate a positive attitude in the local communities to co-exist with wildlife.

Key words: Human-wildlife conflicts, Elephants, Hyenas, Tsavo-West National Park, Taveta district.

4.2 Introduction

Globally, Human-wildlife conflicts (HWCs) have been on the increase and are a major challenge to wildlife managers and conservationists in many countries, Kenya included (Hoare and Du Toit, 1999; Kagiri, 2004; FAO, 2009). This escalation has been attributed to increase in human population, changes in land use patterns, loss of wild habitats, lack of benefit sharing, poor management policies, inadequate scientific understanding of the issue and community attitudes (Barnes et al., 2005; Kamande, 2008; FAO, 2009; Kioko and Okello, 2010; Baruch-Mordo et al., 2011). In Kenya, the problem is more serious especially in human-dominated landscapes surrounding protected areas. Kenya's top six Human-wildlife conflict hotspots include areas surrounding the Tsavo-West and Tsavo-East National parks, Amboseli National Park, Laikipia, Narok, Lamu, and Imenti South. Within these hotspots, Human-wildlife conflicts undermine wildlife conservation efforts and local livelihoods

(http://www.kws.org/parks/community_wildlife_program/PAMU.html)

In the southern rangelands of Kenya, changes in land tenure systems and emerging challenges of human population growth are central to Human-wildlife conflicts, and are partly driven by changes in land use patterns. These rangelands have been inhabited mainly by the Maasai community for centuries. While their mobile pastoral lifestyle was in tandem with wildlife conservation, in the 1940's, their pastoral grazing lands were seized for creation of wildlife conservation areas. In 1960's, group ranches were established within the remaining pastoral grazing lands (Akama, 1998; Seno and Shaw, 2002; Campbell et al., 2003; Okello and D'Amour, 2008). Later, these were subdivided and made private, a situation that made communal access of the group ranches more difficult (Seno and Shaw, 2002) as owners gained land ownership rights. This saw the leasing of land to outsiders who mainly practiced farming and intensified over time as more people continued to migrate to the ASAL's in search of land for agriculture and settlement. In addition, threats to sustainability of the pastoral livestock production system has seen a large population of the Maasai settle down to agro-pastoral lifestyles (Thompson and Homewood, 2002; Okello and Kioko, 2010) that is incompatible with wildlife conservation. Cultivation along wetlands and swamps in ASAL areas has been found to destroy valuable habitats suitable as livestock and wildlife refugia in the dry season (Okello, 2005a). More wildlife habitats have become more isolated and others insularized as a result of habitat degradation outside protected areas (Okello and D'Amour, 2008), a situation that reduces the effective size of a protected area by limiting the movement of species within and between dispersal areas. The presence of permanent water sources for irrigation in some ASAL areas has fueled agricultural intensification thus adding to the conservation crisis. The above scenarios which influence landscape characteristics are eminent in most parts of Kenya's drylands and are precursors to Human-wildlife conflicts and more so when they border wildlife protected areas.

Taveta district is part of the southern rangelands of Kenya that lies adjacent to Tsavo West National Park. It was once part of the area where wildlife outside Tsavo West National Park ranged freely, but currently dominated by human activities mainly farming and livestock grazing. The area is bedeviled by Human-wildlife conflicts that have intensified over the years as land use continues to change. While some research work has been done in Laikipia (Kagiri, 2004), Amboseli ecosystem (Okello, 2005a; Okello and Kioko, 2010) and Narok (Sitati, 2003; Sitati et al., 2005; Sitati and Ipara, 2012; Wakoli and Sitati, 2012) to provide management solutions to Human-wildlife conflicts, little has been done in areas around Tsavo West National park especially in Taveta district.

Human-wildlife conflicts contribute to hunger through crop loss and disruption of life support systems in the ASALs. In order to carry out informed and cost effective management decisions it is a recommendation to have information (scientific data) on Human-wildlife conflicts for any given site. This includes information on recurrent animal problems and the species involved and creation of databases of the information (WWF SARPO, 2005; FAO, 2009) among others. Barnes (2002) concluded that, in order to address crop raiding by wildlife, there is need to examine the local communities and their farming systems. In Taveta district, Human-wildlife conflicts are not only a challenge to wildlife managers but have also been found to contribute to poverty, increased food insecurity (Kamande, 2008), poor performance in schools(Appendix 4), as well as challenging community livelihood support systems. Human-wildlife conflicts have persisted in this district, and indeed information on the nature of the problem, its spatial distribution, key species involved and where, is necessary in a bid to avail information useful in addressing the challenge. This study aimed to; (1) Describe the nature of Human-wildlife conflicts in Taveta district, (2) Describe the spatial distribution of the conflicts, (3) Identify hotspots for the various conflict-causing species in the district and (4) Establish some of the factors that predispose farmers to Human-wildlife conflicts.

4.3 Materials and Methods

4.3.1 Description of the study area

As described in Chapter 3.

4.3.2 Wildlife crop and livestock conflicts

This study focused on the 11 locations in Taveta district. Locations bordering Tsavo West National Park and Kitobo forest reserve, which are more prone to Human-wildlife conflicts, were included in establishing the transects i.e., Njukini, Chala, Mata, Kimala, Nakruto and Kitobo. The remaining 5 locations were allocated two digit random numbers beginning 01 to 05. Out of these, 2 locations were selected giving a total of eight locations within which transects were established. The first household sampled was picked randomly, while the subsequent households were selected systematically on sampling transects running perpendicular to the centers of wildlife concentrations at intervals of 200m. Fifteen sampling transects were covered. Twelve transects were established perpendicular to Tsavo West National Park and three were established perpendicular to Kitobo forest. Sampled households were then allocated into their respective locations. Transects were established such that in each of the eight locations no less than 35 households were sampled taking into account the statistical requirement to have a minimum sample size of 30 per sampling unit (Zar, 1996) and the possibility of non-response. Both immigrants and residents from the various ethnic groups were interviewed (Campbell et al., 2005; Moses et al., 2005), crop and livestock damages assessed and species involved established.

The first households from locations lying adjacent to the protected areas were randomly selected within 200m from the wildlife concentrations. For those two locations not lying adjacent to the wildlife concentration areas, transect were started at a random point on the locations border but perpendicular relative to the two wildlife concentrations. Sampling interval was maintained at 200m.

The animal species involved were documented through indirect techniques using foot prints, diggings, dung, feeding habits (Stuart and Stuart, 2000, 2006) and data collected through questionnaires administered to the farmers. The intensity of crop raiding was quantified through area estimation techniques in which the farm was subdivided into measurable shapes (rectangles, squares, triangles etc) and the areas summed up (Moses et al., 2005; Oppong et al., 2008) and converted to Acres. The variables tested and used as predictors of damage/crop raiding were: types of crops grown, number of crop types, acreage of each crop in the farm and seasonality. The crop raiding behaviour of wildlife was determined based on; group composition, time of the raiding, crops raided, parts of the crop eaten, stage of maturity of raided crops, frequency of raids, description of animal(s) if seen and augmented by use of dung,pellets and animal scats observed. Questionnaires were administered to owners of sampled farms (N=323) to collect data on local community experience with wildlife, timing of raiding, types of conflicts people experienced with wildlife, frequency of negative interactions with wildlife, when they started noticing conflicts, animals that raided in groups, and group composition and the frequency of the raids, parts of crops eaten by the various species, seasonality of raiding and wildlife species that attacked livestock. It was assumed that due to the large number of respondents, then respondent's bias may not have been a limiting factor and that estimates given by respondents were not compromised.

4.3.3 Crop preference

Crop preference for the top three animal species was determined by calculating the preference Index (PI) (Kagoro-Rugunda, 2004) as:-

$$PI = \frac{\%\ \text{Frequency of being eaten}}{\%\ \text{Availability}}$$

Where:-

PI = 1.0 (Means no choice)

PI < 1.0 (Means avoidance)

PI > 1.0 (Means preference)

4.3.4 Data analysis

Statistical analyses were conducted using Statistical Software for Social Scientists (SPSS vs. 20, SPSS Inc., Chicago, USA). Regression analysis was used to determine the relationship between the probability of a farm being raided as a factor of the number of crop types grown. The types of conflicts, their spatial distribution, affected crops, seasonality of attacks, conflict hotspots, crop preference, preferred parts of crop eaten and preferred time of attacks were summarized using descriptive statistics (Tables and Figures). Percentages of data collected and arithmetic mean were used as a means of comparing variables (Zar, 1996).

4.4. Results and Discussion

4.4.1 Types, extent and distribution of conflicts experienced in Taveta district

Generally, the types and spatial distribution of conflicts experienced in Taveta district and their percentages are shown in Figures 4.1 and 4.2. Eating and trampling of crops by wildlife were the most serious forms of conflicts in Taveta District. These two forms of conflicts differed significantly between the locations (χ^2 = 62.87, df =7, p = 0.001) and (χ^2 = 69.51, df =7, p = 0.001) respectively. Likewise, livestock depredation and bothering people, which followed in severity in the district, also differed significantly between the locations (χ^2 = 14.87, df =7, p = 0.005) and (χ^2 = 44.12, df =7, p = 0.001) respectively. A comparison of all types of conflicts between the locations (χ^2 = 323.109, df =49, p = 0.001) was also significant. Access to water and grazing, and spreading of diseases were experienced in low levels and in specific location.

Access to water was a problem reported in Kimala and Mata locations, while access to grazing was experienced in Mata location only. Both are pastoral grazing areas that are also not supplied with water from the main rivers in the district. Although these were experienced in low levels, they could have significant effects on Human-wildlife conflicts as pastoral communities result to retaliatory killings in the face of reduced water availability coupled with increased competition. It is also in watering places that livestock depredation takes place. Killing people was only reported in Mata and Timbila locations. It was apparent that Human-wildlife conflicts were not the same and neither uniformly distributed in the various locations in Taveta district.

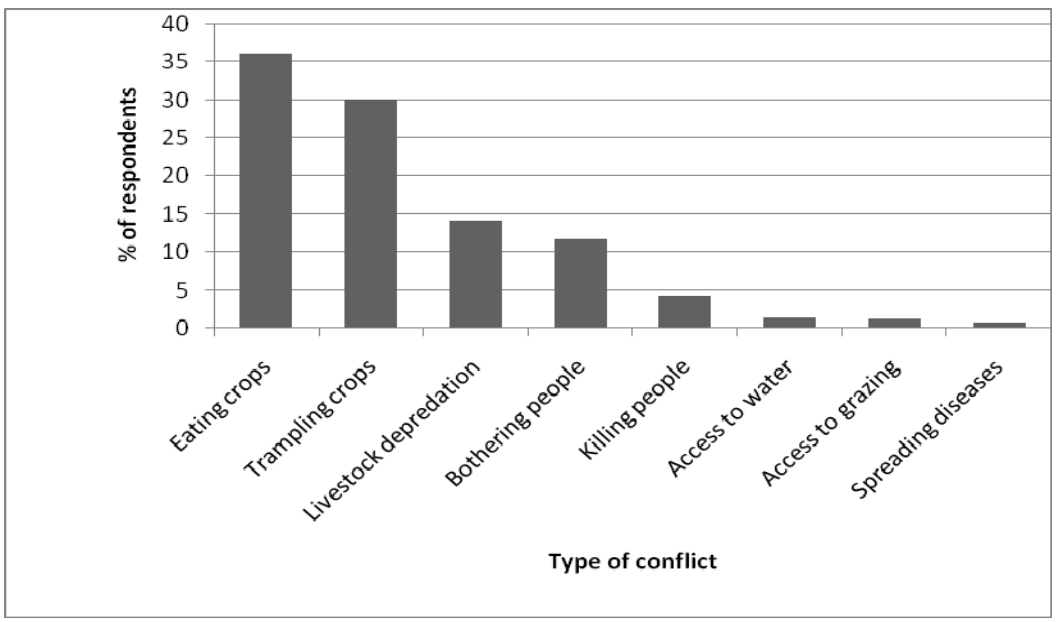


Figure 4.1: Percentage of the various types of conflicts experienced in Taveta district

NB: Bothering people included wildlife activities like passing through peoples land and homesteads without necessarily causing any damage.

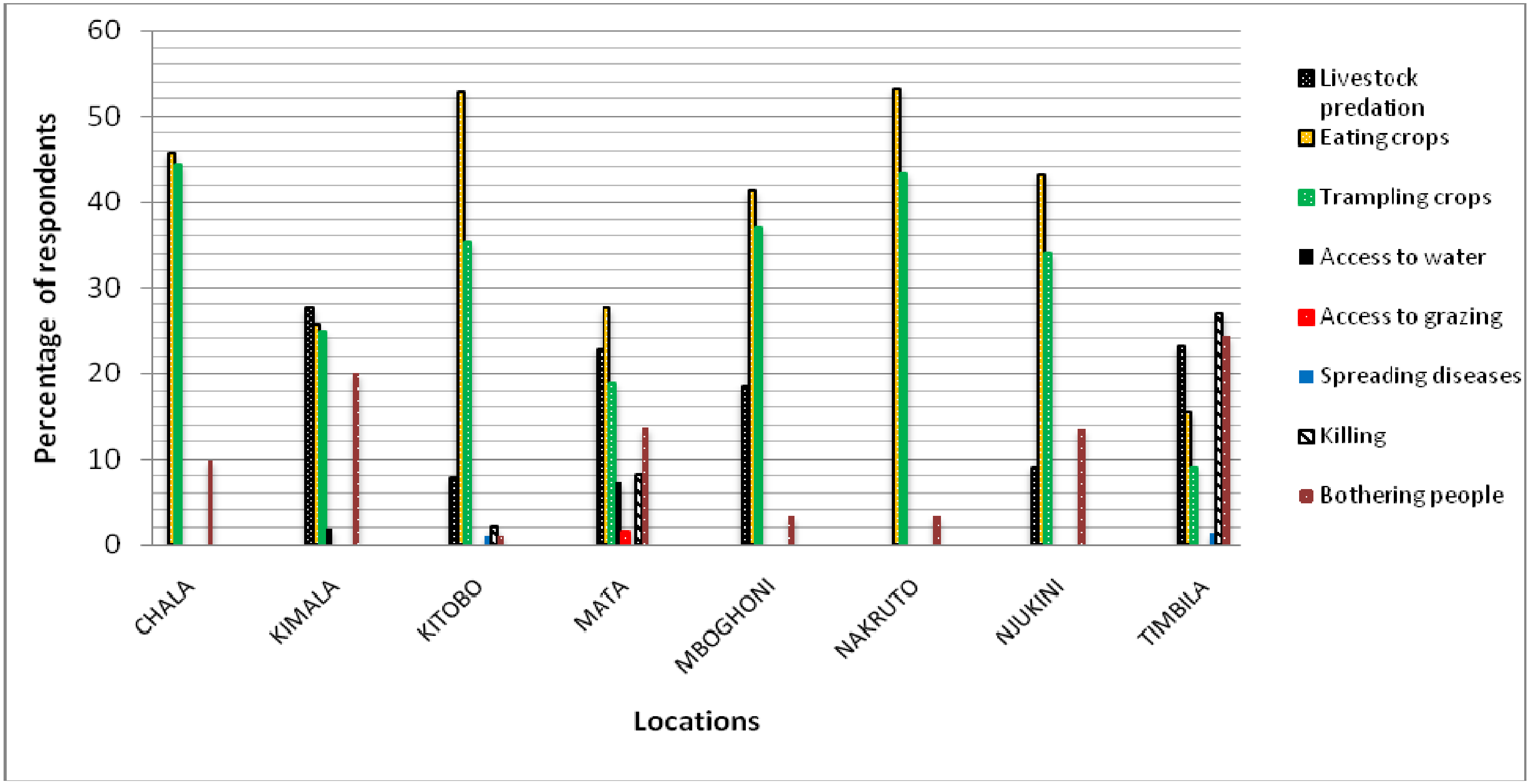


Figure 4.2: Location and % ranking of conflicts within the various locations

Even among the locations bordering the park and Kitobo forest reserve, the intensity and diversity of the conflicts was not the same. Taveta district is largely an ASAL area classified under agro-ecological zones LM5, LM6 and L6, which are mainly suitable for ranching, livestock production and cultivation of millet (Jaetzold and Schmidt, 2005). One possible factor which could have happened in the past three decades, and changed the landscape characteristics to enhance conflicts is land use and land cover changes (see Chapter 5). Most of the district is currently under crop production (maize, beans, vegetables, bananas, cassava, pawpaws, and pigeon peas and different types of fruits). Land use changes have been found to have the potential to exacerbate Human-wildlife conflicts (Sitati, 2003; Kusena, 2009; Kioko and Okello, 2010; Sitati et al., 2012). Okello (2005a) also observed that wildlife damage was related to land use practiced in the Amboseli area of the southern rangelands of Kenya. Plate 4.1, 4.2, 4.3 and 4.4 shows forms of conflicts involving crop destruction and conflicts for water resources respectively.

Plate 4.1: A banana half eaten by hippopotamus in Mboghoni location

Plate 4.2: Makeshift bed for guarding farms at night- exposes farmers to wildlife attacks and extreme weather

Plate 4.3: Bananas covered with polythene sacks to protect them from primates in Kitobo location

Plate 4.4: Survival for the fittest - elephants drive shoats away from Lake Jipe

Most of the respondents interviewed had a negative experience with wildlife before, and this did not differ significantly between the locations (χ^2 = 3.32, df =7, p = 0.854). This gives an indication of the widespread nature of Human-wildlife conflicts in the district. The percentage frequency of negative interactions with wildlife differed significantly between the locations (χ^2 =265.39, df =21, p = 0.001) (Figure 4.3). Areas under irrigated agriculture, namely Kitobo and Mboghoni locations experienced conflicts throughout the year, probably due to the presence of crops in the farms throughout the year. Seasonality was a driving factor influencing conflicts mainly in the rainfed agricultural zones of Kimala, Mata, Nakruto, Njukini and Timbila locations. In these zones most of the crops were attacked at their mature stages towards harvesting period. However, in Timbila and Mata locations, in addition to seasonality, other factors influenced the frequency of conflicts since between 30-40% of the respondents experienced conflicts more than once per month. Conflicts in Chala location were frequent; seasonality was not a driving factor as most of the respondents (76%) experienced conflicts regularly in any given month.

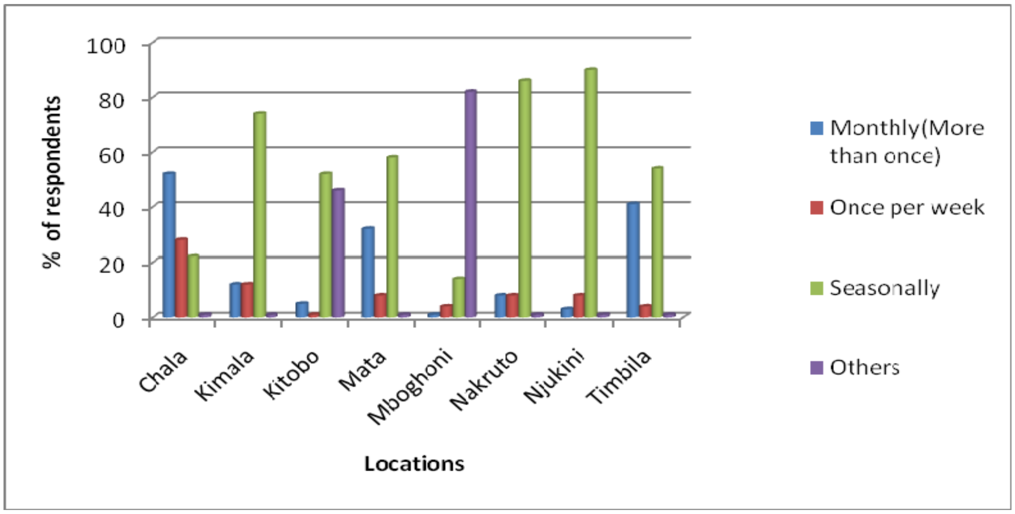


Figure 4.3: Percentage of negative interactions with wildlife

The impact of the various wildlife species on local communities is shown in Figure 4.4. Elephants (*Loxodonta africana*) had the greatest impact on local communities, followed by primates, bushpigs (*Potamochoerus larvatus*) and hippopotamus (*Hippopotamus amphibius*). Except for the bushpigs, squirrels (*Xerus sp.)* and leopards (*Panthera pardus*), all the other species were also found to cause problems in Kuku Group Ranch of the Amboseli area (Okello, 2005a) of the southern rangeland of Kenya, with elephants leading in impact (Okello, 2005a). The effects of elephants on local communities have also been widespread in Kenya as documented in previous studies (Sitati, 2003; Kagiri, 2004; Okello, 2005a; Sitati et al., 2005; Kamonjo et al., 2007; Kamande, 2008; Sitati and Ipara, 2012; Wakoli and Sitati, 2012). Since these top four are species that eat/destroy crops, it is apparent that further agricultural expansion will alter the landscape characteristics towards exacerbating Human-wildlife conflicts in the district, thus increasing the problem of food insecurity.

In similar studies, Kamonjo et al. (2007) and Kioko and Okello (2010) observed that food security depended on crop farming was threatened by Human-wildlife conflicts, especially maize which is a stable food crop for over 95% of the Kenyan population (Sitati et al., 2005). Maize farming especially within elephant ranges around protected areas was significantly threatened by elephant crop raiding. This was found to not only threaten local community livelihood but also a threat to Kenya's food security.

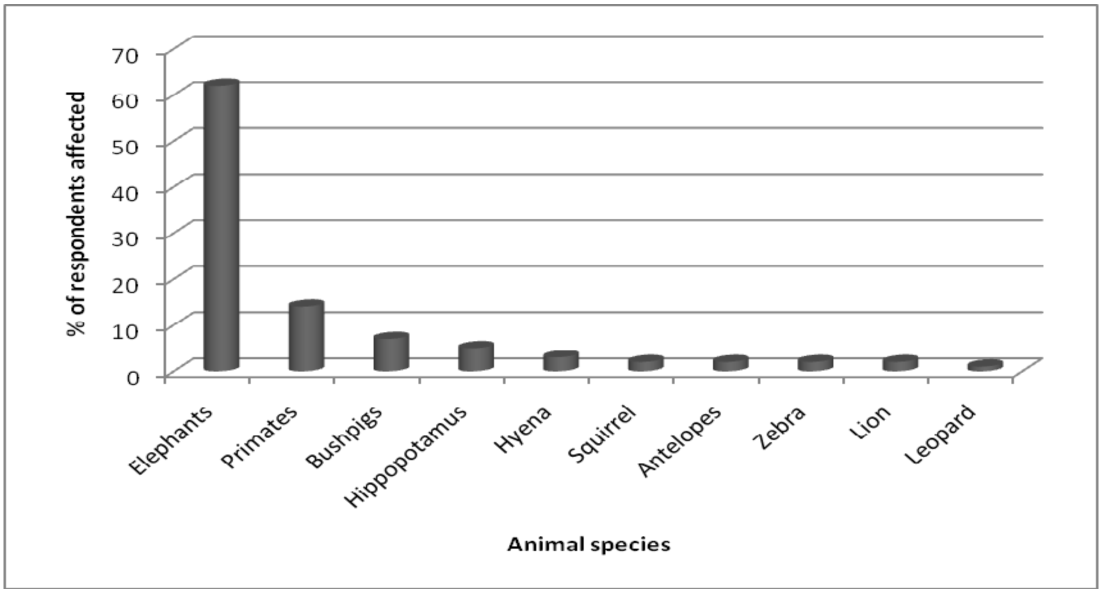


Figure 4.4: Percentage of species attacks on local communities

Figure 4.5 shows the species conflict hotspots. Species impact was not the same in all locations (χ^2 = 479.009, df = 91, p = 0.001). Elephants had the most wide spread area of coverage in Taveta district and their main hotspots were the rainfed agricultural zones of Chala, Nakruto, Mata, Kimala, Njukini and Timbila locations in decreasing magnitude respectively. Elephants were the only wildlife species of concern to local communities in Chala and Nakruto locations. Elephants avoided the irrigated areas of Kitobo and Mboghoni locations. This could partly be explained by the fact that, River Lumi which lies between the national park and the two locations could be posing a physical barrier for the elephants. In addition, elephants tend to avoid areas of intense human presence. For example; in similar studies by Sitati et al. (2005), crop raiding by elephants was found to differ significantly between farms and localities as influenced by variation in local physical and /or geographical factors, or by farmers' efforts to defend their farms. Likewise, Mbau (2006) studying elephant habitat use in the Aberdare ranges observed that, elephants avoided the sub-montane zones of the forest which had the highest levels of human activities. In addition, the two locations lay outside elephant migratory routes within the district.

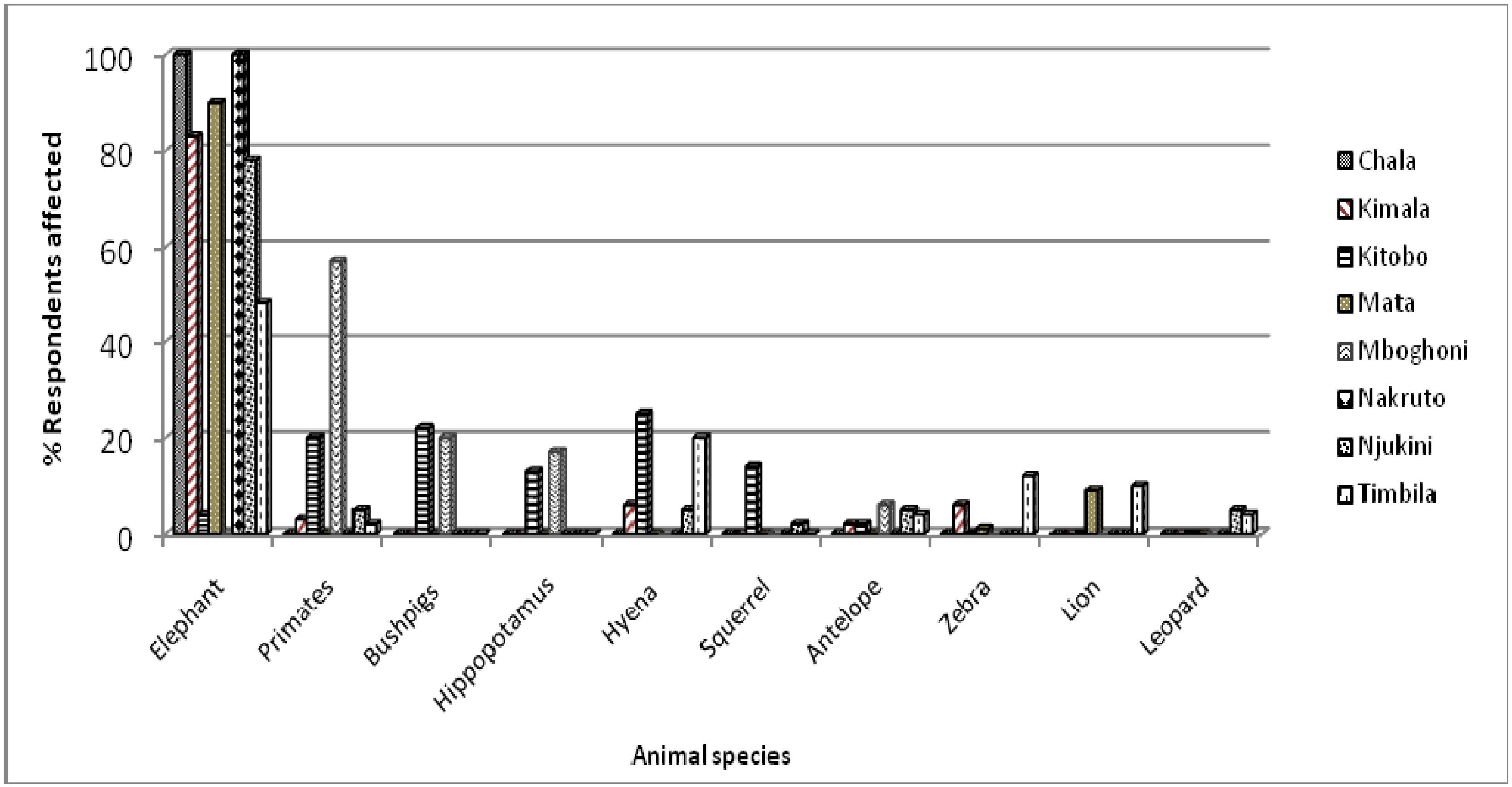


Figure 4.5: Species conflict hotspots in Taveta District

Mboghoni and Kitobo locations were hotspots for bushpigs, hippopotamus and primates. However, more farmers in Mboghoni experienced attacks from primates than in Kitobo location. Kitobo in addition is a hotspot for ground squirrels attacks. Hyenas (*Crocuta crocuta*), affected communities in Kitobo, Timbila, Kimala and Njukini in decreasing magnitude respectively, with greater attacks experienced mainly in Kitobo and Timbila locations. Hotspots for antelopes were mainly Mboghoni, Timbila and Njukini. Effects from zebras (*Equus quagga*) were mainly experienced in Timbila and Kimala locations. These locations lie adjacent to one another in Taveta district and may possibly be the preferred dispersal area for zebras from Tsavo West National park or could be offering important niche resources for zebras. Hotspots for lions (*Panthera leo*) were Timbila and Mata locations while leopards affected communities in Timbila and Njukini locations.

Of all the respondents interviewed, 9.4%, 31.5%, 23.2%, and 16.8% noticed conflicts 20-25, 15-20, 10-15 and 5-10 years ago, respectively. These comprised 80.9 % of the population sampled. Out of the 80.9% respondents, 50% noticed conflicts more than 15 years ago; therefore conflicts have been experienced in Taveta district for quite some time. However, it is possible this may have been influenced by the age of the respondents who noticed conflicts 10-15 years ago, who comprised a younger generation of the age group of 30's. In Taveta district, conflicts are not only caused by wildlife from Tsavo West National Park. Although majority of the respondents (59.7%) believed the animals came from Tsavo West National Park, 24.9% believed the animals resided within their land, while 13.6% believed the animals came from Kitobo forest and 2% believed the animals came from Tanzania. It is possible that animals are still occupying their former ranges and habitats which have been occupied by local communities and converted into farms. Such perceptions could influence how local communities respond to conservation initiatives especially around protected areas as well as tracing possible corridors used by migratory species such as elephants. As observed by 92.4 % of the sampled population, elephants, primates, bushpigs and antelopes raided farms in groups (Table 4.1). Primates and elephants formed groups of the largest sizes. Group raiding is a strategy that enhances access to food resources by wild animals and tends to intimidate farmers protecting their farms.

Table 4.1: Wildlife species that raided farms in groups and their mean group size

Animal Species	Mean Group size	Standard Deviation	Number of respondents (N)
Elephants	31.8	±11.33	166
Antelopes	17.1	±10.26	11
Primates	49.2	±18.58	44
Bushpigs	15.4	±6.39	25

NB: The high standard deviations are likely as a result of erros associated with community estimates of the group sizes, which did not adhere to standard procedures of animal counts.

Most of the attacks occurred at night except for the primates which raided predominantly during the day (Table 4.2). The preferred time of attacks differed significantly (χ^2 =296.16, df =18, p = 0.001) with most species preferring to attack at night. Bruce et al. (2003) made similar observation in reference to livestock attacks by carnivores around Tsavo East National Park. Elephant crop raiding during the day is not a common phenomenon but has been deemed to be a change of strategy for avoiding active problem animal controls. Similarly elephants have been observed to change crop raiding behaviour strategies to prefer raiding in groups instead of males only and raid both day and night (Danquah et al., 2006; Oppong et al., 2008).

Table 4.2: Preferred time (in %) of attacks by wildlife species

Species	Time of crop raiding/livestock attacks		
	Night	Day	Day and Night
Elephants	89.5	0.7	9.8
Antelopes	100	-	-
Primates	-	100	-
Bushpigs	96.2	-	3.8
Squirrels	28.6	-	71.4
Hyena	100.0	-	-
Leopards	100.0	-	-
Lions	100.0	-	-
Zebra	76.9	23.1	-
Hippopotamus	100	-	-

Primates and antelopes preferred the mature stages of crops (100%) while elephants attacked all stages of crop growth (44.4%, 33.3% and 22.2% for mature, middle stage and early stages of growth, respectively) as shown in table 4.3. There was a significant difference between crop parts eaten by the various species (χ^2 =217.63, df =30, p = 0.001) with majority of the species eating the cobs and stems. Elephants, primates and wildpigs reportedly showed a higher preference for cobs, while squirrels showed a higher preference for seeds. Oppong et al. (2008) observed that crop raiding by elephants targeted crops that were mature. Similar observations were made through Indigenous Ecological Knowledge (IEK) studies by Sitati and Ipara (2012) in Transmara where elephants showed high preference for mature and dry maize while they avoided farms with very young maize. Stems were the most preferred parts for the zebra, hippopotamus and the antelopes.

Table 4.3: Preferred parts of crops (in %) eaten by the various species of wild animals in Taveta district

	Cobs	Seedlings	Seeds /grains	Tubers/Bulbs	Stems	Fruits
Elephant	83.7	0	0	0	9.8	6.4
Antelope	30.0	10.0	20.0	0	40.0	0
Primates	47.7	15.9	2.3	0	15.9	18.2
Bushpigs	50.0	25.8	0	4.2	4.2	12.5
Squirrel	17.5	0	62.5	0	20.0	0
Zebra	0	0	0	0	50.0	0
Hippopotamus	15.4	6.2	0	7.7	55.4	7.7

Carnivores attacked livestock in five out of the eight locations sampled (Figure 4.6). Overall, goat and sheep were more frequently attacked by hyena and leopards, while lions frequently attacked cattle and goats at equal magnitude. Donkeys were attacked in Timbila location and by lions only. Attacks by hyena occurred in four out of the five locations and were the highest, making it a species to watch out for in setting strategies for controlling livestock depredation. In Laikipia district, hyenas were also observed to be a key species for livestock depredations with goats being most affected (Kagiri, 2004). In the contrary, Bruce et al. (2003) observed that lions were a key species responsible for most of the livestock attacks in two ranches around Tsavo East National Park, followed by hyenas. The hotspots for leopards were Njukini and Timbila locations. Timbila location also couples as a hotspot for lions in addition to Mata locations. Livestock depredation differed significantly between the location (χ^2 =14.87, df = 4, p = 0.005).

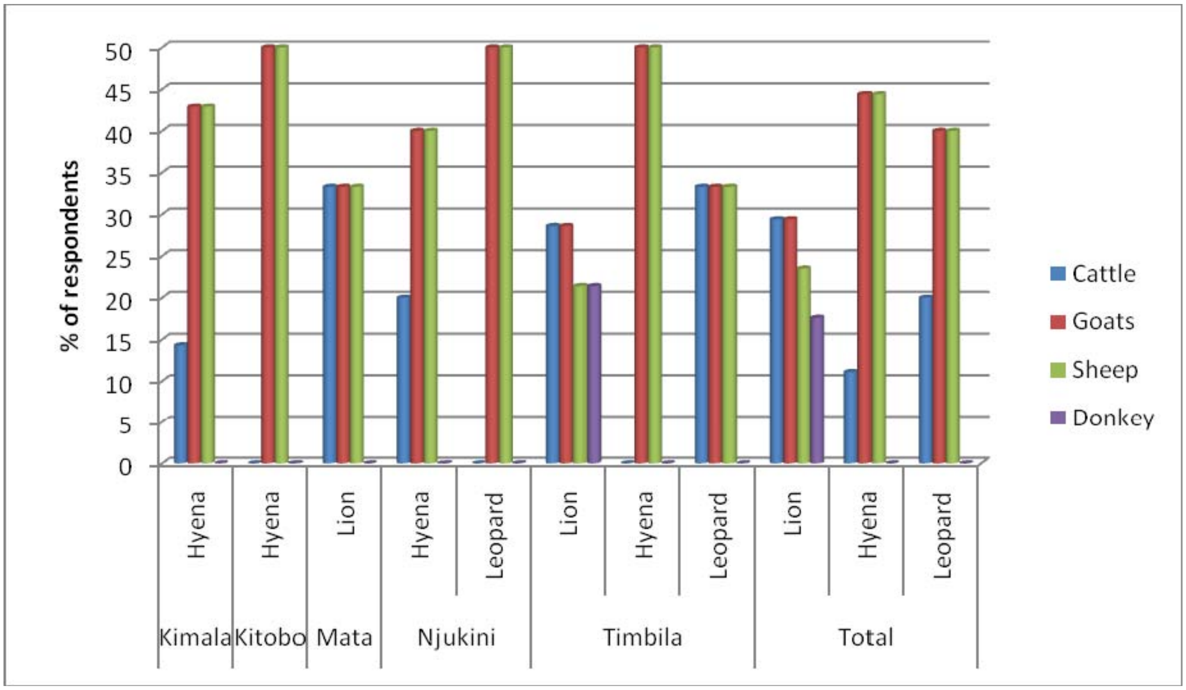


Figure 4.6: Distribution of wildlife-livestock attacks in Taveta district

Livestock depredation in this district is a drawback especially to the pastoral communities found in Mata and Kimala locations as well as parts of Njukini and Timbila locations. Such livestock losses act as a trigger mechanism that will lead to increased persecution and killing of carnivores by the pastoral community as their livelihoods gets threatened.

Figure 4.7 and 4.8 presents the crop preferences of elephants and bushpigs which were among the top three species. Crop preference for the primates which came second was not determined since a number of species were involved and therefore could not be generalized. Maize was the preferred crop for both species. Studies done in Laikipiaand Narok have shown that within the elephant preference range, maize is the most preferred crop especially when it is the predominant crop planted (Kagiri, 2004; Sitati et al., 2005). Oppong et al. (2008) showed that farms that had maize and cassavas were likely to be raided compared to farms with vegetables, bananas and sugarcane.

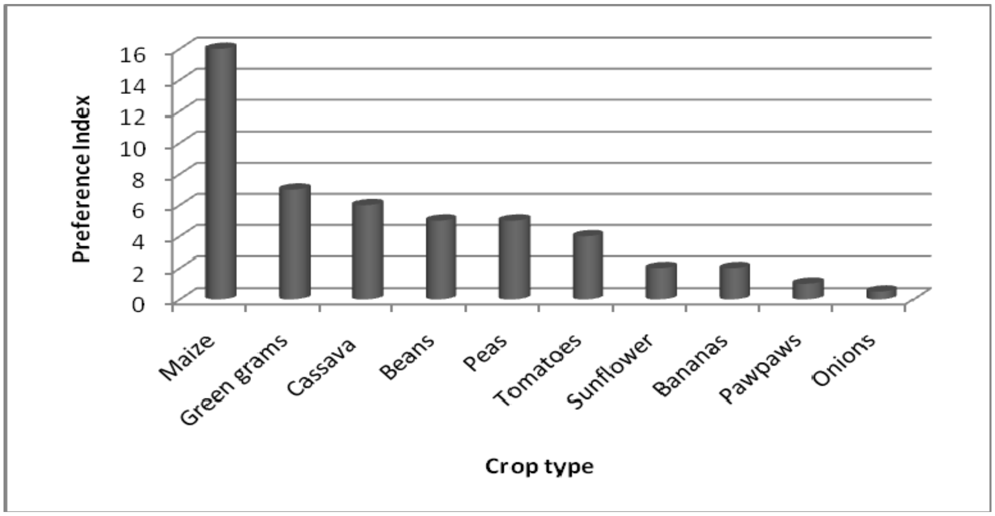


Figure 4.7: Crop preference by elephants

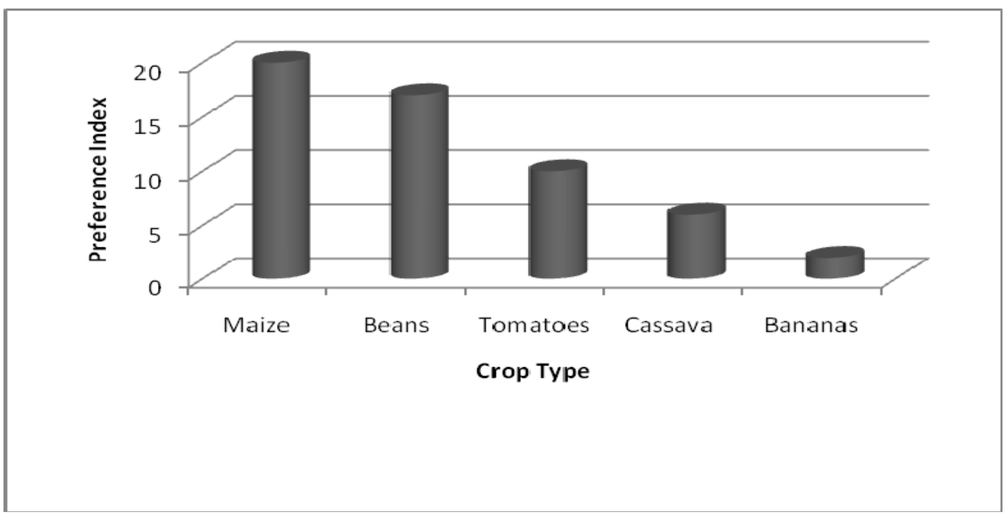


Figure 4.8: Crop preference by bushpigs

Crop preference for bushpigs was similar to studies done by Kagoro-Rugunda (2004) in Uganda where; Cassava, maize, and bananas where among the preferred crops. Although wild animals preferred farms with 3 to 4 types of crops there was no strong relationship between the number of crop types and farms attacked by wild animals as indicated by the low value of the Coefficient of Determination (R^2 = 0.07). These results are, however, different from those obtained by Moses et al. (2005) in Bia Conservation Area of Ghana where crop raiding incidents by elephants increased with the number of different crop types grown in a given farm. Considering that herbivores prefer to maximize on feeding efficiency (feeding on a patch that offers more benefits), small farms with many crops may not have offered them this opportunity. However, while comparing crop preference and raiding of farms in different areas, it is worth noting that this is highly influenced by landscape characteristics and configuration which determines animal habitat selection (Hoare, 1999; Treves et al., 2004; Kretser, 2008; Shota and Takuhiko, 2011). Okello (2005a) also observed that, impacts from wildlife were not related to the types of crops grown but more so to the type of land use practiced. However, planting diverse crops in their farms could be one of the strategies that farmers need to employ to increase their food security at the same time reducing their probability of crop raiding. Other options include planting crops that are less palatable to wild animals such as cotton and coconuts.

Losses to wildlife crop damage in the study area were high as depicted in tables 4.4 and 4.5. Farmers sampled lost estimated costs of eight million six hundred sixty six thousand two hundred and twenty Kenya shillings. Such kinds of losses serve to increase local community vulnerability while enhancing food insecurity. Elephants are a real challenge to farmers in Taveta district. More than half of the cultivated area in all the farms attacked by elephants was destroyed (Table 4.5). In similar studies in Africa, elephants were also found to be the main challenge facing farmers within their ranges (Kagiri, 2004; Okello, 2005a; Moses et al., 2005; Sitati et al., 2007; Oppong et al., 2008; Wakoli and Sitati, 2012). Most of the farmers are small scale farmers owning small farms of about one acre. Majority of them planted maize, beans, peas, green grams, cassava, tomatoes, millet and bananas. While majority of farmers planted maize in farms between 1.5 and 2 acres, beans were planted mainly in farms less than half an acre. Although pawpaws, sugarcane, oranges and mangoes were planted by few farmers within the elephant range in Taveta district, such farmers experienced huge losses as these were highly damaged. The fact that farmers own small farms increases their vulnerability to food insecurity and the impacts of crop raiding.

Table 4.4: Household crop losses from wildlife damage between June and October 2012

Crop type	N	Mean cost of losses per household	Total cost (KSHs)
Maize	225	12565	2827220
Beans	145	10414	1510080
Tomatoes	52	30260	1573500
Peas	36	10206	367400
Bananas	37	18895	699100
Green grams	68	12526	851800
Onions	4	67500	270000
Sunflower	9	3689	33200
Cassava	10	4720	47200
Pawpaw	1	3500	3500
Sugar cane	3	12333	37000
Millet	14	9157	128200
Rice	7	36074	252520
Cotton	2	11400	22800
Oranges	1	12000	12000
Mangoes	4	7675	30700
Total			**8666220**

Estimation units:

Mangoes, Oranges, Pawpaws, Tomatoes, Cassava, Onions = Crates.

Bananas = Bunches; Sugarcanes = Tons; Rice = 100kg bags; Cotton = Bales; Millet = 20kgs bags; Maize, Beans = Kgs; Peas = 5 Kg bags; Green grams = 2Kg packets; Sunflower = 2Kg packets.

Table 4.5: Relationship between extent of damage and acreage of each crop in the farm by elephants

	Acreage of each crop in the farm (Acres)													
Farm sizes	<0.5		0.5-1.0		1.0-1.5		1.5-2.0		2.0-2.5		2.5-3.0		>3.0	
Crop type	Mean Area	Count	Mean Area	Count	Mean Area	Count	Mean Area	Count	Mean Area	Count	Mean Area	Count	Mean Area	Count
Maize	0.39	23	0.71	39	-	0	1.39	76	1.50	2	2.10	15	-	0
Beans	0.30	36	0.56	29	-	0	1.16	8	2.00	1	-	0	-	0
Tomatoes	0.35	12	0.57	7	-	0	0.92	3	-	0	-	0	3.00	1
Pigeon peas	0.38	17	0.79	17	-	0	1.67	3	-	0	-	0	-	0
Bananas	0.35	11	0.46	6	0.50	1	-	0	-	0	-	0	-	0
Green grams	0.33	24	0.63	30	-	0	1.39	7	0.25	1	-	0	-	0
Onions	0.25	3	0.58	3	-	0	0.50	1	-	0	-	0	-	0
Sunflower	0.27	9	0.63	4	-	0	-	0	-	0	-	0	-	0
Cassava	0.30	20	0.48	10	-	0	-	0	-	0	-	0	-	0
Pawpaw	0.50	1	0.63	2	-	0	-	0	-	0	-	0	-	0

Sugarcane	0.27	3	0.75	1	-	0	0.50	1	-	0	-	0	-	0
Millet	0.29	12	0.70	5	-	0	-	0	-	0	-	0	-	0
Oranges	0.25	3	-	0	-	0	-	0	-	0	-	0	-	0
Mangoes	0.26	4	0.75	1	-	0	-	0	-	0	-	0	-	0

The results obtained in this study are similar to those of Oppong et al. (2008). In their study, for the individual farms sampled, the risk of a farm suffering damage was found to increase with the diversity of food crops on the farm. In this study, at the individual farm level, the risk of a farm being raided increased with the diversity of crop types to a maximum of four above which the risk started to decrease. To avoid being easily singled out by elephants, then, increasing the diversity of crops in their farms may be one of the strategies that farmers may have to adopt.

Generally, elephant crop damage in the district is high. Such crop damage occasioned by wild animals has the potential to influence local community attitude towards the species concerned or wildlife conservation in general as observed in the district. Local community attitude towards wildlife was not encouraging, with 72.3% of the people interviewed having a negative attitude and 22% having very negative attitude towards wildlife. Only 0.3% had a positive attitude towards wildlife while the remaining 5.3% were neither negative nor positive. Local community attitudes towards conflict causing wildlife species are summarized in Figure 4.9.

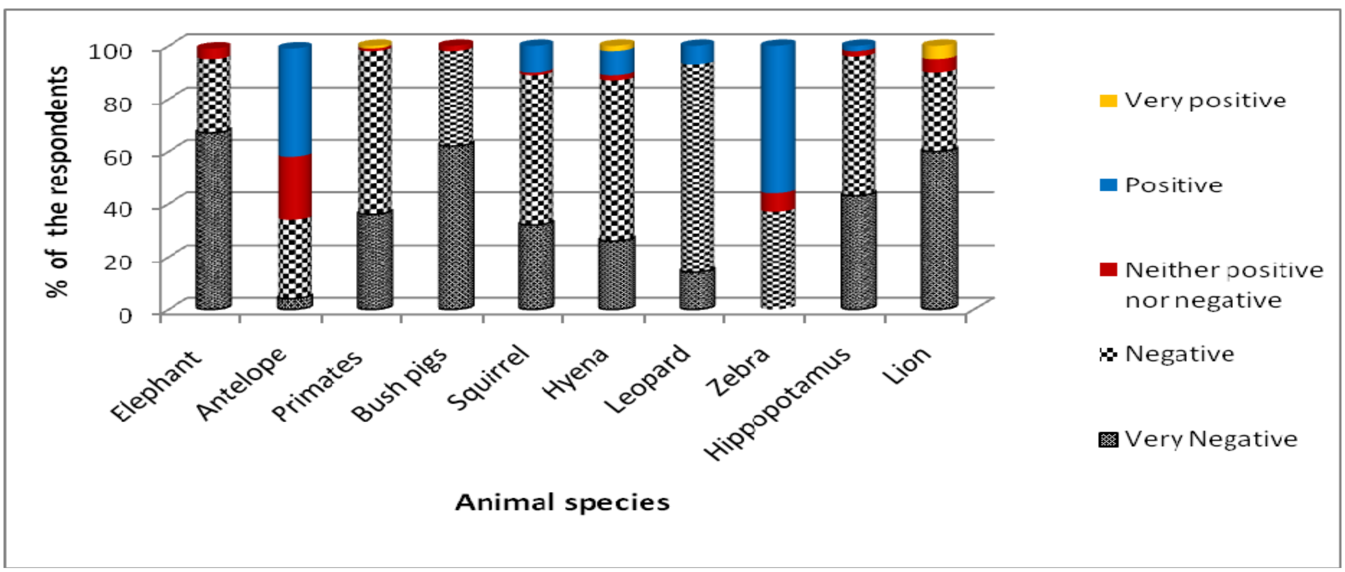


Figure 4.9: Local community attitudes towards conflict causing wildlife species

Except for the antelopes and zebra, local community attitude towards conflicts causing species weighed more heavily on the negative and very negative sides. More than 50% of the respondents had very negative attitude towards elephants, bushpigs and lions, while similar percentages were observed as having negative attitudes towards hippopotamus, leopards, hyena squirrels and primates. With such negative attitudes, local community participation towards their conservation may become compromised since communities tended to view them as pests that made their livelihood difficult yet they received no direct benefits from them. In concurrence with this, 40% of the local community sampled voted construction of the electric fence as the first option the Kenya Wildlife Service needed to implement to separate people from the wildlife. This was followed by moving the other animals back to Tsavo West National Park (28%), compensation (15%), Killing of the wild animals (8%), relocation of elephants (5%) and increase KWS camps at the park boundary (4%) as the other preferred options respectively for mitigating conflicts. In a similar study, Okello (2005a) observed that losses from animals led to lack of support towards free-roaming wildlife and increased local community resentment to wildlife. In this study, local community attitudes could also, however, be explained by the nature of their interactions with the wildlife authority. For example; 99% of the respondents indicated that, they have never been compensated for any damages caused by wildlife. In addition 97.9% of the respondents were not happy with the response by the wildlife authority to their complains on wildlife conflicts.

4.5 Conclusions and Recommendations

Human-wildlife conflicts have the potential to disrupt local community livelihood support systems and are thus an issue of concern in Taveta district. These conflicts are a challenge that undermines community livelihoods and will need to be dealt with. This will have several advantages in that; it will not only improve the status of food security in the district, but will also reduce poverty levels, improve the chances of survival of the species involved and community attitudes towards the species. Mitigating the conflicts will be a sure way of adding value to wildlife for the benefit of mankind and more so the local community bearing the cost of wildlife conservation in the district. Conflicts will need to be addressed per every location depending on the level of impact and the wildlife species causing the conflicts. There is need to characterize the hotspots with regards to their social and ecological characteristics in addition to livelihood systems that may foster conflicts in order to come up with the appropriate strategies for conflict mitigation.

Elephants are a key species that affects communities in six of the eight locations sampled. As a result majority of the local community have a very negative attitude towards elephants. Due to the widespread effects of this species, and the fact that the species currently faces challenges of poaching within this agro-ecosystem, there is need to investigate further and quantify the actual losses incurred by local communities as a result of elephants, enhance community awareness on the conservation status of this species and come up with mechanisms that will incorporate the local communities to participate in its conservation. Conflicts due to elephants thus need to be prioritized in trying to ameliorate Human-wildlife conflicts in this district. However, this should not undermine the cost of Human-wildlife conflicts in the irrigated zones of Kitobo and Mboghoni which are the grain basket for the district. Strategies for managing conflicts occasioned by the different types of species need to be designed and implemented. This should however benefit from incorporating local communities in strategy design. Community involvement will most likely increase the chances of uptake of strategies agreed upon despite their negative attitudes towards conflict causing wildlife species. Community wildlife education through seminars, study tours and workshops will be necessary to increase their knowledge about wildlife.

Maize is the most preferred crop type by the top three wildlife conflict causing species in this district. Apparently it is produced for domestic (as the main staple food) and commercial purposes. To reduce the impact experienced due to maize loses and increase their food security, local communities need to be encouraged to plant alternative crops that are less palatable to these wildlife species. The crops can be produced for commercial purposes to avail money with which local communities can purchase their food. In addition, it is also important to identify and encourage alternative livelihoods to farming, especially in areas where conflicts are high and those of low crop production potential. Diversification of income generating programmes will also be necessary. This will create a win-win situation where wild animals can range freely while communities are able to secure their livelihoods.

Livestock depredation affecting the pastoral communities also needs to be brought under control. Livestock depredation has been found to trigger killing of wildlife in addition to reducing the value of pastoral livelihood systems. Pastoralism is, however, one of the compatible land uses within wildlife ranges and its sustainability in Taveta district will need to be examined and the challenges addressed. Water is a key resource competed for by wildlife and livestock in the main pastoral zones. The Kenya Wildlife Service will need to increase water supply to wildlife within the park to reduce competition for water especially in Kimala and Mata locations which are the main pastoral zones in Taveta district that also border Tsavo West National Park. This will reduce opportunities for livestock depredation which also happens in watering places other than at night. At the same time, it will increase the value of pastoral livelihoods in this district and contribute to a reduction in the current trends of changing lifestyles of the pastoral communities to agro-pastoralism. There is need to investigate the spread of diseases from wildlife as a problem in Kitobo and Timbila Locations. This could have profound effects on the local community health and livestock if left unchecked.

Since competition for resources is a reality that calls for strategic planning and proactive conservation initiatives, conflicts will need to be confronted, managed and monitored in this district. This will need to be done at the species level so as to develop appropriate strategies relevant for each species. One of the most plausible approaches for long-term sustainability is land use planning. There is need to identify and categorize the district into ecological zones with respect to conservation, agriculture and other land uses. In addition there is need to develop a regional land use policy to regulate cultivation within the elephant ranges, especially in areas that have poor agricultural potential. However, this will benefit from an analysis of land use change as one of the principal factors known to influence Human-wildlife conflicts. A land use change analysis will avail baseline information on which land use planning can be based on, in order to cater for conservation and local community livelihood needs.

CHAPTER 5

5.0 LAND USE AND LAND COVER CHANGES AND THEIR IMPLICATIONS ON HUMAN-WILDLIFE CONFLICTS IN TAVETA DISTRICT, SOUTHERN KENYA

5.1 Abstract

Land use and land cover changes are important processes that influence the ecological integrity of wildlife dispersal areas and the dynamics of Human-wildlife conflicts in rangelands around protected areas. This study investigated trends in both land use and land cover changes in Taveta district. Remote Sensing imageries for Taveta District were analysed for the years 1987, 2001, and 2011. Percentage changes in land use and land cover types for the years 1987-2001, 2001-2011 and 1987-2011 were determined. Between 1987-2011, significant ($p < 0.05$) changes occurred in woodlands, sisal plantations, rainfed and irrigated agricultural areas. Shrublands, forests and water bodies showed no significant changes. Wildlife habitats are expected to further decrease significantly due to agricultural expansion. Land use and cover changes were as a result of agricultural expansion and human population growth. The land use and cover maps produced can be used as input to decision making that balances restrictions on human land use while maintaining the ecological function of the landscape, through designation of Zones of Interaction as a first step to identifying opportunities that satisfy conservation and livelihood needs. Proper land use planning and community awareness on the implications of these land use and land cover changes are necessary.

Key words: Land use change, land cover change, Rangelands, Taveta district, Human-wildlife conflicts.

5.2 Introduction

In developing countries, most of the human population depends almost entirely on natural resources for their livelihoods. Thus there exists increasing competition between utilization and sustainable management of land resources resulting into land use and land cover changes over a given period of time. Worldwide, land cover change has been occasioned by changes in the way people use and manage land (Millennium Ecosystem Assessment (MEA), 2005a). This arises mainly from the direct effects of population growth such as agricultural expansion, grazing and land for settlement as well as indirect effects of pollution (UN/ECE, 2002; MEA, 2005b).

Many protected areas are too small to independently support viable wildlife populations and therefore rely on surrounding areas to provide forage and water resources, breeding grounds, and mating opportunities (Newmark, 1993; Wishitemi and Okello, 2003; Okello and Wishitemi, 2006). The presence of dispersal areas and migration corridors around protected areas is critical to successful wildlife conservation. However, most protected areas are subject to livelihood-based activities from local communities living in and around them. Although park managers have little authority over the surrounding landscape, land use change and infrastructure development can have major impacts on the integrity of the protected area. The need for scientifically-based regional-scale land use planning around protected areas is acute in human-dominated landscapes to balance conservation goals with livelihood needs for fuel wood, fodder, and other ecosystem services (DeFries et al., 2010).

While Kenya’s population growth remains high at 2.9% p.a (Republic of Kenya, 2009), its population growth has mainly been associated with expansion of agricultural activities into drier landscapes (Gobin et al., 2001; MEA, 2005a; Okello, 2005a; Kioko and Okello, 2010; Baaru, 2011). Human activities are currently subjecting ecosystems to the highest rates of change that have ever been recorded for large regions (FAO, 1996; MEA, 2005b), and Kenya’s drylands have not been spared either. Kenya’s drylands, which occupy about 80% of the lands surface, have undergone tremendous changes in land use and land cover (Okello and Kioko, 2010). Although rangelands outside protected areas are utilized by wildlife to maximize their daily and seasonal forage requirements, these grazing areas for livestock and wildlife have declined over time through land fragmentation, occasioned by subdivision of group ranches and leasing of land to newcomers/immigrants practicing agriculture (Kioko and Okello, 2010). This scenario coupled with the changing lifestyles of the pastoral communities within the rangelands has resulted in tremendous changes in land use and land cover over the years. Information on land-use and land cover changes and their drivers may provide a better understanding of land utilization, and play a vital role in the formulation of policies and programmes required for development planning at both local and national levels (Dovie et al., 2005; Palmer et al., 2005).

Kenya's economy, like many other developing countries is based on agriculture and a large percentage of its populace depends on natural resources for their survival leading to varying impacts on its natural resources. In the Arid and Semi-Arid areas comprising some of the southern rangelands in the country, the impacts of land use and land cover change have not been well documented and quantified. Such data becomes necessary in planning and for projecting the consequences of these changes on the conservation of natural resources, and their sustainable management (Petit et al., 2001; Kioko and Okello, 2010). Taveta district has been experiencing intensification of Human-wildlife conflicts for resources, which are also considered the third factor that has contributed to poverty in the district (Kamande, 2008; Republic of Kenya, 2011). No work has been done in the district to establish spatial-temporal changes in land use and land cover. This study therefore sought to analyze trends in land use and land cover and human population growth, and establish their possible contribution to Human-wildlife conflicts experienced in Taveta district. Land use and land cover changes were analysed from multi-temporal images and ground truthing data, with a view to understanding the dynamics of land use and land cover changes from 1987 to 2011 in the district.

5.3 Materials and Methods

5.3.1 Study area

The study area is as described in Chapter 3.

5.3.2 Land use and land cover changes analysis

Satellite data was analysed in conjunction with ground truth observation as proposed by Chakraborty (2001). Using a Geographic Information System (GPS), points corresponding to the various land uses and land cover forms where recorded as forest, rainfed agriculture, irrigated agriculture, shrublands, woodlands, sisal plantations and water bodies. Jenson (1986) recommends the use of at least two time-period data sets to detect changes in land use and land cover. In this study three time period Landsat images i.e., one Thematic Mapper (5TM), and two Enhanced Thematic Mapper plus (7 ETM+), one for 2001 and another for 2011, for study area for the years 1987, 2001 and 2011 were analysed. The images were downloaded from USGS Global Visualization Viewer (GLOVIS) URL: http://glovis.usgs.gov. Two of the images used in the analysis (1987 and 2011) were for the month of February while the 2011 image was for early March. Both time periods coincide with the dry season to avoid uncertainties.

5.3.2.1 Image classification

Land use and land cover maps where developed from the satellite images through defining spectral classes by clustering image data and assigning pixels into classes. Multi-temporal Landsat data processing was done using ENVI 4.7 software (ESRI, 2009). Regions of Interest (ROI) were defined to extract statistics for classification. Supervised classification was used with false colour composite (Bands 4, 3, 2) bands to cluster pixels in a dataset into classes corresponding to the selected ROI. Mahalanobis distance classification methods were used to classify the images. Seven land use and land cover types were classified according to Anderson (1998) guidelines as forests, irrigated agriculture, rainfed agriculture, woodlands, shrublands, sisal plantations and water bodies.

5.3.2.2 Change detection

Change detection was done for the classified land use and land cover types. ENVI EX Software (ESRI, 2009) was used for thematic change detection by comparing two images of different time periods (1987 and 2001 images, 2001 and 2011 images). This resulted into classification images and statistics. The resultant statistics were analysed for land use and land cover changes and their percentage changes calculated using Excel software. Overall land use and land cover change statistics were calculated from the 1987and 2011 statistics.

5.3.3 Human population trends

Data on human population trends spanning the years 1969, 1989, 1999 and 2009 was collated from the Kenya National Bureau of Statistics (Republic of Kenya, 2009). This was compared to the land use change data to establish if there was any relationship between land use change and human population trends.

5.3.4 Projections for land use and land cover trends

Data for the analysed trends in land use and land cover were used to project future trends for a ten year period. The assumptions were that the status quo remains, i.e., no new interventions and/ or relevant policy changes or implementations are done, same human population growth rate and all other factors remain constant.

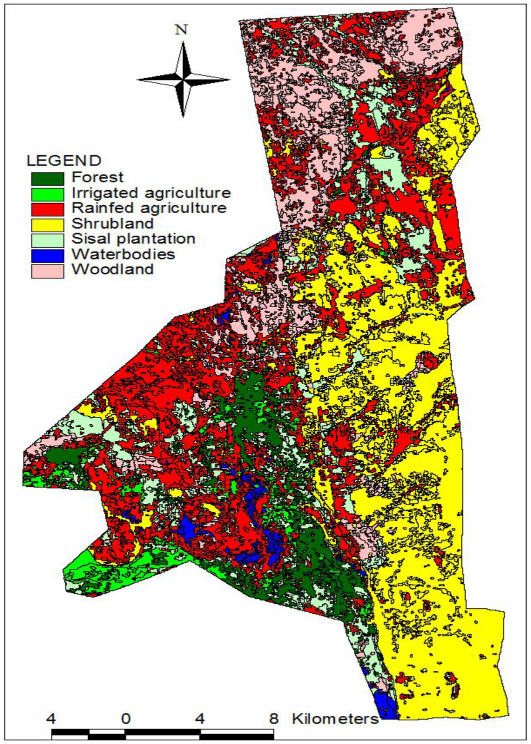
5.3.5 Data analysis

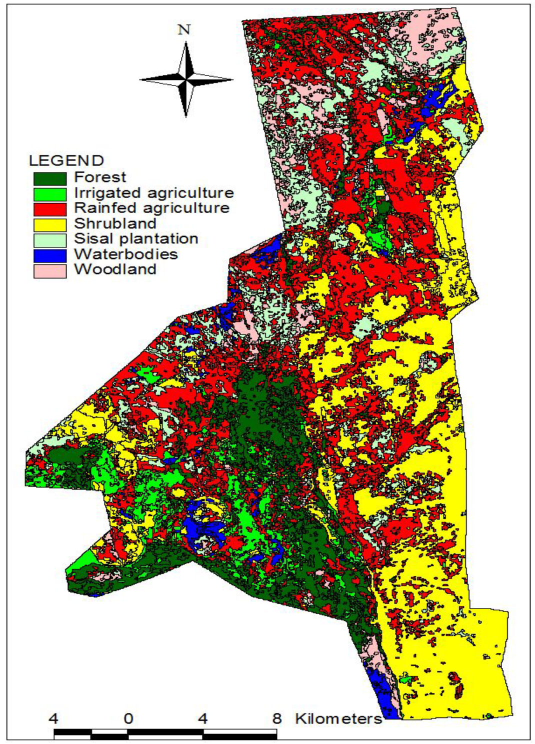
The area of land under different land uses and cover was used to calculate percentage changes in land use and land cover using Excel software. Overall land use and cover changes were calculated from the 1987and 2011 statistics. Chi-square goodness of fit was used to determine if there were significant changes in land use and land cover. The relationship between land use change and human population growth with time and future projections of land use and cover changes were established through linear regression analysis (Zar, 1996).

5.4 Results and Discussion

5.4.1 Land use and cover changes between 1987and 2011

Seven land use and land cover types and their dynamics were discriminated as forests, irrigated agriculture, rainfed agriculture, shrublands, woodlands, sisal plantations and water bodies as shown in the classified land use and land cover maps below (Figures 5.1, 5.2 and 5.3).





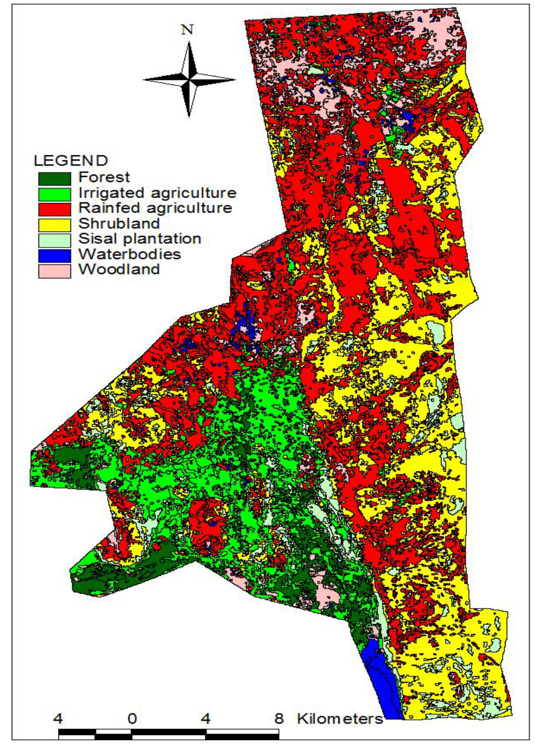


Figure 5.1: Land use and land cover (1987) **Figure 5.2: Land use and land cover (2001)** **Figure 5.3: Land use and land cover (2011)**

By 1987, irrigated agriculture was confined to the far eastern part of the district from where it has continued to expand directly replacing forests. The most drastic expansion occurred between 2001 -2011.

The area of each land use and land-cover class for the three time periods and their percentage changes were analyzed as shown in Table 5.1. Between 1987 and 2001, major changes were observed mainly in forests, irrigated agriculture, woodlands and water bodies. In the subsequent time period (2001 to 2011), major changes occurred in the forests, irrigated agriculture, sisal plantations and water bodies. While forest cover increased by 117.2% by 2001, it decreased by 58.88% by the year 2011. The overall change in forest cover between the three time periods was a 10.69% decrease. Compared to all the other land use and land cover types, forest cover size showed the least overall changes. The area under woodland cover decreased by 58.2% by 2001 and gained by 8.66% by 2011. The overall change was however a decrease by 54.57%. The area under cultivation increased over the three time periods by 299.4%. However, marked increase was observed for irrigated agriculture since 1987 culminating with a 268.6% overall increment by the year 2011. Sisal plantations decreased by 50.19 % overall, especially between 2001 and 2011. Water bodies showed the second least overall changes with an increase of 18.87%. The decrease in woodland and shrublands occurred mainly between 1987 and 2001, while water bodies, sisal plantations and forests decreased mainly between 2001 and 2011, a time during which both forms of agriculture experienced the highest levels of increase.

Table 5.1: Land use /cover change (Km^2) in Taveta District between 1987 and 2011

	1987		2001		2011		Change (1987-2001)		Change (2001-2011)		Overall change (1987-2011)	
Land use / Land cover	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
Forest	38.06	5.85	82.67	12.7	34	5.23	44.6	117.2	-48.7	-58.88	-4.07	-10.69
Woodland	96.23	14.8	40.23	6.19	43.72	6.72	-56	-58.2	3.48	+8.66	-52.52	-54.57
Shrublands	215.61	33.16	179.39	27.60	178.66	27.5	-36.2	-16.8	-0.73	-0.41	-36.95	-17.14
Rainfed Agriculture	191.26	29.42	213.74	32.9	250.16	38.5	22.49	11.76	36.41	+17.04	58.9	+30.8
Irrigated Agriculture	25.84	3.97	44.94	6.91	95.25	14.7	19.09	73.89	50.32	+111.97	69.41	+268.6
Sisal plantations	73.09	11.24	73.2	11.3	36.41	5.6	0.11	0.15	-36.8	-50.26	-36.68	-50.19
Water Bodies	10.1	1.55	16.03	2.47	12.01	1.85	5.93	58.69	-4.02	-25.09	1.91	18.87

5.4.2 Land use and cover transformation between 1987-2001

Table 5.2 shows the dynamics of land use/cover change between 1987 and 2001. Forests increased at the expense of mainly sisal plantations and in areas under irrigated and rainfed agriculture. Woodlands decreased as they were converted to rainfed agriculture, sisal plantations and degraded to shrublands. The conversion of woodlands, shrublands and sisal plantations saw the area under rainfed agriculture increase. Shrublands were also converted to sisal plantations. Irrigated agriculture expanded to areas under rainfed agriculture, sisal plantations, forests and water bodies. Sisal plantations remained more or less the same. During this period water bodies increased mainly in areas under rainfed agriculture.

Table 5.2: Percentage Land use/cover converted to other land uses between 1987 and 2001

Land use / land cover	% Acreage gained from the conversions by the various land use / land cover types						
	Forest	Woodland	Shrubland	Rainfed Agriculture	Irrigated Agriculture	Sisal	Water bodies
Forest	0	0.07	0.03	0.28	0.24	0	0
Woodland	0.6	0	0.18	2.71	0.04	2.64	0.08
Shrubland	0.15	0.03	0	4.23	0.2	1.02	0
Rainfed agriculture	1.2	0.6	1.98	0	1.96	2.0	0.7
Irrigated agriculture	1.14	0.05	0.03	0.23	0	0.03	0.02
Sisal plantations	1.16	0.24	0.5	2.65	0.4	0	0.06
Water bodies	0.02	0.04	0.05	0.12	0.18	0.00	0

5.4.3 Land use and cover transformation between 2001 and 2011

Forest cover decreased mainly due to expansion of irrigated agriculture, followed by degradation of forests to woodland and conversion to rainfed agriculture. Irrigation agriculture also expanded at the expense of rainfed agriculture. Some areas under rainfed agriculture were abandoned leading to development of shrublands. Land under woodlands and shrublands was mainly brought under rainfed agriculture. Sisal plantations were converted mainly to rainfed agriculture, followed equally by displacement by shrublands and woodlands (Table 5.3).

Table 5.3: Percentage Land use/cover converted to other land uses between 2001 and 2011

Land use / land cover	% Acreage gained from the conversions by the various land use / land cover types						
	Forest	Woodland	Shrubland	Rainfed Agriculture	Irrigated Agriculture	Sisal	Water bodies
Forest	0	0.47	0.18	0.37	3.3	0.1	0.01
Woodland	0.08	0	0.11	1.1	0.05	0.01	0.44
Shrubland	0.02	0.03	0	2.5	0.19	1.97	0
Rainfed agriculture	0.21	0.86	2.93	0	1.99	0.31	0.2
Irrigated agriculture	0.15	0.07	0.59	0.32	0	0.4	0.01
Sisal plantations	0.04	0.65	0.65	4.36	0.15	0	0
Water bodies	0	0	0.2	0.79	0.04	0	0

To determine whether the observed land use/cover changes were significant, results of chi square goodness of fit test are as shown in table 5.4. The most significant changes ($p = 0.001$) were observed in irrigated agriculture, sisal plantations and woodlands. Likewise, rainfed agriculture followed with a significant increase ($p = 0.015$). Decrease in shrublands cover ($p = 0.092$), water bodies ($p = 0.479$) and forests ($p = 0.836$) were not significant.

Table 5.4: Chi-Square goodness of fit test for the various land use /cover changes in Taveta district between 1987 and 2011

Land cover type	1987 (Km^2)	2001 (Km^2)	2011 (Km^2)	% change in land use cover	χ^2 Goodness of fit test
Forest	38.06	82.67	34	-10.69	χ^2 = 0.359, df = 2, p=0.836
Woodland	96.23	40.23	43.72	-54.57	χ^2 = 32.533, df = 2, p=0.001
Shrubland	215.61	179.39	178.66	-17.14	χ^2 = 4.770, df = 2, p=0.092
Rainfed Agriculture	191.26	213.74	250.16	30.8	χ^2 = 8.101, df = 2, p=0.015
Irrigated Agriculture	25.84	44.94	95.25	268.6	χ^2 = 45.916, df = 2, p=0.001
Sisal plantations	73.09	73.2	36.41	-50.19	χ^2 = 15.044, df = 2, p=0.001
Water bodies	10.1	16.03	12.01	18.87	χ^2 = 1.474, df = 2, p=0.479

5.4.4 Human population trends

Human population increase in the district was steady and strongly related to time (Figure 5.4). Although human population increased throughout the four time periods, a sharp increase occurred between 1989 -1999 compared to all other time periods. Overall, the study area has a population growth rate of 2.94 % p.a and a population density of 104.5 individuals per Km^2 (Republic of Kenya, 2009).

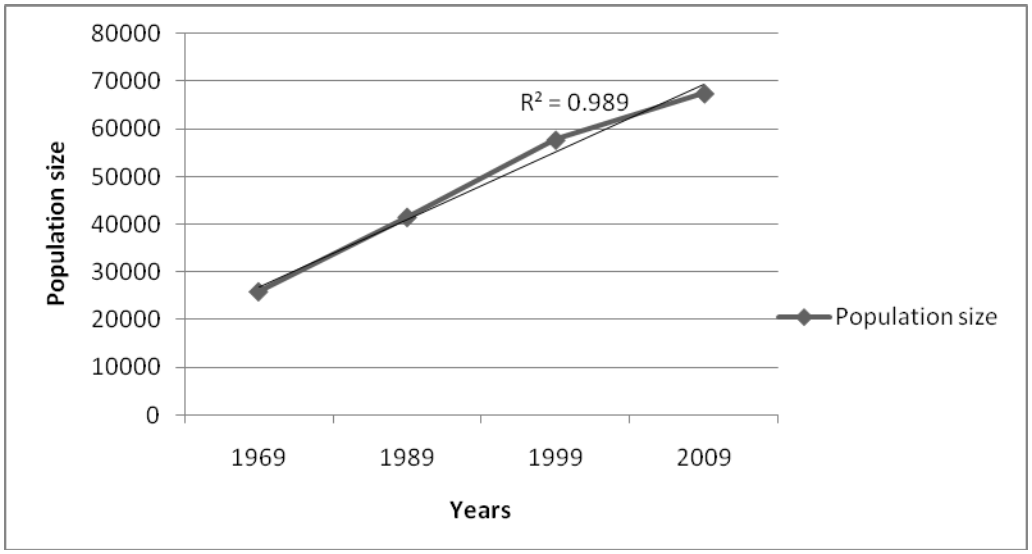


Figure 5.4: Human population trends in Taveta District between 1969 to 2009
Compiled from Kenya National Bureau of Statistics (KNBS)

5.4.5 Projections for land use and land cover trends

Ten year projections for land use and land cover changes are shown in Figure 5.5. Agriculture is expected to increase tremendously while habitats suitable for wildlife and livestock are expected to decrease further, e.g., woodlands will almost be decimated while shrublands will continue to decrease. Forest cover is expected to show no changes while sisal plantations are expected to decrease further.

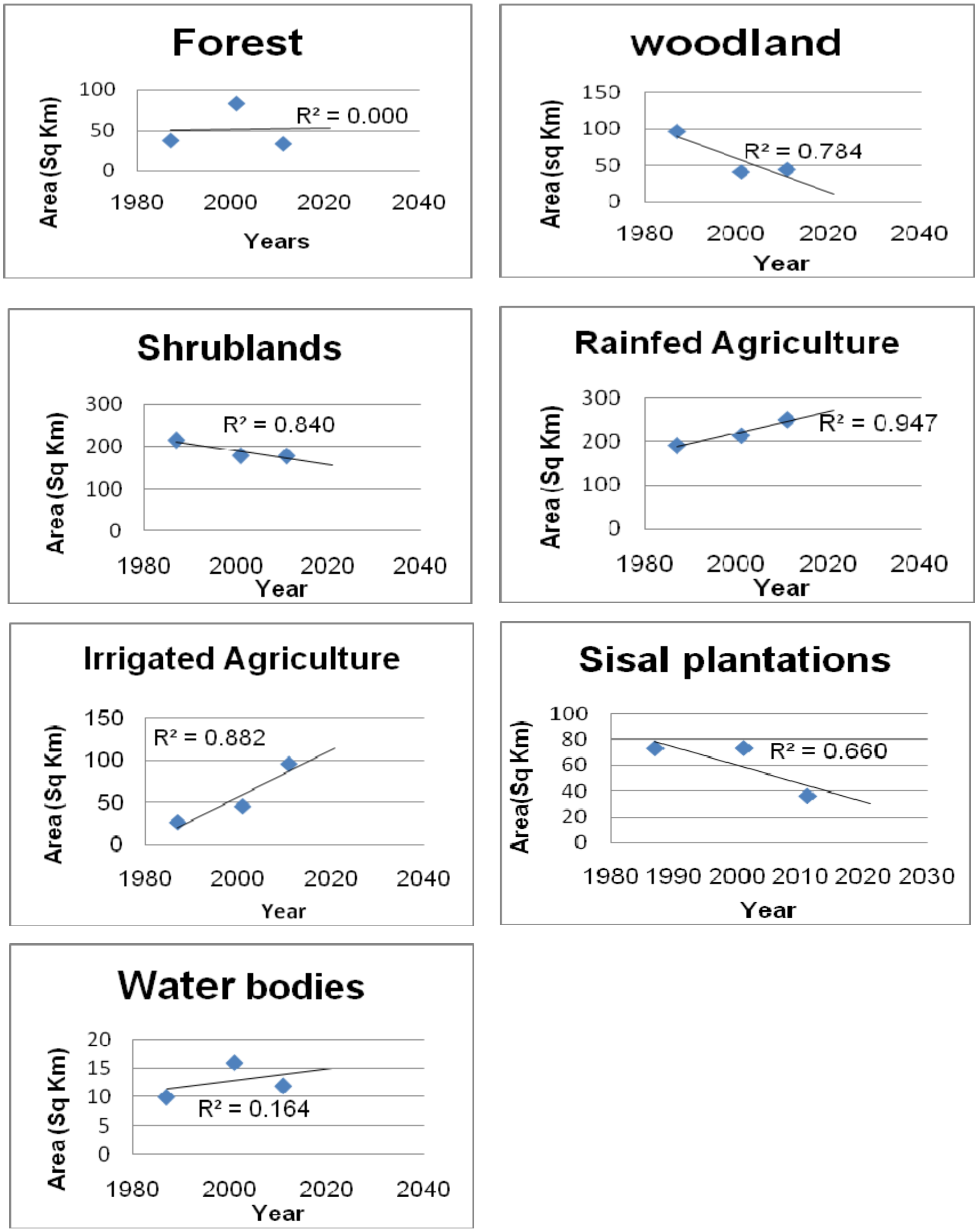


Figure 5.5: Ten year projections of land use and land cover change in Taveta district

Satellite image analyses showed that land use and land cover changes have occurred in the study area between 1987 and 2011. Between 1987 and 2001, wildlife and livestock habitats especially woodlands and shrublands were mainly converted to rainfed and irrigated agriculture. During the same period, woodlands were degraded to shrublands while forests increased. In the subsequent period (2001 to 2011), both irrigated and rainfed agriculture continued to expand, again at the expense of wildlife and livestock habitats (Forests, woodlands and shrublands) and sisal plantations. The expansion of irrigated agriculture has been attributed to recurrent rainfall failure (Republic of Kenya, 2011), commercialization of agriculture and the demand for food resources occasioned by population increase. These results point to similar studies in Kenya; for example, Kioko and Okello (2010) studying land use cover and environmental change in the semi-arid Amboseli ecosystem observed concurrent changes within a period of 30 years (1976-2007), i.e., the extent of land under both irrigated and rainfed agriculture increased significantly while riverine vegetation and perennial swamps decreased significantly as well. However, although forest cover and rangelands decreased, the changes were not significant, a situation similar to the observed changes of forests and shrublands in this study. From the results obtained in this study human activities in these rangelands have led to loss of wildlife dispersal areas through agricultural expansion. Considering the fragile nature of rangelands, such trends point to future hazards in-terms of rangelands sustainability whether for agriculture (due to degradation and climate change impacts) or for wildlife conservation unless interventions are put in place.

Although forests did not change significantly for the period under observation, it was observed that the area under forests expanded in the first 14 years. This was mainly as a result of planting of exotic trees, invasion by *Prosopis juliflora* and horticultural expansion mainly large scale establishment of mango (*Mangifera indica*) plantations. Forests however decreased between 2001 and 2011 due to agricultural expansion. In agreement with this, agriculture has been described as a major driver of forest loss. Mwavu and Witkowski (2008) working in areas around Budongo forest in Uganda observed that the major land cover conversions were from forests/woodlands to sugarcane plantations, settlement and shifting cultivation. Studies by Campbell et al. (1993, 2003), Geist and Lambin (2002), MEA (2005a, b), Alejandro et al. (2007) as well as Okello and Kioko (2010) indicate that agricultural expansion has been associated with deforestation in Asia, Africa and Latin America. Kathumo (2011) observed a similar relationship in river Gucha catchment in Kenya between 1976 and 2010. Generally, such trends of forest loss pose a challenge to the conservation of forests and their associated biodiversity while their ecological role as dry season refugia for wildlife and livestock, water source among other roles will continue to remain at stake in the face of increased demand for agricultural land and settlement as is happening in Taveta district.

The demand for land resources for development and agricultural activities in this study area has led to opening up of sisal plantations. The drastic expansion of irrigated agriculture is also attributed to the fact that the preceding time period of 1989 to1999 was characterized by the highest population increase in the district and later by infrastructural improvement with the completion of the Emali - Oloitoktok road. This facilitated easy access to agricultural produce markets in Mombasa and Nairobi cities as well as Emali town thus driving agricultural expansion. Similar observations were made by Baaru (2011) in Kathekakai in Machakos district where, between 1988 – 2009, land use and land cover changes were found to be influenced by human population increase, infrastructure and proximity to Nairobi city and Machakos town.

Land use and land cover changes are influenced by the way people use and manage land. This has been linked to the direct effect of population growth although that is not to imply that population growth is the only factor affecting land use change. There appears to be a relationship between land use change and human population growth dynamics in Taveta district. The time period coinciding with the highest population increase (1989-1999) also coincides with the highest decrease in woodlands and shrublands and a corresponding increase in human dominated activities of agriculture as the area under water bodies expanded due to establishment of large aquaculture ponds. This was followed by an increase of both irrigated and rainfed agriculture between 2001 and 2011, leading to decline of shrublands and woodlands and more so in the northern part of the district which is also a wildlife corridor. Generally such agricultural expansion within wildlife dispersal areas has its implications; an increase in resource competition mainly for water and food resources, blockage of wildlife dispersal areas and migratory routes and loss of wildlife habitats. An unpleasant output of these land use and land cover changes within wildlife dispersal areas is an increase in Human-wildlife conflicts and more so if there is no proper land use planning. This confirms the challenge local communities and their livelihoods are experiencing with wildlife in Taveta district, i.e., an escalation of Human-wildlife conflicts over the years. Considering that Kenya's population growth is high and that the global human population is projected to reach 9 billion by 2050, a nearly 2 billion person increase from current estimates (UN, 2009), it is expected that more challenges will be experienced in natural resource management in rangelands especially due to immigrants mainly from densely populated areas, and from commercial agricultural expansion in Kenya.

Although Taveta district has an ecological potential for cotton, sisal, millet and livestock production, the current land uses in most of the areas are not in tandem with this potential. Currently, most of the agricultural production is not suitable for the area especially where agriculture is dependent on rainfall. Rainfed agricultural production of maize, beans, bananas, and other horticultural crops occupies 38.5% of the district while irrigated agriculture occupies 14.7% of the area. Rainfed agriculture is characterized by high levels of crop failure occasioned by decreased rainfall (Republic of Kenya, 2011). Also, unsustainable agriculture is closely linked to environmental degradation. Cotton, sisal and livestock production are suitable for the greater parts of Taveta district. However, sisal plantations have been cleared in favour of crop land, as well as individual land ownership. The production of cotton has continued to decrease in the district over the years, a situation that has been blamed on lack of markets.

Pastoralism is suitable for the district, but the rate at which pastoral grazing land is being lost to agriculture point to possible future threats and decline of this practice. This could be attributed to the high costs of livestock production, lack of markets for livestock products, and climate change leading to water scarcity, as well as government policies that promote local self-sufficiency in food production based on crops. In addition, this has been fuelled by the fact that, agriculture has become an important alternative livelihood for the pastoral communities and a good complement to the local economy (Republic of Kenya, 2011). For example; Kitobo, Njukini and Mboghoni areas of the district, which were important for dry season grazing and water sources for wildlife and livestock have become key horticultural production areas serving Mombasa, Emali and Nairobi markets. Similar trends in market forces opening up former pastoral grazing lands have been witnessed in other semi-arid areas in Kenya. Cheeseman (2001) observed that the semi-arid Narok district of Kenya which is home to the famous Maasai Mara

Game reserve and is known for its vast wildlife resources was already transformed to a major wheat and barley production zone. Although pastoral grazing systems and wildlife within the drylands have coexisted over the centuries (Berger, 1993), the above scenarios of land use and land cover change threaten the future survival of this subtle practice in Taveta district.

Land use changes in this wildlife dispersal area could have far reaching implications in terms of wildlife conservation. Having reduced the spatial coverage of wildlife habitats, land use change will likely affect species from Tsavo West National Park especially those that have large home ranges (e.g., elephants) as well as influence their migration by blocking migratory corridors. Elephants are known to migrate yearly from Tsavo West National Park to Tanzania through the northern part of the district, which is currently intensively cultivated. As a result, local communities within this area are experiencing intensified Human-wildlife conflicts occasioned by blockage of this elephant migratory corridor.

A relationship exists between land use change, population increase and the levels of Human-wildlife conflicts in the district. The land use and land cover options compatible with wildlife conservation (woodlands, shrublands, forests and sisals) in the district have experienced significant decrease over the last 24 years. These have been replaced with crop farming covering 53.2% of the study area. While crop farming has blocked migratory corridors, it also attracts wildlife to human-dominated landscapes. Intensive and uncontrolled crop farming is not a suitable option for such a wildlife dispersal area which is also utilized as a dry season refugia. While this is the scenario, changes in land use patterns are known to influence local community's opinion on wildlife and their conservation due to the impacts experienced (Okello, 2005a; Kioko and Okello, 2010). The land use change patterns observed in Taveta district, where agricultural expansion is high; will most likely have an impact on local community's view for wildlife and its conservation since most of the local communities are dependent mainly on agriculture and livestock for their livelihoods. Considering the current status of Human-wildlife conflicts in the district, wildlife will have to pay for utilizing such human dominated landscapes to compensate for and enhance community tolerance. For example, in similar experiences observed within the Amboseli area of Kajiado district by Kioko and Okello (2010) and Okello and Kioko (2010) while studying land use change and Human-wildlife conflicts, they found that, support for free-roaming wildlife was dependent on type of land use practiced and the type of species causing livestock depredation. In addition, appreciation for wildlife resources was dependent on whether significant benefits from wildlife resources or wildlife related tourism were obtained.

From the projections, a significant decrease of woodlands, shrublands and sisal plantations will characterize the coming ten year period in the district due to a significant increase in the area under agriculture. These scenarios may be counterproductive and lead to land degradation as more areas will be opened up for rainfed agriculture which has been unsustainable due to decreased rainfall amounts. With no interventions, the decimation of wildlife and livestock habitats coupled with further expansion of agriculture within the district will set a scenario for further escalation of Human-wildlife conflicts. This therefore calls for agricultural zonation, land use planning and community awareness on the implications of these resource use changes. Despite the fact that land use planning is difficult to implement, it is a basic Human-wildlife conflict management strategy which offers the best option for co-existence of wildlife and people since it tackles the root cause of the problem (Muruthi, 2005).

5.5 Conclusions and Recommendations

Taeta district is a dispersal area for wildlife from Tsavo National Park.There is need for a scientifically-based land use planning to balance human needs and conservation goals in this landscape. This can be achieved through improved understanding of the ecological processes affected by land use. There is need for clear land use planning to counteract possible land resource degradation and ameliorate negative implications of land use and land cover change mainly Human-wildlife conflicts which are currently an issue of concern in the study area. Land use planning ought to employ the ecosystem approach and aim at establishing a "Zone of Interaction'' which caters for local community and wildlife needs within this district. This will involve targeting locations and processes of particular importance that enhance community livelihood at the same time the ecological integrity of the adjacent Tsavo West National Park. Such ventures will include delineating the migratory corridors and catchments of rivers and streams such as Kitobo, Njoro, Tsavo and Lumi rivers which are important for local community and wildlife survival. Wildlife migratory corridors will need to be protected and monitored to allow wildlife migration and reduce conflicts in the face of increasing human population.

Appropriate land use options need to be put in place. In the face of climate change vulnerability and the Agro-Ecological Zonation of Taveta district, pastoral grazing systems, ranching, sisal, cotton and millet production would be less harmful to the environment especially in areas where rainfed agriculture is currently practiced and experiencing high crop failures. Although local communities have continued to clear sisal plantations for other forms of land use, it is one of the suitable land use option that is also compatible with a wildlife protected area adjacent to it. Efforts are needed to evaluate the applicability of this form of land use and more so in the evaluation of its markets for sustainability. Encouraging the above land use production systems in rainfed agricultural zones, can act as a mechanism to curb Human-wildlife conflicts, if coupled with proper land use zonation to enhance environmental sustainability.

The conservation of natural resources on community's lands depends on the communities' goodwill to participate in their management. Establishing the level of local community's understanding of resource change dynamics is necessary in this district. In tandem with this, it is also necessary to establish community knowledge and awareness on the links between resource change dynamics and their implications. This will be necessary to facilitate development of strategies for their participation and land use planning that balances local community restrictions on land use and community needs while maintaining the ecological integrity of the landscape.

CHAPTER 6

LINKING LOCAL COMMUNITIES TO LAND USE AND LAND COVER CHANGES AND THEIR IMPLICATIONS TO HUMAN-WILDLIFE CONFLICTS USING PARTICIPATORY GEOGRAPHIC INFORMATION SYSTEMS (PGIS)

6.1 Abstract

Land use and land cover changes are important processes that influence the dynamics of Human-wildlife conflicts in human dominated landscapes surrounding wildlife protected areas. Effective management of Human-wildlife conflicts requires the participation of local communities and other stakeholders. However, local communities need to identify and understand resource use changes and their role in the process, so as to facilitate uptake of appropriate land resource management strategies aimed at counteracting Human-wildlife conflicts. Governments need to understand the socio-ecological factors governing the dynamics of conflicts. Approaches aimed at changing local community behavior towards natural resource use require appropriate technologies that bridge the technology and knowledge gaps between policy makers and local communities. Participatory Geographic Information System (PGIS) was used to assess and educate local communities on land use and land cover changes as well as visualize the problems associated with resource changes in Taveta district. Through PGIS; linkages between land use / land cover changes and Human-wildlife conflicts were clearly established, agricultural expansion was found to shape the nature and extend of Human-wildlife conflicts while increase in human population was a driving factor for land use change in Taveta district. Both conventional and participatory GIS approaches showed that, significant ($p < 0.05$) changes occurred in woodlands, rainfed and irrigated agricultural areas, while shrublands and forests showed no significant changes. Local communities were found to be significantly knowledgeable ($p < 0.05$) about changes in most of the resources and their causes. PGIS compared well to conventional GIS analysis and therefore an appropriate technology for analyzing land use and land cover changes. The technology is appropriate for educating local communities on the implications of resource changes and convincing them to participate in Human-wildlife conflicts management. The PGIS maps developed are an important input to decision making in appropriate land use planning and natural resource management to counteract Human-wildlife conflicts. PGIS is a suitable tool for

evaluating and monitoring resources and for land use planning in a multi-stakeholder participant process in the management of Human-wildlife conflicts.

Key words: Land use, land cover, PGIS, GIS, Human-wildlife conflicts, Tsavo West National Park, Taveta district.

6.2 Introduction

The article "The tragedy of the commons" by Hardin (1968) created ever since a growing debate on natural resource management approaches in the world. Communities throughout the world are increasingly being involved in the bottom-up management of local natural resources and the environment, a change from the top-down approach which previously formed the framework of common natural resource management approaches. This has been promoted more so in Africa as governments take policy reviews to enhance the process. Currently many countries, including Kenya, have already developed, or are in the process of developing changes to national policies and legislation that fully or partially decentralize natural resource management (Republic of Kenya, 2005; Tran et al., 2007; Republic of Kenya, 2010; Republic of Kenya, 2011).

Changes in land tenure system, land use and agricultural intensification in the arid and semi-arid lands (ASALs) have seen an increase in Human-wildlife conflicts over resources worldwide (FAO, 2009; Terry, 2009). These changes affect land use patterns, which have been found to influence local community opinions on wildlife and conservation. In Kenya for example, Human-wildlife conflicts have persisted over the years despite efforts to manage the wildlife, thus necessitating the need for holistic approaches. Kenya's top six high conflict intensity zones are areas surrounded by National Parks/ Reserves, among them being the dispersal area surrounding the Tsavo West National Park where wildlife confronts local communities (http://www.kws.org/parks/community_wildlife_program/PAMU.html; Okello and D'Amour, 2008). Wildlife habitats around the Tsavo West National Park, formerly used as pastoral grazing lands have undergone tremendous changes in land use patterns (Campbell et al., 2000; Okello, 2005a; Okello and Kioko, 2010). The diminishing of resources, reduced accessibility to water resources and grazing pastures has led to intensification of Human-wildlife conflicts as both wildlife and people strive to survive. In this ecosystem, Human-wildlife conflicts have been on the increase leading to increased destruction of livelihood support systems, food insecurity and poverty (Kamande, 2008).

Despite the fact that Human-wildlife conflicts have been found to impact wildlife conservation and jeopardize human livelihoods and safety, most of the research devoted to addressing the conflicts has tended to focus on managing the wildlife (Smith et al., 2000a). Such approaches have been described as "working with a tool box that is half way full" and limits the manager's ability to resolve conflicts. This in most cases tends to provide a temporally fix or only a palliative to the problem (Barnes, 2002; Moses et al., 2005; Baruch-Mordo et al., 2009).

One of the known factors that can lead to escalation of Human-wildlife conflicts and which communities need to understand in order to enhance their participation is land use and land cover change. In analyzing land use change, conventional Geographic Information Systems (GIS) tools and approaches have in most cases taken a center stage in the process. This however, does not offer local communities an opportunity to participate in analyzing the causes of problems that affect them, which is key in determining community's response to the implementation of management strategies. In addition, information produced only from analysis of conventional GIS may not represent the reality on the ground. Therefore, policies produced and implemented based on purely conventional GIS data may be unattractive to local communities, leading to minimal or lack of their participation in all the steps required in development (Perez, 2003). Involving local communities in wildlife management requires appropriate technologies that bridge the technology gaps that exist between wildlife managers as experts and the local communities as custodians of resources on which wildlife ranging outside protected areas depend on. A more recent and plausible approach that not only gathers information from local communities but also enhances participation, empowerment, development of local skills in graphically representing ideas and problems (maps) in natural resource management is the use of Participatory Geographic Information Systems (PGIS). The approach allows communities not only to better analyze and communicate ideas of changes but also implement more sustainable projects (Aynekulu et al., 2006; ERMIS, 2007; Kathumo and Gachene, 2012; USAID, 2012).

Both Kretser et al. (2009) and Baruch-Mordo et al. (2009) emphasize the need to understand stakeholders and the root causes of the conflicts in developing effective Human-wildlife conflict management strategies. Further, there has been an increasing recognition that solutions focused mainly on wildlife limit the managers' ability to effectively resolve conflicts (Baruch-Mordo et al., 2009, 2011). This therefore, requires increasing local community participation/cooperation and knowledge on the possible factors that precipitate conflicts. In order to facilitate local community participation in natural resource management, people need to understand variations in land, their causal attributes and the linkages between them. For this to be achieved, these variations must be identified, characterized and information communicated via the most inclusive and cost effective means. Governments need to understand the underlying social and ecological drivers of natural resource changes and their implications. To fully develop the knowledge portfolio required to design and implement natural resource management strategies in remote areas, an adaptable, robust and credible system of ethno-ecological knowledge representation, analysis and communication is required (Aynekulu et al., 2006).

Among the initial approaches to community participation was the use of participatory rural appraisal methods, which were aimed at understanding the real situation occurring on the ground and developing adequate policies aimed at ensuring the sustainability of any plans and techniques implemented (Perez, 2003; FGLG, 2008). However, in recent years, PGIS technology has been considered to be more appropriate in addressing natural resource challenges facing local communities. PGIS has been found to be more adaptable and flexible and bridges the technological gaps between governments and local communities (Aynekulu et al., 2006; Kathumo and Gachene, 2012). Linking conventional GIS and PGIS produces a hybrid methodology that strengthens the local capacity in the multi-participant planning process. In addition it reduces the drawbacks associated with top-down approaches that are deemed to impose opinions on people. PGIS encourages multi-stakeholder participation in participatory development thus enhancing governance of resources (McConchie and McKinnon, 2002; Kathumo and Gachene, 2012). Most of the land use change analysis work done in Kenya mainly uses the conventional remote sensing and GIS which have not been effective in transforming the attitudes of the communities in regard to natural resource management.

Parker et al. (2007) described the management of natural resources as a complex process driven by among other factors, the interactions between the dynamics of the natural system, the decision-making and behavior of stakeholders. Today, rural coexistence with wildlife is precarious and heavily aid dependent. With the shortcomings of top-down approaches, the magnitude of the challenge to make coexistence with wildlife more sustainable in the longer term clearly requires more than a law enforcement response. Wildlife management requires a multi-stakeholder approach, with the cooperation of rural communities being indispensable as has been in traditional times. Attempts to address Human-wildlife conflicts require stakeholders to understand the ecological and social drivers of the conflicts as well as the status of the challenge. In addition, the management of natural resources in the hands of communities depends heavily on the community's good will. Therefore, there is need to involve communities in analyzing natural resource changes and their implications and coming up with strategies for conservation of wildlife. Little has been done on the application of PGIS in natural resource management in Kenya and more so in Human-wildlife conflicts which challenge community livelihoods.

This study dealt with the analysis of land use and land cover changes by local communities and government administrators in Taveta district using PGIS and linking the resource use changes to the dynamics of Human-wildlife conflicts. This was aimed at evaluating how effective communities are in analyzing the root causes of conflicts in the district, their knowledge on resource use change and enhance their capacity to participate in managing Human-wildlife conflicts. The study also aimed at using PGIS as an Information Communication Technology (ICT) to promote awareness of the links between land use and land cover changes, and their ecological outcomes such as Human- wildlife conflicts so as to spur a change of behavior in the way land resources are used and promote the use of sustainable land use and management strategies. The goal of the study was to use PGIS and Remote Sensing to trace the changes in land use and land cover in Taveta district and to use the generated imagery and maps to create awareness of the benefits of sustainable land use in order to promote sustainable management of land resources and reduce Human-wildlife conflicts.

The specific objectives were:

1) To assess to what extent local communities can communicate information and knowledge on resource changes through mapping.
2) To map land use and land cover changes and develop an inventory of their images using PGIS and Remote Sensing.
3) To relate the changes in land use and land cover to Human-wildlife conflicts over resources.
4) To identify sustainable land use and management strategies to reduce Human-wildlife conflicts.
5) To identify policy options for sustainable community management of land resources that can lead to reduction of Human-wildlife conflicts.

6.3 Materials and Methods

6.3.1 Description of study area

The study area is as described in Chapter 3.

6.3.2 Participatory GIS and community land resource mapping

Mental maps for the years 1970, 1990 and 2012 were drawn for four villages in Taveta district. About twenty year's interval was purposively chosen in order to cater for temporal sensitivity in resource changes by local communities. These villages included; Kitobo, Mboghoni, Njoro and

Sir Ramsons all from different locations. Kitobo and Mboghoni villages represented the irrigated agricultural zone; Njoro village represented the pastoral livestock production zones, while Sir Ramsons village represented the rainfed agricultural zone. Twenty participants from every village were selected. These were separated into two groups of ten each consisting of mixed gender and age. Each group of twenty was composed of five old men (above 50 years), five old women (above 50 years), five young women (18 to 35 years) and five young men (18 to 35 years). The young men and women were useful in drawing the mental maps in addition to contributing information about resource changes for the past twenty years. The participants listed and drew on manila papers land resource mental maps showing some of the land resources within each of the village for the years 1970, 1990 and 2012, e.g., Plate 6.1. The land resources included; woodlands, natural forests, shrublands, irrigated and rainfed agricultural lands, sisal plantations and water bodies. Participants drew the maps facing the north to ease in geo-referencing them relative to the actual geographic Northing's. These resources, which the community considered very important for their survival, are also competed for by wildlife residing within the district and the surrounding Tsavo West National Park. Participants selected the most representative three mental maps for the years 1970, 1990 and 2012. The mental maps were used to assess land use and land cover changes in Taveta district as perceived by the local communities. Photographs of these maps were then taken using a digital camera. These selected maps were used for discussions during the open forum sessions. Features that acted as boundaries and were also found within the maps drawn such as mosques, churches, dispensaries, bridges, road junctions, police posts, water springs/dams, park boundary etc were mapped using Global Positioning System (GPS) for geo-referencing of the mental maps in order to analyze natural resource changes as perceived by the local community.

Plate 6.1: Local Maasai community members drawing their mental maps at Njoro village

6.3.3 Satellite images and analysis

As described in Chapter 5.

6.3.4 Participatory GIS community forums

Community forums of thirty participants per village were carried out in the four villages after the mapping exercises to discuss trends in land use and land cover changes as observed from both the mental maps and satellite images. The forums were composed of thirty participants among them being the twenty selected participants who participated during the PGIS activity. Each village discussed their own mental maps. Trends in land use and land cover changes were evaluated from the Landsat images and the mental maps. Participants compared and listed the similarities and differences in the satellite and developed mental maps. The participants noted the changes of the major land resources mainly forests, woodlands, shrublands, water bodies, sisal plantations and agricultural farmlands over the years. Participants discussed and listed the undesirable effects of land resources changes, and gave recommendations towards sustainable land resource and Human-wildlife conflicts management.

6.3.5 Land use and land cover change from the PGIS maps

The ground-truthing data of the georeferenced features were used to geo-reference the year 2012 mental maps. The control points were typed in excel file and saved as delimited text (notepad). These were converted into shapefiles using ArcView GIS 3.2. The downloaded photographs of the mental maps were exported to Arc GIS 9.3 software for geo-referencing using the control points. The geo-referenced mental maps for the year 2012 were used to geo-reference the year 1970 and 1990 mental maps. The geo-referenced mental maps (1970, 1990 and 2012) were exported to ArcView-GIS 3.2 software. Areas under the different land uses and land cover (shrublands, woodlands, forest, sisal plantations, agricultural land, water bodies and settlements) were then calculated using on-screen digitizing. Land use and land cover change analysis of the PGIS maps for the periods between 1970-1990 and 1990 - 2012 were then computed using Excel software.

6.3.6 Linking land resource changes with Human-wildlife conflict dynamics

Communities were asked to evaluate how Human-wildlife conflicts have evolved and changed over the years between 1970, 1990 and 2012. This was also done using data from the questionnaires question 3.4 to evaluate the intensity of Human-wildlife conflicts for the years 1970, 1990 and 2012 as perceived by the local communities. These were then related to the mental maps drawn by local communities corresponding to 1970, 1990 and 2012. The aim was to enable local community visualize the links between land resource changes and Human-wildlife conflict dynamics within their landscape. The objective was to enable the local communities discern their contribution to the persistent challenge of Human–wildlife conflicts in the district and therefore empower them to participate in Human-wildlife conflict management strategies.

6.3.7 Strategies for land resource and Human-wildlife conflict management

Communities were asked to make proposals for land resources conservation strategies that would lead to sustainable conservation of resources and a reduction of Human-wildlife conflicts.

6.3.8 Data analysis

6.3.8.1 Land use and land cover change analysis

The area of land under different land use and land cover for the Landsat images and PGIS maps was used to calculate percentage changes in land use and land cover using Excel software. Overall land use and land cover change statistics for the land sat images were calculated from the 1987 and 2011 statistics while for the PGIS maps, these statistics were calculated from the 1970 and 2012 maps. Chi-square goodness of fit was used to determine if there were significant changes in land use and land cover in both the Landsat images and the PGIS mental maps (Zar 1996).

6.3.8.2 Evaluation of local community knowledge on land resource changes

Similarities in Chi-square goodness of fit tests of trends in land use and land cover changes as envisaged by the local community were compared to trends in Chi-square values obtained from the Landsat images as a measure of local community knowledge in evaluating resource use changes. In addition, percentages of the land use and land cover changes from satellite (1987, 2001 and 2012) and PGIS maps (1970, 1990 and 2012) were computed and also used in evaluating local community knowledge on resource use change. The performance of the PGIS maps from the Chi-Square tests were regarded as a measure of the precision with which local communities were able to tell the spatial-temporal changes in land resources (Zar, 1996).

6.4 Results and Discussion

6.4.1 Trends in land use and land cover changes from the PGIS maps

The following mental maps were drawn for the sampled four villages based on the PGIS resource mapping exercise (Figures 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11and 6.12). These covered the years 1970's, 1990's and 2012.

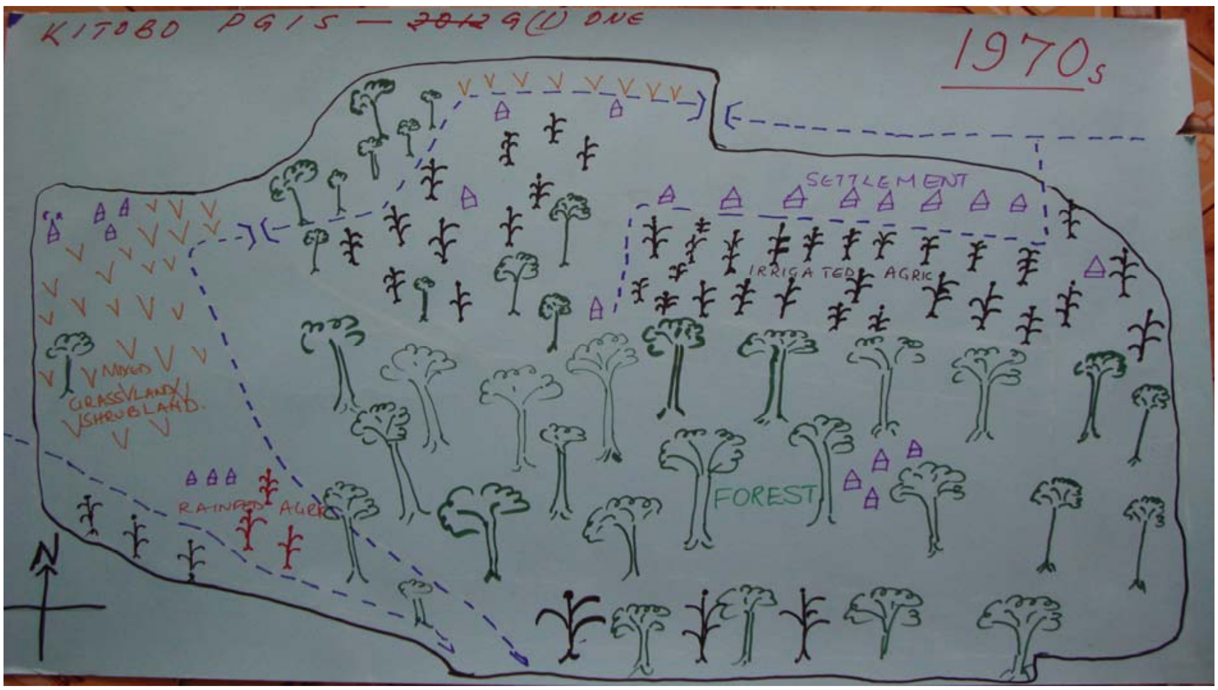


Figure 6.1: Kitobo village Participatory GIS map for the years 1970's

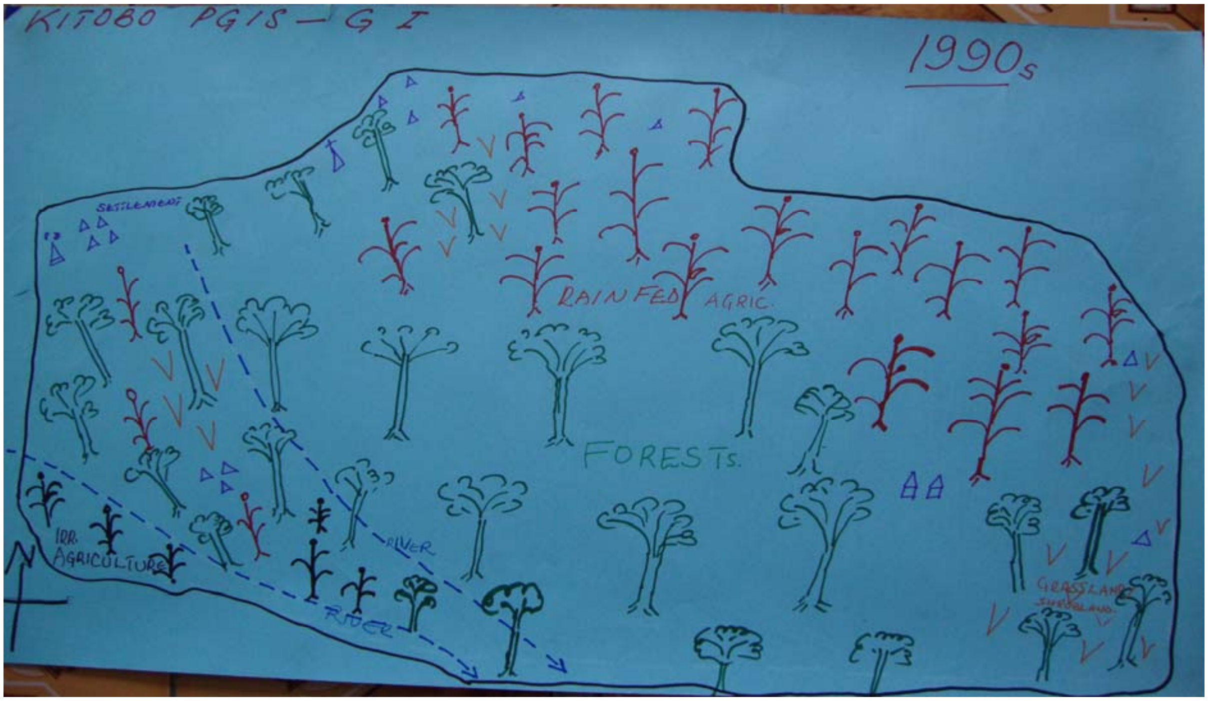


Figure 6.2: Kitobo village Participatory GIS map for the years1990's

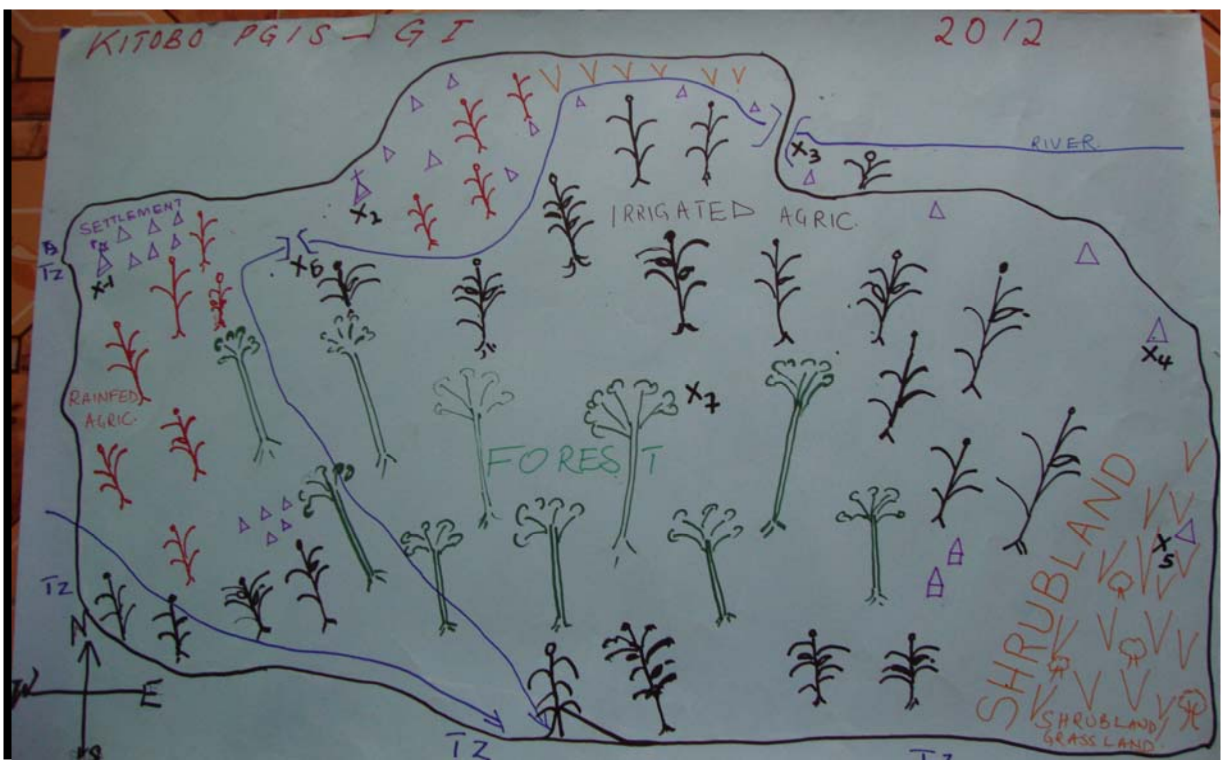


Figure 6.3: Kitobo village Participatory GIS map for the year 2012

Five land use and land cover types were described within Kitobo village for the three time periods; shrublands, rainfed agriculture, irrigated agriculture, settlements and forest (Figure 6.1, 6.2 and 6.3). The area covered by each of these fluctuated over the three time periods studied. There appears to be a redistribution of human settlements and possibly human population dispersal/migration as areas under irrigated agriculture were brought under rainfed agriculture in the 1990's with the breakage of the Njoro Canal. However, this trend changed by 2012 as more people moved in to tap on the irrigation potential around Kitobo forest after the canal was repaired.

From figures 6.4, 6.5 and 6.6 below, the local community in Mboghoni village described seven land use and land cover types as sisal plantations, settlements, forests, water bodies, shrublands, irrigated agriculture and rainfed agriculture.

Figure 6.4: Mboghoni village Participatory GIS map for the years 1970's

Figure 6.5: Mboghoni village Participatory GIS map for the years 1990's

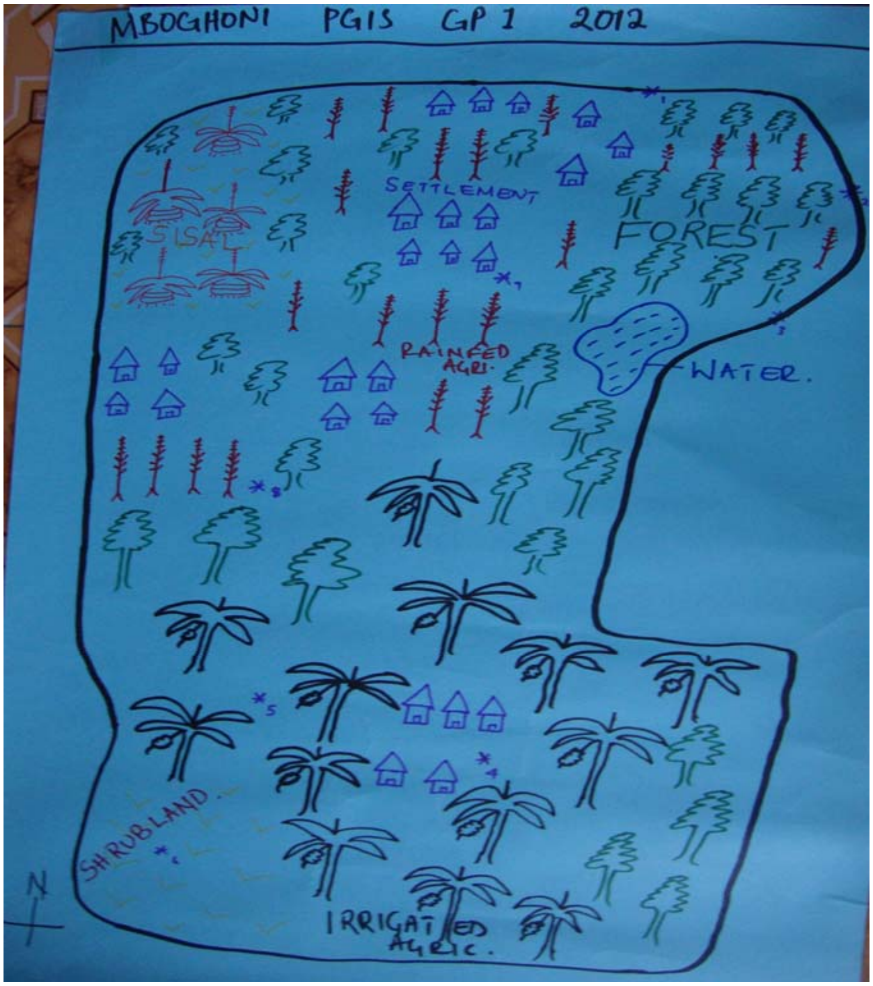


Figure 6.6: Mboghoni village Participatory GIS map for the year 2012

Within Njoro village whose main livelihood is livestock keeping, the main land use and land cover types described were shrublands, rainfed agriculture and settlements (Figure 6.7, 6.8 and 6.9).

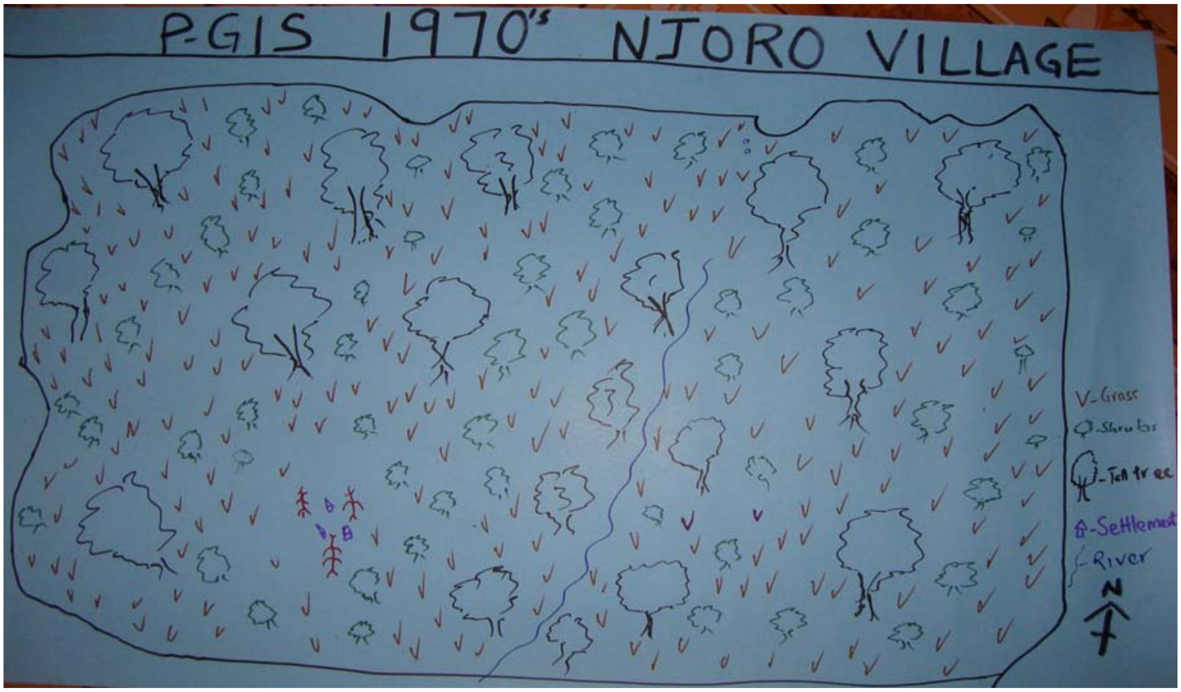


Figure 6.7: Njoro village Participatory GIS map for the years 1970's

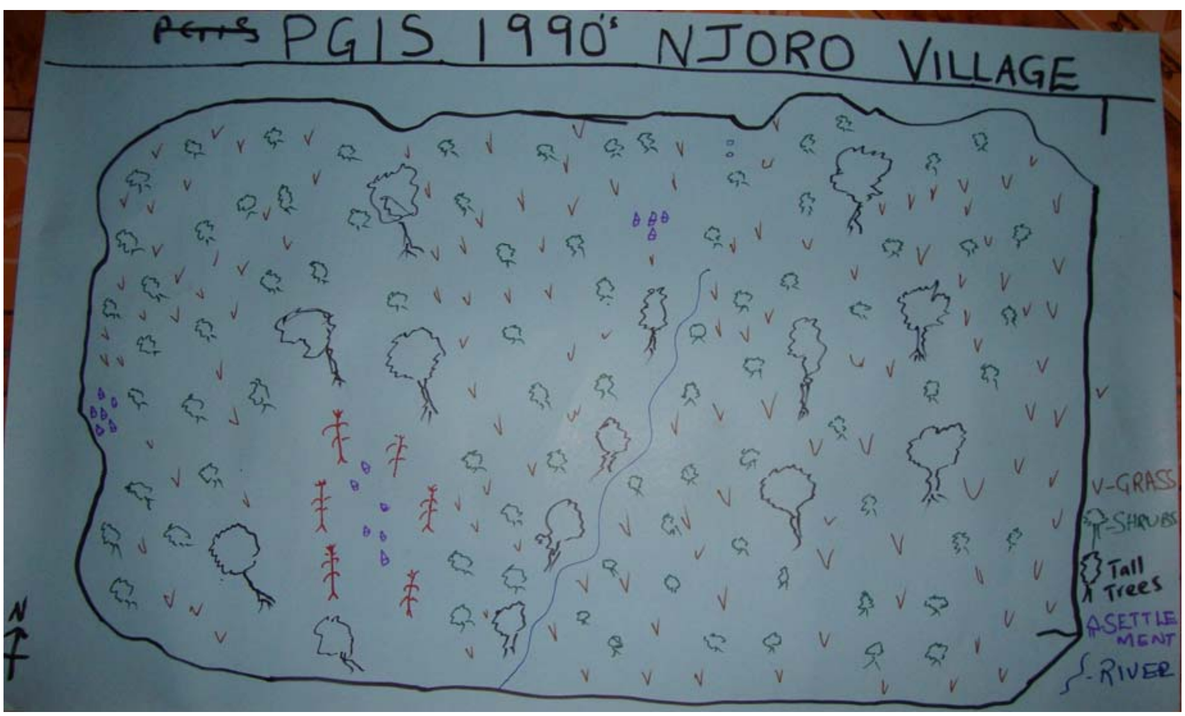


Figure 6.8: Njoro village Participatory GIS maps for the years 1990's

Figure 6.9: Njoro village Participatory GIS map for the year 2012

Figures 6.10, 6.11 and 6.12, show woodlands depicted by trees of varying heights, rainfed agriculture and settlements as the land uses/land cover types in Sir Ramsons village of Njukini location. Notable change was mainly observed in the intensification of rainfed agriculture and reduction of woodlands from 1990's.

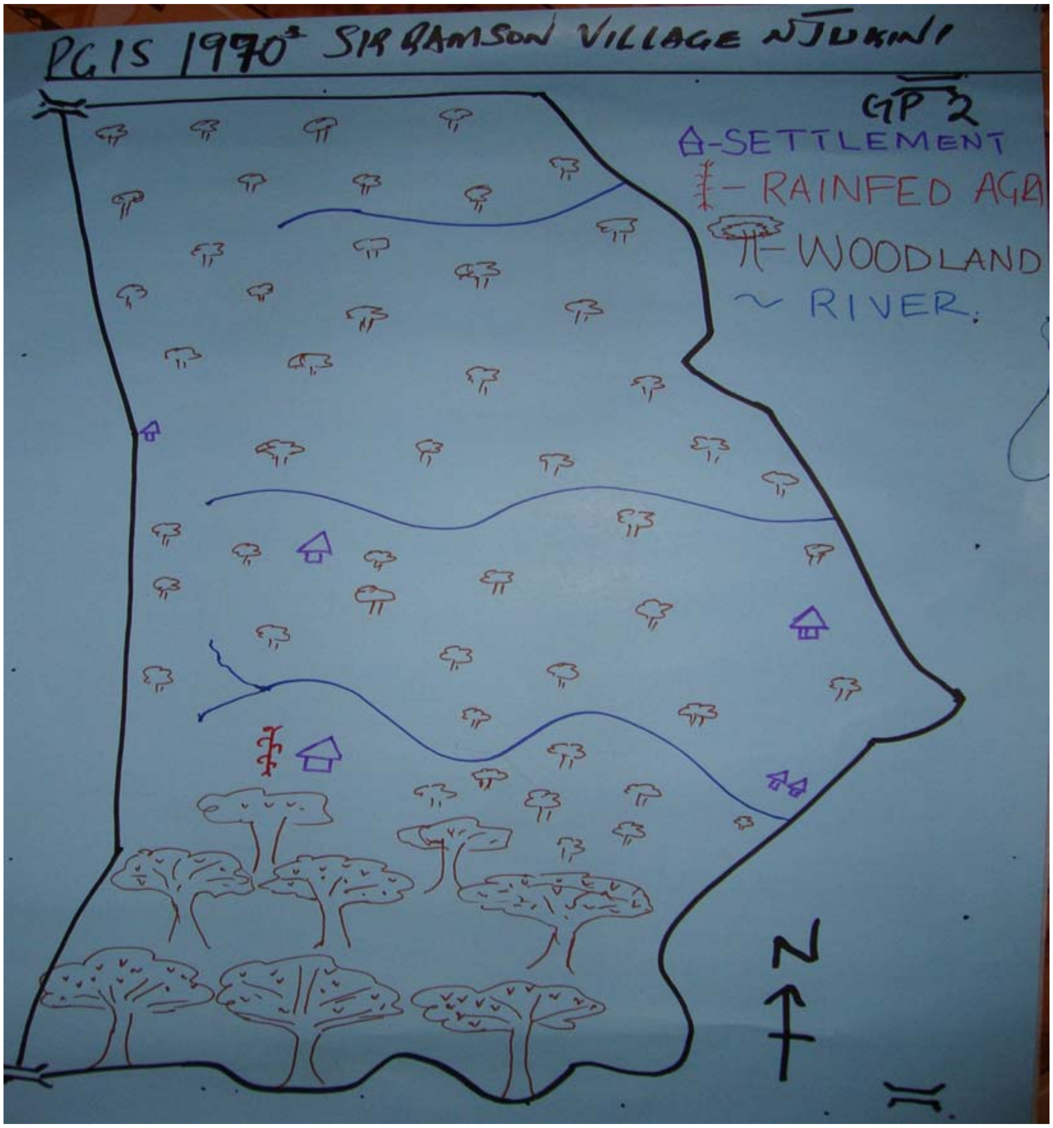


Figure 6.10: Sir Ramsons village Participatory GIS map for the years 1970's

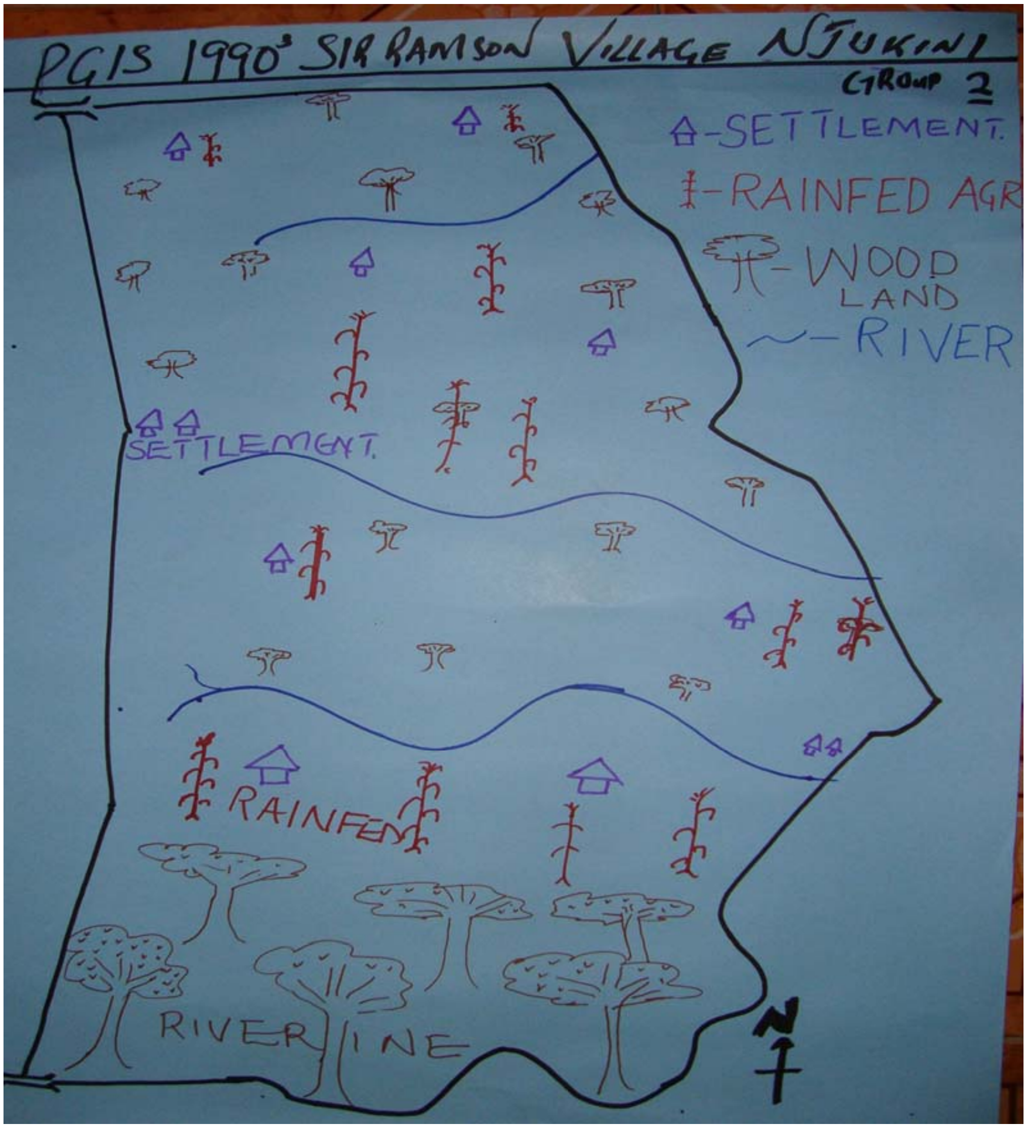


Figure 6.11: Sir Ramsons village Participatory GIS map for the years 1990's

Figure 6.12: Sir Ramsons village Participatory GIS map for the year 2012

6.4.2 Land use and land cover changes between 1987 and 2011 as determined using Remote Sensing imageries

Land use and land cover types are as described in Chapter 5.

The percentage cover changes of the land uses are shown below (Figure 6.13). The most drastic expansion of irrigated agriculture occurred between 2001-2011.

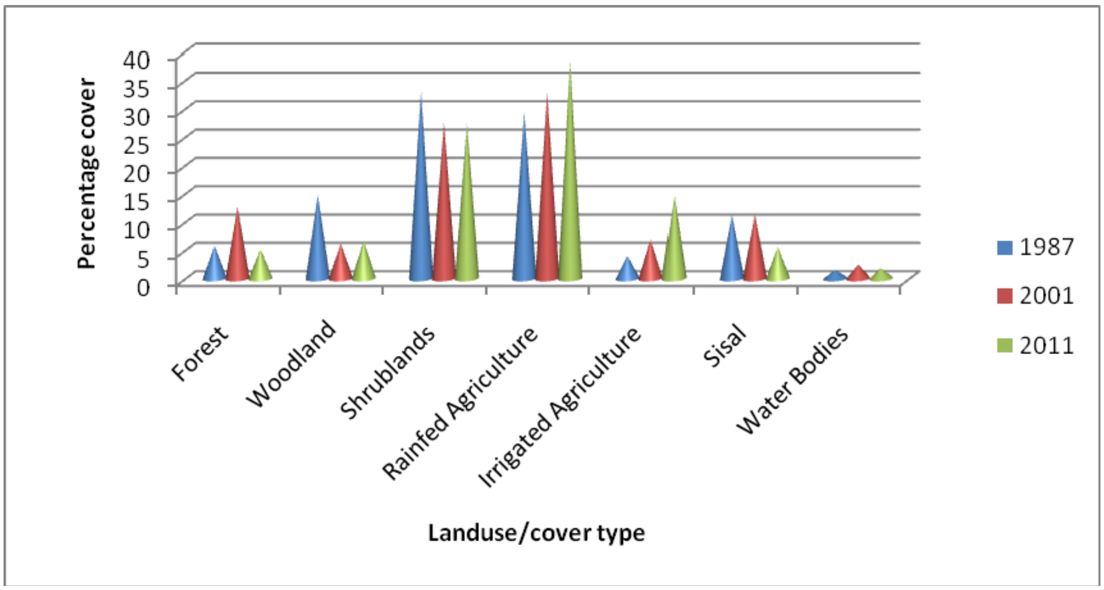


Figure 6.13: Land use and land cover changes in Taveta District between 1987 and 2011

Generally, Taveta district is largely covered by shrublands and rainfed agriculture while water bodies covered the least area. Shrublands cover however decreased over the three time periods while rainfed agriculture increased over the same time period. Although irrigation agriculture increased over the three time periods, a drastic increase was observed between 2001 and 2011. Forest cover showed high fluctuations over the three time periods, while woodlands initially showed a sharp decrease followed by a period of stabilization. Sisal plantations decreased during the third time period studied. Of all the land uses/land cover types, water bodies exhibited minimum changes. Decrease of natural land cover occurred throughout the study period at the expense of agriculture. Overall, the most drastic percentage change was observed in irrigated agriculture. This was followed by woodlands, sisal plantations, rainfed agriculture, water bodies, shrublands and forests respectively (Table 6.1).

Table 6.1: Percentage changes in land use and land cover in Taveta district between 1987-2011 (Landsat images)

Land use /land cover type	1987-2001	2001-2011	1987-2011
Forest	117.2	-58.88	-10.69
Woodland	-58.2	8.66	-54.57
Shrublands	-16.8	-0.41	-17.14
Rainfed Agriculture	11.76	17.04	30.8
Irrigated Agriculture	73.89	111.97	268.6
Sisal plantations	0.15	-50.26	-50.19
Water Bodies	58.69	-25.09	18.87

While rainfed agriculture and water bodies increased with less than 50% over the three time periods, similar percentage changes were observed in the decline of shrublands and forest cover. The most drastic percentage increase of irrigated agriculture occurred between 2001 and 2011, a time period that also saw high decrease in sisal plantations, forests and water bodies. However, forest cover showed the greatest percentage increase of all the land uses/land cover between 1987 and 2001. This was occasioned by establishment of artificial forests, invasion of *Prosopis juliflora* and establishment of mango plantations in the area. Generally, forests, shrublands, woodlands and sisal plantations decreased as both rainfed and irrigated agriculture increased over the twenty four years examined.

6.4.3 Land use and cover changes as perceived by local communities in Taveta district between 1970 – 2012

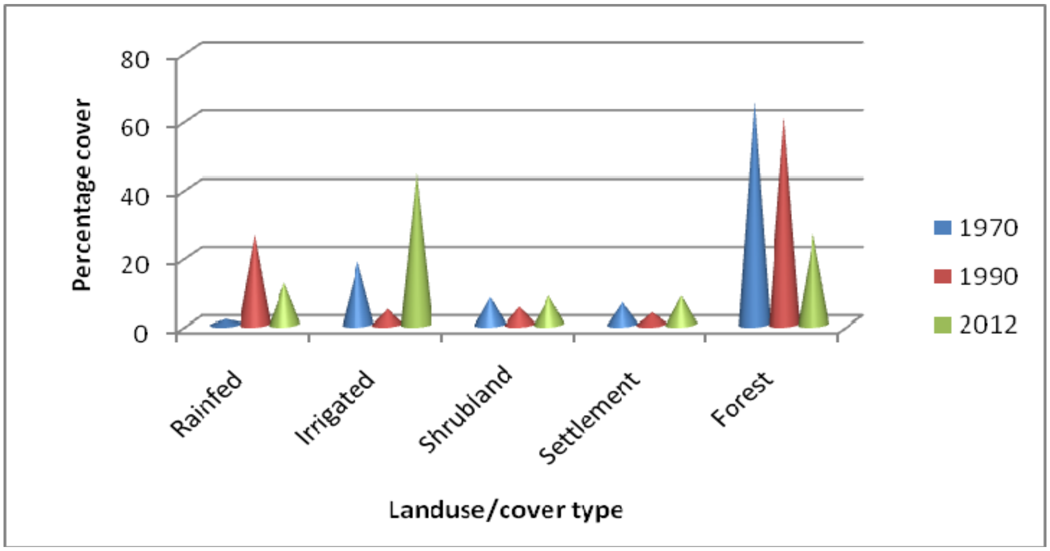


Figure 6.14: Land use and land cover changes in Kitobo village between 1970 - 2012

From figure 6.14, the area covered by each of the land use/land cover types varied over the time period investigated. There appears to be synchronised changes between rainfed and irrigated agriculture between 1970's and 1990's in Kitobo Village. As the area under rainfed agriculture drastically increased between 1970 and 1990's, irrigated agriculture decreased. Similarly, while rainfed agriculture decreased between 1990's and 2012, the same time period saw a more drastic increase in the areas under irrigated agriculture. The area under shrubland cover and settlements remained more or less the same over the three time periods. The area under forest cover decreased over the three time period but most changes occurred between 2001 and 2012, a time period during which irrigated agriculture increased most. From the group discussions, land use and land cover changes were influenced by human population increase in Kitobo village. Human population flactuations influenced the area under shrublands, rainfed and irrigated agriculture. Rainfed agriculture is less labour intensive compared to irrigated agriculture hence the synchronised descrease in settlements and irrigated agriculture as rainfed agriculture increased between 1970's and 1990's.

Rainfed agriculture showed the highest percentage change over the study period followed by irrigation agriculture (Table 6.2). This was an indication of the magnitude of human activities in Kitobo.

Table 6.2: Percentage changes in land use and land cover in Kitobo village between 1970 – 2012

Land use /land cover	1970-1990	1990-2012	1970-2012
Rainfed agriculture	1614.65	-53.49	697.45
Irrigated agriculture	-75.82	894.75	140.53
Shrubland	-35.53	63.45	5.37
Settlement	-48.03	141.57	25.55
Forest	-7.2	-56.15	-59.31

While the most extensive land cover type in Mboghoni village was forest cover followed by shrublands, irrigated agriculture was the most extensive land use type (Figure 6.15). Major changes in percentage cover were observed in irrigated agriculture and forests between 1990's and 2012. The decrease of shrublands and water bodies occurred throughout the time period as settlements and agriculture increased.

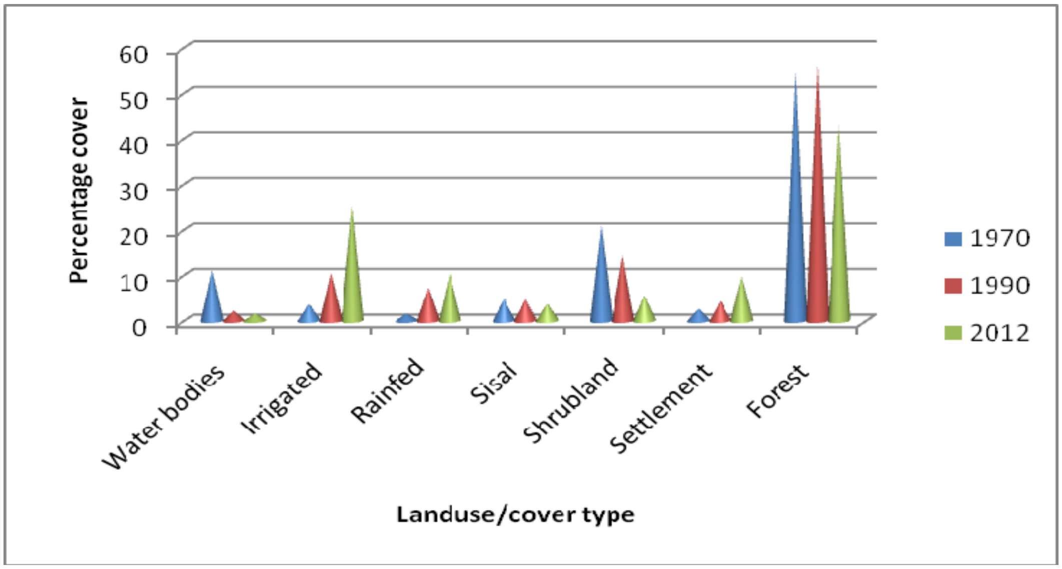


Figure 6.15: Land use and land cover changes in Mboghoni village between 1970 - 2012

Anthropogenic impacts manifested in the expansion of both irrigated and rainfed agriculture as well as settlements were the main drivers of land use and land cover change in Mboghoni village (Table 6.3). This saw the deccrease of natural habitats compatible with wildlife survival mainly the water bodies, shrublands, sisal plantations and forests.

Table 6.3: Percentage changes in land use and land cover in Mboghoni village between 1970 -2012

Land use / land cover	1970-1990	1990-2012	1970-2012
Water bodies	-78.9	-29.80	-85.19
Irrigated agriculture	184.05	144.10	593.24
Rainfed agriculture	352.8	45.10	557.14
Sisal plantations	-3.89	-17.20	-20.45
Shrubland	-32.41	-60.30	-73.19
Settlement	62.55	128.30	271.16
Forest	2.99	-22.90	-20.61

No major human activities occurred in Njoro, the pastoral livelihood zone for the entire time period (Figure 6.16, Table 6.4). This is expected especially since livestock keeping is the major land use type.

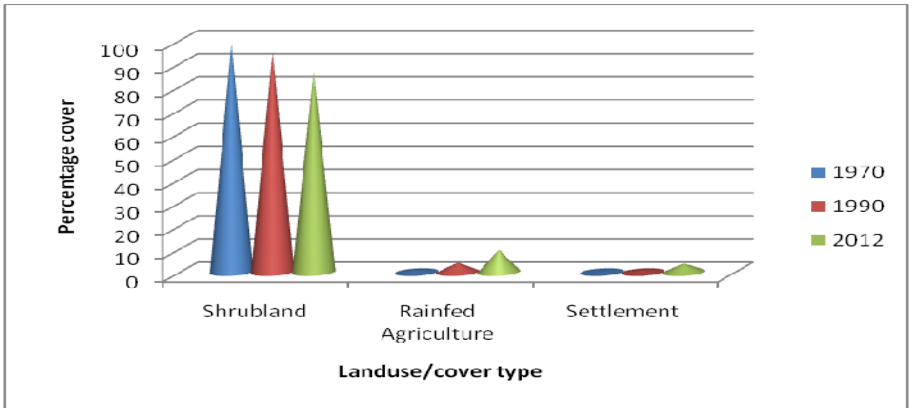


Figure 6.16: Land use and land cover in Njoro village between 1970 - 2012

Table 6.4: Percentage changes in land use and land cover in Njoro village between 1970-2012

Land use / land cover	1970-1990	1990-2012	1970-2012
Shrubland	-3.84	-8.89	-12.39
Rainfed Agriculture	388.89	131.82	1033.33
Settlement	100	310	720

Despite the fact that Njoro village is occupied by mainly pastoral communities, rainfed agriculture and settlements showed marked changes in percentage cover change. Although both land use types occupy a small area in the village, it points to the changing lifestyles of the pastoral communities who view agriculture as an alternative livelihood in the context of climate change impacts.

The intensification of rainfed agriculture in Sir Ramsons village saw the decimation of woodlands as human population continued to grow during the period evaluated (Figure 6.17). This is exacerbated by the fact that Sir Ramsons village lies close to Mt. Kilimanjaro and receives relatively higher amounts of rainfall compared to other regions of the district. Agriculture showed the highest percentage change followed by settlements. These led to the decimation of once suitable wildlife habitat in Njukini location, i.e., the woodlands (Table 6.5).

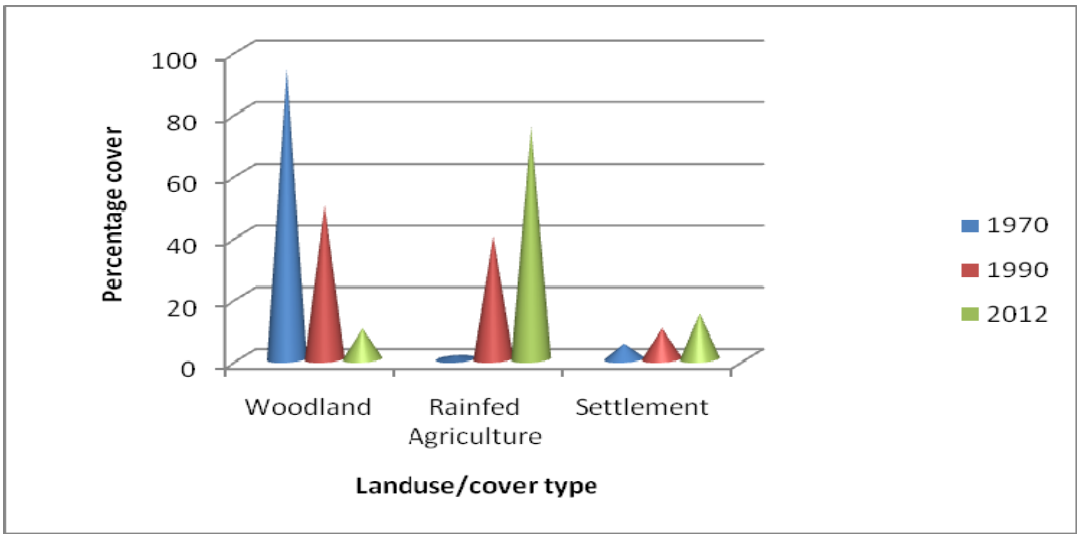


Figure 6.17: Land use and land cover changes in Sir Ramsons' village between 1970 - 2012

Table 6.5: Percentage changes in land use and land cover in Sir Ramsons village between 1970 - 2012

Land use/ land cover	1970-1990	1990-2012	1970-2012
Woodland	-46.8	-80.00	-89.36
Rainfed Agriculture	3900	87.00	7400
Settlement	100	50.00	200

6.4.4 Performance of the PGIS maps against the Satellite images analysis for the various land uses and land cover types

Derived goodness of fit results based on PGIS techniques for the study area and sites are presented in tables 6.6, 6.7, 6.8, and 6.9, below. Like the Landsat imagery results (Chapter 5), local community groups showed significant changes had occurred in irrigated agriculture and woodlands (Tables 6.6, 6.7 and 6.9). Except Mboghoni (Table 6.7), Kitobo, Njoro and Sir Ramson's (Table 6.6, 6.8 and 6.9) showed significant changes in rainfed agriculture similar to the Landsat imageries. However, local community precision on forest changes differed between Kitobo (Table 6.6) and Mboghoni (Table 6.7) areas with the later showing predictions similar to those of the Landsat imageries. It is expected that local community knowledge may differ between sampled populations. From the above results, the PGIS approach therefore compares well with Landsat image analysis in analysing land use and land cover changes.

Table 6.6: Chi-Square goodness of fit test for the various land use and land cover changes In Kitobo village between 1970's and 2012 as perceived by the local community

Land use/ Land cover	1970 Area (Km^2)	1990 Area (Km^2)	2012 Area (Km^2)	% change in land use cover	χ^2 Goodness of fit test
Forest	22.31	20.71	9.08	-59.31	χ^2 = 6.04, df = 2,p = 0.049
Rainfed agriculture	0.52	8.97	4.17	697.45	χ^2 = 7.000, df = 2,p = 0.030
Irrigated agriculture	6.30	1.52	15.15	140.53	χ^2 =11.565,df = 2,p = 0.003
Shrubland	2.73	1.76	2.88	5.37	χ^2 =0.250, df =2, p = 0.882
Settlement	2.28	1.19	2.87	25.55	χ^2 = 1.000,df = 2, p = 0.607

Table 6.7: Chi - Square goodness of fit test for the various land use and land cover changes in Mboghoni village between 1970's and 2012 as perceived by the local community

Land use/ land cover	1970 Area (Km^2)	1990 Area (Km^2)	2012 Area (Km^2)	% change in land use cover	χ^2 Goodness of fit test
Forest	18.29	18.84	14.52	-20.61	χ^2 =0.500, df = 2, p = 0.779
Irrigated agriculture	1.23	3.50	8.55	575.14	χ^2 =7.000, df = 2, p = 0.030
Rainfed agriculture	0.54	2.43	3.53	557.14	χ^2 =2.000, df = 2, p = 0.368
Sisal plantations	1.63	1.57	1.30	-20.45	χ^2 =0.400, df = 2, p = 0.819
Shrubland	7.01	4.74	1.88	-73.19	χ^2 =2.714, df = 2, p = 0.257
Water bodies	3.71	0.78	0.55	-87.88	χ2 =3.000, df = 2, p = 0.223
Settlement	0.89	1.45	3.30	271.16	χ^2 =1.000, df = 2, p = 0.607

Table 6.8: Chi-Square goodness of fit test for the various land use and land cover changes in Njoro village between 1970's and 2012 as perceived by the local community

Land use/ land cover	1970 Area (Km^2)	1990 Area (Km^2)	2012 Area (Km^2)	% change in land use cover	χ^2 Goodness of fit test
Shrubland	10.41	10.01	9.12	-12.39	χ^2 =0.069, df = 2, p = 0.966
Rainfed Agriculture	0.09	0.44	1.02	1033.33	χ^2 =85.406,df = 2,p = 0.001
Settlement	0.05	0.1	0.41	720	χ^2 =40.750, df =2,p = 0.001

Table 6.9: Chi-Square goodness of fit test for the various land use and land cover changes in Sir Ramson's village as perceived by local community between 1970's and 2012

Land use / land cover	1970 Area (Km^2)	1990 Area (Km^2)	2012 Area (Km^2)	% change in land use cover	χ^2 Goodness of fit test
Woodland	19.94	10.61	2.12	-89.36	χ^2 =14.727,df =2, p = 0.001
Rainfed agriculture	0.21	8.48	15.91	7400.00	χ^2 =13.000,df =2, p = 0.002
Settlement	1.06	2.12	3.18	200.00	χ^2 = 1.000,df =2, p = 0.607

The PGIS technology compares well with the satellite Landsat images for analysing resource use changes. There was uniformity between the landsat images and the PGIS mental maps result on the magnitude of change on woodlands, irrigated agriculture and shrublands. Except mboghoni village changes in rainfed agriculture were visualised in the same way in all other three villages and were the same as in the landsat images. Variations between communities in the way they visualised changes in resources could be attributed to the the fact that local community knowledge is expected to spatially differ between localities and individuals.

6.4.5 Human-wildlife conflict dynamics as perceived by the local communities in 1970's, 1990's and 2012

The type of conflict experienced in a given area was influenced by the main livelihood options developed by the local community over the years. Areas where agricultural intensification increased significantly over the years also experienced increased incidences of crop destruction and rodent attacks as observed in Kitobo, Mboghoni and Sir Ramson's (Figure 6.18). Although livestock depredation affects all the villages and has been on a downward trend, it remains the main challenge for the pastoral communities as depicted in Njoro village.

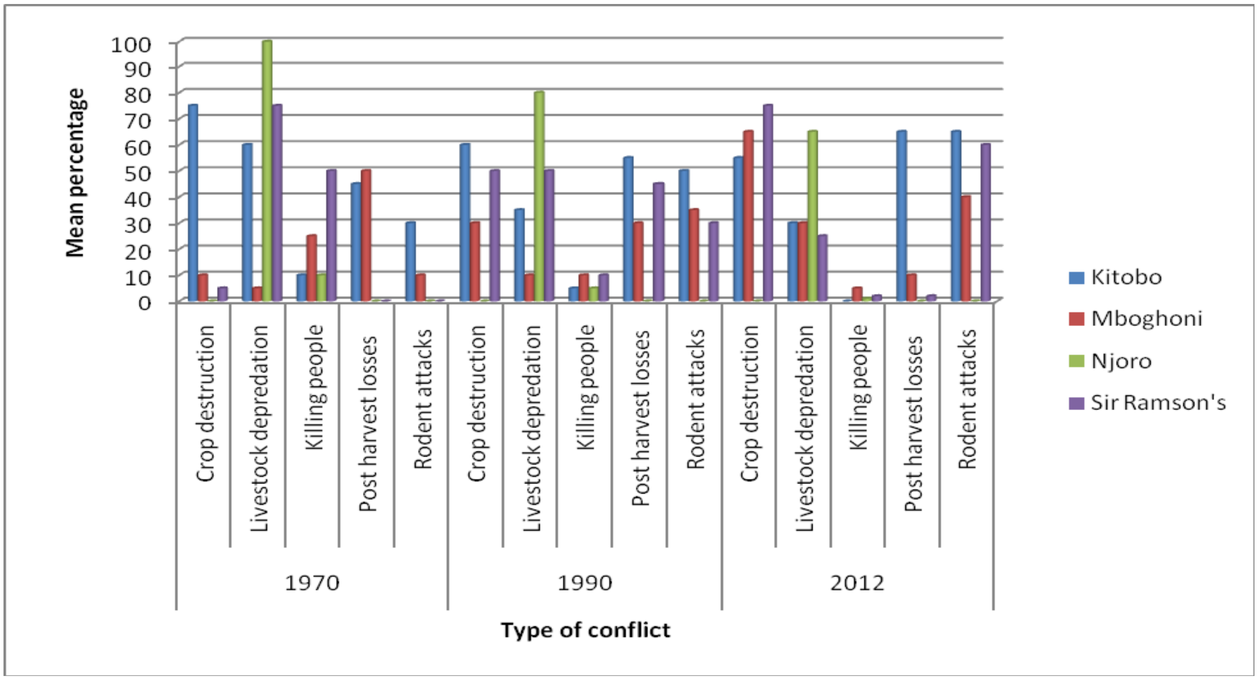


Figure 6.18: Human-wildlife conflict dynamics as perceived by the local communities in 1970's 1990's and 2012

Figure 6.19 shows how the intensities of the various types of Human- wildlife conflict compared in the various villages and how the conflict intensity changed over the years. Crop destruction has remained a challenge for Kitobo since 1970's while it has consistently increased in Mboghoni and Njukini areas . Livestock depredation is a serious threat at Njoro while relatively the same in the other three areas sampled. Post harvest losses occassioned by small and large mammals are a serious threat at Kitobo. Incidences of wildlife killing people are highest at Mboghoni followed by Njukini. Rodent attacks are currently threatening food resources with the same magnitude at Njukini and Kitobo areas. These however seem to have started in the 1990's in Njukini unlike Kitobo where they existed since 1970's.

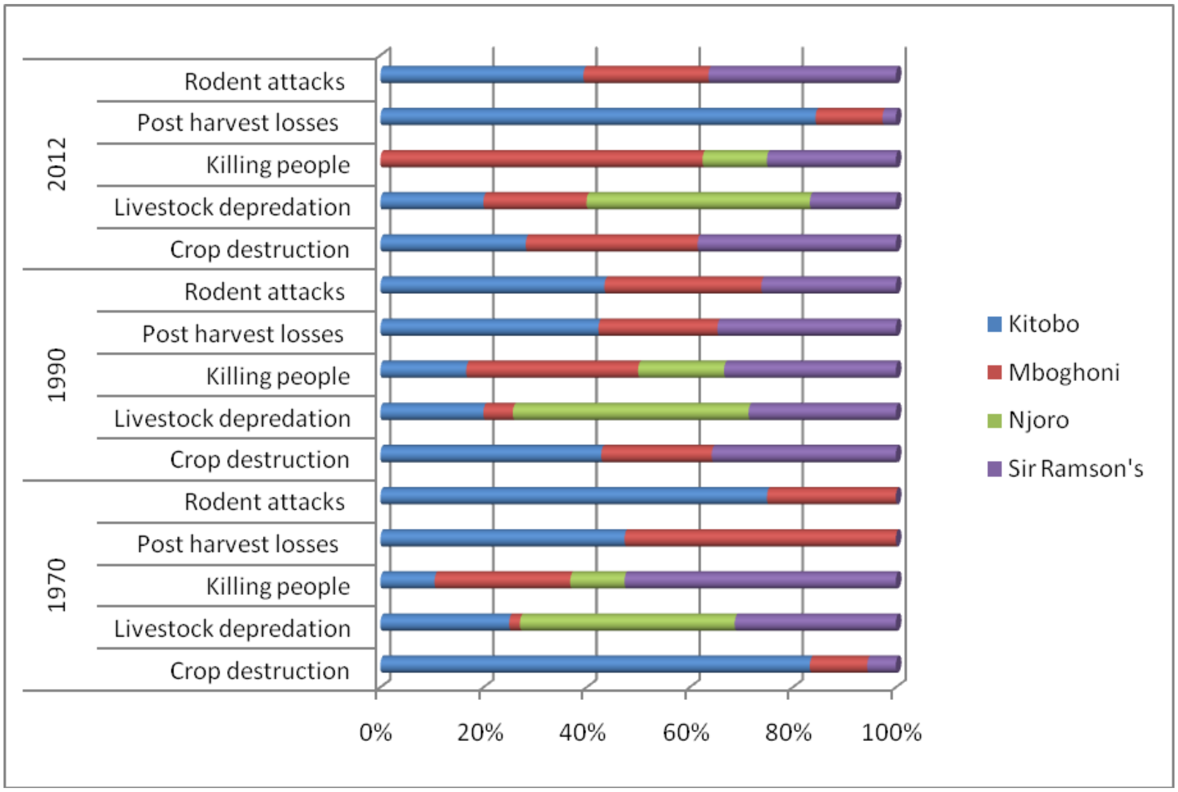


Figure 6.19: Comparison of the various Human – wildlife conflicts intensities among the villages from the various locations in 1970, 1990 and 2012

Crop destruction from large mammals and rodent attacks have been on the increase since 1970's (Figure 6.20). Both are an issue of concern in Taveta district due to their potential of influencing commmunity livelihoods and increased food insecurity. Likewise, although livestock depredation has been on the decrease since the 1970's, it still remains at high levels in the district. This will need to be put under control to enhance local community survival and promote livestock production as a good land use option which is also compatible with wildlife.

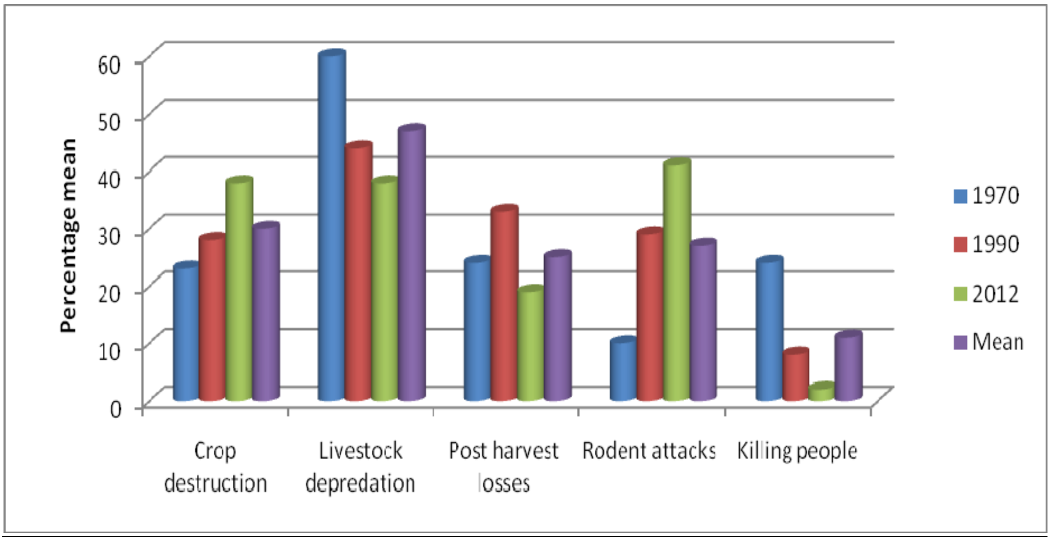


Figure 6.20: Mean percentages for Human-wildlife conflicts between 1970 and 2012

Although post harvest losses have been fluctuating and their future trends may not easily be predicted, coupled with crop destruction, and rodent attacks form a strong synergy through which local community food security by crop production becomes threatened. All these combined point to the need to control crop losses to mitigate the increasing levels of poverty which currently stands at 56% (absolute poverty) and 48% (food poverty) in the district (Republic of Kenya, 2011).

6.4.6 Undesirable effects of land use and land cover changes as envisaged by the local community in Taveta District

The local community identified almost all the expected negative effects of land use and land cover changes (Table 6.10). The most undesirable effect of the land use and land cover changes was the increase in crop destruction followed by erratic rainfall, rodent and insect pest attacks and environmental degradation at equal frequencies.

Table 6.10: Frequency of undesirable effects of the changes as envisaged by the local community in Taveta district

EFFECT	KITOBO	MBOGHONI	NJORO	NJUKINI
Increased crop attacks	*	*	*	*
Increased temperatures		*	*	*
Increased rodent and insect pest attacks	*	*		*
Environmental degradation		*	*	*
Recurrent droughts			*	*
Decreased rainfall		*		*
Increased conflicts over water			*	*
Loss of grazing land	*			*
Increased land conflicts	*	*		
Decrease in wood fuel resources			*	*
Decreased availability of building material			*	*
Biodiversity loss	*	*		
Decrease in water level		*		
Flooding	*			
Increased livestock depredation			*	

NB: * Implies occurrence of the undesirable effect

Environmental degradation led to drying up of some water catchments (Plate 6.2) while encroachment into wildlife habitats through farming was a major challenge leading to crop destruction as observed in Kitobo location (Plate 6.3). The local community demonstrated good ability in understanding the impacts of anthropogenic activities. Most important was their ability to link land use and land cover changes to the increasing levels of Human-wildlife conflicts.

Plate 6.2: Dry source of Maduli springs in Nakruto location (Picture taken during the wet season)

Plate 6.3: Agricultural expansion leading to encroachment into Kitobo forest (Unsustainable farming adjacent to a protected wildlife habitat)

6.4.7 Strategies for land resource and Human-wildlife conflict management

Local communities and other stakeholders proposed a number of strategies for managing land resources and mitigating Human-wildlife conflicts as shown in table 6.11. These strategies if employed will serve to address Human-Wildlife conflicts in an ecosystem approach by integrating the management of land resources, wildlife and people.

Table 6.11: Ranking of strategies proposed to reduce Human-wildlife conflicts and increase land resource use sustainability

Strategy	Rank	Proposers				Implementer/s
	1	Kitobo	Mboghoni	Njukini	Njoro	
Fencing homesteads and farms	1	*	*	*	*	LC
Rehabilitation of water sources	1	*	*	*	*	NEMA, MoA, LC
Streamlining compensation protocols	1	*	*	*	*	KWS, PM
Inter-sectoral coordination	1	*	*	*	*	KWS, NEMA, MoA, KFS
Compensation for crop damage, livestock depredation and human injuries and death	1	*	*	*	*	KWS
Scare crows	1	*	*	*	*	LC
Fencing the protected areas	2	*	*	*		KWS
Eco-tourism to improve community livelihoods	2	*	*	*		LC, KWS
Agricultural intensification, e.g., using greenhouses	2	*	*	*		MoA, LC
Agro-forestry – to reduce demand for fuel wood, medicinal plants and building material	2	*	*	*		MoA, KFS, LC
Attitude change towards wildlife	2	*	*	*		KWS, LC
Educating the local communities about wildlife	2	*	*	*		KWS
Increase dialogue between Kenya Wildlife Services and local communities	2	*	*	*		KWS

Increase compensation due to wildlife damages and injuries	2	*	*	*		KWS, PM
Improve water supply to wildlife in Tsavo National Park	2		*	*	*	KWS
Increase KWS personnel in Taveta district	2	*	*	*		KWS
Water harvesting	3	*		*		MoA, KWS, LC
Planting crops that are less edible to wild animals, e.g., coconuts, cotton	3		*	*		MoA, KWS, LC
Reduced charcoal burning	3		*		*	MoA, MoA, LC
Involving youths in wildlife conservation	3		*	*		KWS, LC
Community policing	3		*	*		KWS, LC
Improving wildlife habitat quality	3	*	*			KWS
Reshuffle KWS personnel after every two years	3		*	*		KWS
Increase vehicles for KWS personnel in Taveta district	3		*	*		KWS
Use of security lights in homesteads to protect livestock including kerosene lamps	4				*	LC
Rural electrification	4				*	LC, MoE
Overnight stays within the cattle sheds	4				*	LC
Improvement of communication network	4		*			KWS, MoR
Infrastructural improvement	4		*			KWS, MoR
Proper storage of crops after harvest	4		*			LC, MoA

Establishing sanctuaries	4	*			LC, KWS
Creating essential buffer zones through changes in cropping systems	4	*			LC, KWS, MoA
Use of efficient agricultural technologies	4		*		LC, MoA
Appropriate technologies to reduce demand for energy from wood	4		*		LC, MoA,NEMA
Re-Afforestation	4		*		LC, KFS, MoA
Protect Kitobo forests as a wildlife habitat	4	*			LC, KFS
Attitude change by KWS personnel towards local communities claims	4		*		KWS
Translocation of hippopotamus from Mboghoni location	4		*		KWS
Wildlife population control	4			*	KWS
Government to purchase land under sisal plantations for the local communities and issue title deeds	4	*			Gvt.
Human population control	4			*	MoH, LC
Crop damage to be assessed by Ministry of Agriculture	4		*		MoA
Introduce Small and Medium Enterprises to reduce over-reliance on crop production	4		*		MoA, NGO's, LC

Land cover change is a characteristic reflection of a human society interacting with the physical environment. In this study, local communities recognized that significant land use and land cover changes have happened in Taveta district for the last forty years as observed in their mental maps and chi-square tests. From the group discussions, land use/land cover changes were associated with a number of factors among them; human population growth, presence of permanent water sources in some parts of the district, climate change, market forces leading to commercialization of agriculture as well as low levels of agricultural technology adoption. Agricultural expansion

(both rainfed and irrigated), charcoal burning and overgrazing were found to lead to decrease of wildlife and livestock habitats of woodlands, forests, shrublands and wetlands. This also degraded important niche habitats for elephants especially in Olo-bosoit area of Njukini location that has historically been used as a calving zone. Water as a key resource in this district was competed for by people (for irrigation agriculture and domestic use), livestock and wildlife, and was noted to have decreased over the years as a result of land use and land cover changes, with some water catchments drying up. The decrease of sisal plantations, a land use form that is more compatible with wildlife and livestock was also claimed by agricultural expansion. All these scenarios continue to precipitate Human-wildlife conflicts over resources in the study area.

Local communities were able to link the decrease of wild habitats to the intensification of Human-wildlife conflicts. This indigenous knowledge held within the local community provides an opportunity for engaging them in Human-wildlife conflicts management especially through land use planning. PGIS provided a suitable tool for resource planning and identification of compatible land use options that can lead to mitigation of Human-wildlife conflicts. In similar studies, Cheeseman (2001) and Okello (2005a) and Okello and Kioko (2010) observed that, agricultural expansion within landscapes adjacent to protected areas destroys valuable wildlife habitats, including those preferred by wildlife and livestock during the dry season e.g., swamps, forests and riverbanks. Okello (2005a) observed that, cultivation was considered to be more beneficial than either pastoralism or conservation, and set the scenarios for escalation of Human-wildlife conflicts in the Amboseli area of Kenya. Likewise, Kusena (2009) observed that while deforestation, cultivation, and human-elephant conflicts increased in *the Zimbabwe, Mozambique and Zambia (ZiMoZa) Transboundary Natural Resource Management Area* over time, forest area cover decreased for the same time period. The rate of agricultural expansion in Taveta district points to the same notion; that agriculture is a more preferred land use option in the district. While a lot of effort will be needed to convince local communities to consider other land use options useful for adoption, agricultural intensification through use of fertilizers, certified seeds and green houses, as well as training on soil and water management to increase crop production in areas already cleared for cultivation will be necessary to reduce further agricultural expansion.

Agricultural expansion in this district is likely to increase and more so due to availability of markets for farm produce and its consideration as a supplement to pastoral household income. Taveta district is known for its production of horticultural produce feeding Emali town, Nairobi and Mombasa cities as well as markets in the neighbouring Tanzania. Without any mitigation, further uncontrolled agricultural expansion is a likely scenario as government policies push for local self sufficiency in food production. This will however constrain wildlife conservation in this agro-ecosystem, considering that support for free-roaming wildlife in local community lands has been found to be related to the type of land use practiced (Okello, 2005a; Kioko and Okello, 2010). Agriculture will not only block wildlife migration corridors but will also interfere with wildlife dispersal patterns. There is need for intervention through land use planning and selection of suitable land use options to mitigate further escalation of Human-wildlife conflicts in the district.

Perez (2003), Aynekulu et al. (2006), USAID (2012), and Kathumo and Gachene (2012) observed that PGIS is a useful tool for empowering and convincing communities on the importance of conserving land resources hence minimizing undesirable effects of future land use changes on natural resources. Apparently, in this study area, local communities were able to link anthropogenic disturbances to their challenges associated with environmental degradation such as droughts, decreased rainfall and water, increased temperatures, and flooding through PGIS. In addition, they were able to recognize that as their land use options changed and/or intensified as did happen with agriculture, this led to loss of natural habitats of forests, woodlands, wetlands and shrublands, thus influencing the dynamics and intensity of Human-wildlife conflicts. For example, local communities pointed out that, agricultural intensification led to blockage of migratory corridors especially in Njukini and Challa locations, where Human-wildlife conflicts mainly on crop destruction are at high levels. Likewise in Kitobo area, as communities continued to encroach into Kitobo forest through agricultural expansion and harvesting of Non- Timber forest products, conflicts from primates and other wildlife residing in the forest increased.

As observed in the PGIS maps for Sir Ramson's village, woodlands were decimated due to agricultural expansion between 1990 and 2012. With this knowledge then, PGIS can be used for mapping and monitoring key resources competed for by people and wildlife such as water catchments and calving zones; and in land use planning, opening up of migratory corridors and monitoring/conservation of water resources as a long term approaches to mitigating Human-wildlife conflicts in the district. This will however require the participation of all stakeholders involved in natural resource management for the effectiveness of the process. Similar approaches of managing socio-ecological challenges facing local communities using PGIS tools have been found useful due to their sustainability, bottom-up and multi-stakeholder approach (Aynekulu et al., 2006; ERMIS, 2007; iMAP Africa, 2009; VACID-Africa, 2010; USAID, 2012; Kathumo and Gachene, 2012). Since it is not possible to completely stop human activities within wildlife dispersal areas, it is necessary to designate agricultural activities into the suitable areas to avoid agricultural expansion into wildlife rangelands. Human-wildlife conflicts due to crop damage are more likely to increase with increased and unplanned crop production within and across wildlife dispersal areas.

The collective management of large ecosystems by indigenous populations has come to be seen as one of the models that have gained considerable attention because of its ability to address a variety of indigenous self-determination, ecosystems conservation, and sustainable development objectives (Paradino, 2005; Maass, 2008). The new generation PGIS seeks to enable mapping, modeling and monitoring within an integrated framework encompassing planning, development and conservation needs defined and developed by user groups (Tane and Yu, 2002; Haikai and

Xiaojun, 2007). PGIS technology was easily used by local communities to showcase their indigenous knowledge on resource changes and a suitable tool for communication that offers communities the opportunity to communicate to natural resource managers and researchers.
Through the community forums, participants were able to note changes and understand resource use changes, highlight on direct and indirect benefits and discriminate undesirable effects while offering them an opportunity to propose from an informed point of view approaches to enhance land resources sustainability. Some of the proposals made for reducing Human-wildlife conflicts, can only be implemented by the local communities themselves. This will require the community's goodwill to invest in such ventures, and therefore local communities will need tangible/realistic benefits from such investments. This calls for negotiations, clear understanding and transparency between wildlife managers, land resource managers, policy makers and local communities. The PGIS approach can lead to win-win situations and therefore suitable for such negotiations and implementation of strategies for mitigating Human-wildlife conflicts. The approach is suitable for setting up areas for multiple resource uses such as dry season grazing and water resources that are important for wildlife and livestock, eco-tourism initiatives, and community wildlife sanctuaries that can benefit local communities who bear the brunt of the conflicts. Communities were convinced of the importance of sustainable land use options and land use planning in order to reduce the negative impacts of unplanned and unwarranted opening of unproductive land. For the benefit of wildlife and people, Human-wildlife conflicts management approaches need to utilize the principles of the "ecosystem approach" for natural resource management in this district. In this approach, the main focus will be on biotic and abiotic interactions and the interacting components, viewed in a single integrated system including the interaction of human being with the ecosystems. The approach is based on the understanding that human beings cannot have limitless extractions of resources from the environment. It is this extraction of resources from the environment which leads to resource competition between people and wildlife, and which is manifested in the form of Human-wildlife conflicts. With this is mind then, it is possible to implement adaptive management strategies for managing Human-wildlife conflicts together with the communities, while allowing for inter-sectoral cooperation as observed from the many implementers expected to participate in Human-wildlife conflicts in this study. PGIS will be indispensable in promoting this multi-stakeholder and multi-participant process.

6.4.8 Local community feedback on PGIS technology

Local communities were excited and emphasized the appropriateness of PGIS for resource mapping irrespective of their level of education. They considered PGIS a useful technology that offers an opportunity to express knowledge on resource changes over time, held within local community domain. PGIS was considered useful for communicating to resource managers and also has the potential to break communication barriers. They stated that, the maps are replicated in their minds (knowledge transfer) and can be used to educate both the old and the young with ease. It also helped them understand resource use changes as a reason behind Human-wildlife conflicts thus enabling them to focus on how to cope with land resource management to counteract the conflicts while enhancing co-existence with wildlife. PGIS enabled them understand why they needed other livelihood options to counteract the impacts.

Local community appreciated the PGIS process of analysing land use change. They were elated and described the PGIS exercise in their dialects as; Maasai community gave an overview phrase as "*Sidai Oleng*", i.e., excellent. They described it as "*Engutuk oo Maasai engigiereto olpolosie lempiron e ngop naa sidai naa oreengita duata engibelekenyata e nye too larin ootulusoitie ometabaiki enakata taata naa ore enikingo temiki ramat tengoitoi sidai ebaiki ekakata o ngologi naaponu".* This in English translated as; the mapping process is an excellent way of enlightening them on the implications of resource changes over the years. The Taveta community felt that PGIS mapping was an excellent process in analyzing and explaining the causes of Human-wildlife conflicts, and facilitated strategizing for future approaches for reducing the conflicts. In Kiswahili they described it as follows; " *Ni njia ya busara sana kutumia ramani (Mapping) ya raslimali kuelezea sababu ya migogoro baina ya wanyama na binadamu, zamani na hata sasa*" , while in Taveta they described it as; *' Ni – Kindu Ki-inare mno kutama kighongo na wuzuri hena kutwarija mawoo ghati ya wandu na nyamao, iki na kae".* The Kamba community was equally thrilled and described it in Kamba dialect as "*Usoli wa mavu ya mali ni nzia nzeo kwa kutwonethya ualyuku wayo kuma ivinda ya myaka ya navu itina kuka kuvika umunthi, na undu tutonya kuitumia nesa ivinda yii na yila yukite".* The Taita community appreciated the process and described it as excellent in local dialect as " *kuchora kwa mapu ni kukumbuka malgho gha kala na maghesho gha kala nag ha itana a kwiya didimagha kughitumia kwa chia I poie katuma* *itana na wakati ghuchagha"*. Individuals from the Luhya community described it as excellent too. In their dialect as; "*kuchora kwa map kwakongora vurahi kumanya amabadiliko mabadiliko ngene khutura mihenga jakare njiene mpaka useno khure khungara khutumire mzira indai khutura isainu khuridiku rinza"*. In general, all communities felt the process was excellent in educating local communities about resource use changes and their implications. The elderly participants felt that it was a good way of teaching since they were able to participate despite their age and low level of education.

Farmers appreciated the technology for its ability to help them link resource use change to escalating Human-wildlife conflicts experienced and their dynamics. Some were excited about how a mapping process could easily help them understand the root causes of Human-wildlife conflicts and encouraged for an apology to the wildlife managers, for they now knew that they had a share of their contribution too. Through this technology they felt they needed to actively participate in managing resources and wildlife to reduce Human-wildlife conflicts in the district.

6.5 Conclusions and Recommendations

Since Human-wildlife conflict management requires; problem identification (causes) and development of objectives, formulation of management strategies or alternatives and evaluation of the success of management actions, then PGIS technology offers that opportunity to achieve sustainable management of Human-wildlife conflicts in a multi-stakeholder – multiparticipant process. In conjunction with the local communities, PGIS technology can be used to assist the wildlife resource managers and planners in mapping out key resources and the Zones of Interactions (ZOI) to facilitate identification of opportunities that satisfy conservation and livelihood needs.

It is apparent that the decline of wild habitats of shrublands, woodlands and forests in Taveta district coupled with uncontrolled agricultural expansion has a direct link to the nature, escalation and spatial distribution of Human-wildlife conflicts. It is necessary that further changes on wild habitats are monitored as part of the efforts to counteract negative implications of the changes including Human-wildlife conflicts. PGIS can be used for enhancing community awareness on the implications of the changing scenarios of land use and land cover changes and hence facilitate planning. This way local community understands the possible scenarios that precipitate Human-wildlife conflicts. Such knowledge increases local community capacity to participate in implementing strategies proposed, that can mitigate the conflicts.

PGIS technology can lead to win-win situation whereby managers and planners balance the opportunity costs for different approaches in managing resources and evaluating ways/ strategies that can win support from local communities. PGIS will allow local communities to participate in Human-wildlife conflict management through communication and direct involvement. It can be used to campaign for sustainable use of land resources and convince local communities to participate and uptake strategies implemented. It offers communities the opportunity to learn about resource use change, participate in their conservation and own problems irrespective of their age and level of education.

PGIS technology has the potential to improve the ability of wildlife managers to manage wildlife by filling the managers "tool box" through improved understanding and integrating stakeholders in the development of applicable and sustainable Human-wildlife conflict management strategies. PGIS has the potential to enhance transparency, empowerment, dialogue and negotiation from existing positions thus improving stakeholders' possibility of formulating sustainable wildlife management strategies in a multi-participant process. It can have profound implications and stimulate innovation and social change in the district.

CHAPTER 7

7.0 GENERAL DISCUSSION, CONCLUSSIONS AND RECCOMMENDATAIONS

7.1 General Discussion

In Taveta district, Human–wildlife conflicts took various forms. Among the key types of conflicts were; eating crops, trampling on crops, livestock depredation, and bothering people. Majority of the respondents (59.7%) associated the conflicts to wildlife from Tsavo West National Park. The intensity and diversity of conflicts were found to be significantly different between the locations. Seasonality was considered to be a key factor driving conflicts except in the irrigated zones of the district. Elephants had the greatest impact on local communities, followed by primates, bushpigs and hippopotamus in that order. The impact of the various species was found to differ significantly between locations, with elephants affecting six out of the eight locations sampled. Hotspots for hippopotamus, which are aquatic species, were highly limited to the irrigated zones with deep aquatic habitats. Livestock depredation differed significantly between the five locations affected and was occasioned by hyenas, lions, and leopards. Elephants, primates, bushpigs and antelopes raided farms in groups. Most of the attacks by wildlife occurred at night except for the primates which raided predominantly during the day. Majority of the wildlife species preferred to eat cobs and stems. Maize was the most preferred crop by elephants and bushpigs which were also the top ranked species in crop destruction. Wild animals preferred farms with 3 to 4 types of crops. Most of the farmers were small scale farmers owning small farms of about one acre, a situation that was found to increase their vulnerability to conflicts since more than half of the farms visited by elephants were destroyed. Conflicts have been experienced in Taveta district for quite some time with more than 50% of the respondents having noticed them more than 15 years ago. These had changed local community attitude towards wildlife, with 72.3% and 22% of the people interviewed having negative and very negative attitudes towards wildlife respectively especially for elephants, bushpigs and lions.

The escalation of Human-wildlife conflicts has been attributed to increase in human population, changes in land use patterns, loss of wild habitats, lack of benefit sharing, community attitudes and lately approaches to their management. Considering the status of Human-wildlife conflicts in

Taveta district and in order to provide scientific information on which appropriate strategies for their management can be based on, this study focused partly on land use and land cover changes and human population dynamics as some of the known root causes of conflicts. Seven land use and land cover types were discriminated as forests, irrigated agriculture, rainfed agriculture, shrublands, woodlands, sisal plantations and water bodies. Woodlands (the third largest land cover) and sisal plantations decreased significantly, while rainfed agriculture (the second largest land cover) and irrigated agriculture increased significantly. Shrublands which occupy the largest land cover did not change significantly. Likewise forest (the third least land cover) and water bodies which is the least land cover did not change significantly. Human population increase in the district was steady and strongly related to time. However, a sharp increase occurred between 1989 -1999 compared to all other time periods. Assuming the status quo remains, a ten year projection for land use and land cover changes revealed that agriculture is expected to increase tremendously while habitats suitable for wildlife and livestock are expected to decrease further, e.g., the woodlands which tended towards decimation as shrublands and sisal plantations continue to decrease further.

Although Taveta district has an ecological potential for cotton, sisal, millet and livestock production, agricultural expansion has in the last decades seen rainfed production of maize, beans, bananas, and other horticultural crops occupy 38.5% of the district. These land use and land cover changes which favored agricultural expansion directly corresponded to the increase of human population in the district over the years. These land use and land cover transformations set the scenario for further escalation of Human-wildlife conflicts in the district and will have far reaching implications for wildlife conservation. Although local communities have continued to clear sisal plantations for other forms of land use, it is one of the suitable land use option for the area, which is compatible with wildlife conservation. In addition, livestock production is yet another sustainable option of land use suitable within this wildlife dispersal area. Encouraging the above land use production systems in rainfed agricultural zones, can act as a mechanism to curb Human-wildlife conflicts, if coupled with proper land use zonation to enhance environmental sustainability.

A relationship was found to exist between land use change, population increase, local community attitude towards wildlife and the levels of Human-wildlife conflicts in the district. Addressing Human-wildlife conflicts will require active engagement of the local communities who are the custodians of the land adjacent to the Tsavo West National park. PGIS tools and approaches were found to be appropriate for analyzing land use and land cover changes, as one of the root cause of conflicts by the local communities. Through PGIS, communities were able to recognize all the seven land use and land cover types as identified using conventional GIS and RS. PGIS was also found to be appropriate for analysing the dynamics of Human-wildlife conflicts as influenced by the socio-ecological settings (SESs) and challenges of the local communities. Through PGIS sessions, crop destruction from large mammals and small mammal attacks were found to have been on the increase since 1970's in many parts of the district in response to land use and land cover changes. Although livestock depredation was found to have slowly declined since the 1970's, it still remains at high levels in the district and will need to be brought under control. Livestock depredation was also associated to attempts by the local pastoral community's insistence to graze in the park, thus exposing their livestock to carnivore attacks. In addition, inefficient livestock protection measures were also a contributing factor.

Through PGIS sessions, local community identified the negative effects of land use and land cover changes and their implications to Human-wildlife conflicts. In addition they identified their role in shaping the complex socio-ecological systems interactions that influence the dynamics of Human-wildlife conflicts. Strategies for sustainable land resource and Human-wildlife conflict mitigation were proposed. Among the strategies proposed by the local communities were fencing of farms and homesteads, rehabilitation of water sources, inter-sectoral coordination in managing the conflicts, compensation for both crop damages and livestock depredation, and injury or death of people from wildlife attacks, and erecting scare crows. Rural electrification will come in handy in mitigating livestock depredation. From the strategies proposed, improved lighting is a necessity for mitigating livestock depredation from homesteads. Pastoral communities were not keen on fencing of the park, a pointer to their interest in continued use of resources from the Tsavo West National park. This will be counterproductive in reducing livestock depredation which also happens during grazing in the park. Worth noting is the notion by local community from Njukini location, that, conflicts are as a result of increasing wildlife population hence the need for its control. This is in contrally to wildlife population trends in Tsavo West National Park.

Ideally, dialogue forms the basis of resolving conflicts. Conflict resolution stems from building trust, honesty, accountability and appropriate implementation of issues under discussion. Since Human-wildlife conflicts are a manifestation of resource competition between wildlife and local communities, future attempts for managing conflicts in this district will immensely benefit from PGIS tools and processes in a number of ways. These will specifically be useful for; Long-term sustainability of Human-wildlife conflicts management in the district by addressing the key issues in relation to socio-ecological settings approaches to wildlife management; implications of mismatch between manager (KWS) and local community objectives leading to non-compliance with regulations and the implications of complex decision making of actors. PGIS tools and approaches bring actors together into the same platform for decision making unlike the conventional GIS and RS approaches. PGIS will also be beneficial in delineating the Zones of Interaction including wildlife corridors to Tanzania, implementing integrated monitoring and evaluation of land use and land cover changes as processes that influence community livelihoods sustainability, Human-wildlife conflicts and conservation. In addition PGIS will be useful in identifying and strategizing for opportunities leading to sustainable wildlife utilization with the local communities, e.g., eco-tourism potentials, wildlife farming among others for the benefit of the community and in implementing ecosystem approaches for integrated watershed management initiatives. The district has rivers important for sustaining local community livelihoods and wildlife needs. These include rivers Lumi, Tsavo, Njoro and Kitobo and important springs such as Kwa Tom springs, Maduli springs, and Kitobo springs that are in dare need for conservation measures. In addition are lakes Jipe, Salengwa and Chala that can be multi-purpose. PGIS also serves to open communication channels between local communities, natural resource managers and policy makers in a more amicable way that creates transparency and win-win situation, in addition to enhancing community awareness on wildlife and natural resources that could lead to attitude change towards wildlife and sustainable natural resource utilization. Evaluating the efficiency of implemented approaches and strategies for Human-wildlife conflict management and developing Participatory Three Dimensional Models (P3DM) that will allow stakeholders to visualize and feel the implications of continued LULCC in relation to environmental and livelihood sustainability and Human-wildlife conflicts intensification are also other ways in which PGIS can be applied.

Implications of the research findings to policy

Human-wildlife conflicts result when the actions of humans or wildlife have an adverse impact upon the other. Principal areas of concern indentified for Taveta district in this study include: species with economic impact on local farming communities by damaging crops and livestock depredation, influence of the social fabric of the community as people spend more time during the day and night guarding crops, competition for water and grazing and the potential for disease transmission between wildlife and domestic animals or to humans. These research findings highlight the need for better understanding, action and awareness of the nature and complexity of factors contributing to Human-wildlife conflicts in Taveta district, including agricultural practices and wildlife management initiatives. Agricultural policies that advocate for increased food production through increasing area under cultivation in low production zones that are wildlife dispersal areas, will exacerbate Human-wildlife conflicts. On the other hand, the fact that the conflicts have persisted over a long time is an indication of challenges that have not sufficiently been addressed through appropriate policy directions and /or implementation. The study findings have important implications on current draft wildlife policy of 2011(Republic of Kenya, 2011), draft wildlife conservation and management bill (Republic of Kenya, 2012), the Environmental Management and Coordination Act (EMCA, 1999) and Environmental management and Co-ordination Regulations for wetlands and riverbanks (NEMA, 2009) in the country.

As observed in this study, Human-wildlife conflicts are a real challenge facing wildlife conservation and community livelihoods in Taveta district. The conflicts were partly attributed to land use change, human population increase and community attitudes towards wildlife. Apparently, the Draft Wildlife Policy (2011) Section 9.1 recognizes the challenges posed by land use change and population pressure as drivers of Human-wildlife conflicts. The policy further recognizes the need to ensure that local communities and landowners are involved in putting in place measures that mitigate Human – wildlife conflicts (Section 9.2). Of interest is the fact that the draft policy embraces diverse stakeholders in addressing the immense threats and challenges facing wildlife conservation in the country, including the private sector, Non-Governmental Organizations (NGOs) and development partners to mobilize the needed resources. This approach was found to be fundamental in conflict resolution. However, it does not describe the mechanisms of stakeholder involvement. PGIS approaches can play a key role in enhancing stakeholder participation in the process.

Stakeholder involvement is a more inclusive process compared to the past approaches, and if well managed can avail the much needed resources which could play a role in implementing innovative and effective mechanisms for prompt and adequate compensation for human injury and loss of life, crops, livestock and property as proposed in the policy (Section 9.3.8). However, local community benefits could be impaired through the proposed Draft Wildlife Bill (Republic of Kenya, 2012), which pegs compensation on the fact, that injury or death does not occur in the course of any conduct on the part of the person concerned. This poses a challenge to the local communities based on the fact that, injury or death by wildlife could occur in the course of protecting their livestock and/ or crops which are part of their livelihood. In addition, the bill also indicates that no compensations will be accrued if the owner of the livestock, crops or property failed to take reasonable measures to protect the crops, livestock or property from damage by wildlife or his land use practices are incompatible with the ecosystem-based management plan for the area. These are aspects that will need to be reviewed and appropriate mechanisms put in place to ensure that farmers and pastoral community vulnerability to wildlife impacts is not increased.

Human-wildlife conflicts are about competition for resources whose efficient management will require more stakeholders than local communities and landowners. Human-wildlife conflict challenges will benefit immensely from PGIS tools and approaches through which local communities have an opportunity to discuss and understand causes of their problems with wildlife, communicate directly to wildlife managers and air their concerns while giving views and proposals for improved wildlife legislation and management. In a multi- participant process, PGIS tools and processes will be useful in evaluating and monitoring resources competed for by wildlife and people such as land, water, pasture, habitats etc, while offering a user friendly plat form that can create win-win situations in managing Human-wildlife conflicts, e.g., delineating wildlife corridors which has always been a daunting task for wildlife managers. Addressing challenges occasioned by land use change and land use planning to counteract Human-wildlife conflicts will inevitably require local community participation since they are main actors for implementing most of the strategies while at the same time being the custodians of the land on which wildlife depends on as dispersal areas.

As observed in this study, some of the issues that need to be addressed in land use planning are land zonation, the size of farms owned by farmers and the number of crop types in the farms. Community farms may be an option local communities need to discuss and agree upon, since small farms were found to enhance farmers' food insecurity due to the destructive nature impacted by wildlife especially elephants. On the other hand wild animals preferred farms with 3 - 4 types of crops. As one of the strategies for managing conflicts, then farmers together with the ministry of Agriculture in the district may need to review farming systems with regards to levels of intercropping to mitigate on conflicts, i.e., either plant fewer crops or increase the number of crops per given farm. These scenarios were less preferred especially by elephants.

The Environmental Management and Coordination Act (EMCA) of 1999, and the Environmental management and Co-ordination Regulations for wetlands, riverbanks, lake shores and sea shores (NEMA, 2009) states the need to utilize wetland resources in a sustainable manner compatible with its continued presence together with their hydrological, ecological, social and economic functions and service. Most farmers however planted their crops especially bananas into the riverbank thus enhancing the conflicts.

7.2 Conclussions

From this study it can be concluded that human-wildlife conflicts around protected areas are a common phenomenon. As observed in the land use and land cover change analysis, the dwindling of wildlife resources outside protected areas has been linked to human actions and is a major cause of conflicts. Due to the negative impacts local community have experienced in Taveta (damage to crops, livestock depredation, attacks by wild animals, restricted access to grazing and sometimes water resources, and killing people), they consider wildlife a liability. It is thus necessary that efforts are made to ensure wildlife contributes to development of local communities so as to spur attitude change towards wildlife conservation. For this to be achieved then, a multi-participant process is a meaningful approach in resolving the prevailing Human-wildlife conflicts with a view of lobbying for social acceptability, enhancing environmental sustainability of wildlife resources and making wildlife an economically viable land use option in the eyes of local communities. In particular, the Kenya Wildlife Service as the lead government agency in dealing with conflicts should;

- Spearhead community mobilization to map the wildlife corridors to Tanzania; elephant corridors through Njukini and Challa locations.
- Improve wildlife habitats including water resources in the agro-ecosystem
- Strive to address the conflicts using PGIS approaches so as to facilitate a multistakeholder-multiparticipant process. This will specifically address; delineating Zones of Interaction, implementing integrated monitoring and evaluation of trends in land use and land cover changes, identifying and strategizing for opportunities leading to sustainable wildlife utilization with the local communities and evaluating the efficacy of implemented approaches and strategies for Human-wildlife conflicts management.
- Implement acceptrable compensation levels due to wildlife conflicts, and
- Ensure the existence of a functional electric fence around the Tsavo West National Park.

On the other hand local communities should be encouraged to;

- Adopt sustainable utilization of wildlife resources through wildlife farming, eg, guinea fowl, ostrich and crocodile farming.
- Embrace community farms where applicable especially in areas of high agricultural potential such as the irrigated zones.
- Adopt other alternative farming approaches such as agricultural intensification, use of efficient agricultural technologies that enhance water use efficiency and conservation, compatible farming systems eg, planting crops that are less palatable to wildlife, and cotton farming, and
- Avoid encroachment into wildlife conservation areas.

7.3 Recommendations

From this study, the following recommendations can be drawn with regards to Human-Wildlife conflicts, land use and land cover changes and wildlife management approaches for enhanced wildlife conservation and management, improved local community livelihoods and food security:

- Address conflicts in this district to safeguard local community livelihoods and enhance wildlife conservation.
- Raise community awareness on wildlife to improve understanding and appreciation of wildlife resources.
- Undertake land use planning in the district in order to prevent unplanned agricultural expansion and uncontrolled opening up of agriculturally unproductive rangelands to farming.
- Implement alternative livelihoods/approaches to farming especially in areas where conflicts are high and where crop production potential is low, in particular, SMEs, community farms, wildlife farming (guinea fowls, ostrich farming, crocodile farming) and ecotourism for example nature trails in Kitobo forest.
- Strategic management of livestock production to minimize losses to depredation and improve its potential through value addition in the livestock production-marketing chain thus reducing the demand for farming expansion by the pastoral communities.
- Embrace PGIS tools and processes in order to promote wildlife and land resources conservation and management in an ecosystem approach.
- Emphasize and implement the environmental and wetlands management regulations to avert conflicts especially from hippopotamus, an aquatic species inhabiting most rivers of the irrigated zones in Taveta district.
- Evaluate the applicability of sisal production as a compatible land use option, and
- Characterize the conflict causing species hotspots with regards to their social and ecological characteristics that may foster conflicts in the future.

7.4 Future research areas

1. Detailed study on key conflict causing species mainly the elephants, primates, hippopotamus, hyenas, lions and leopards. Such studies should focus on mapping their feeding ranges, identify and characterize their specific hotspots as well as their feeding behaviours.
2. Determine the efficacy of the traditional approaches to Human-wildlife conflicts management applied by local communities.
3. Establish approaches that can enhance the sustainability of livestock production systems and sisal production as compatible land use options .

8.0 REFERENCES

African Elephant Specialist Group (AfESG). (2010). Human-elephant conflict integration model, Mozambique and Tanzania. *IUCN African Elephant Specialist Group. 28 pp.*

African Elephant Specialist Group (AfESG) (2000a). Compensation schemes for agriculture and other damage caused by elephants. *AfESG Technical Brief Series. IUCN African Elephant Specialist Group, Human Elephant Conflict Working Group, Nairobi, Kenya*.

Akama, J.S. (1998). The evolution of wildlife policies in Kenya. *Journal of Third World Studies* ***2****: 103–107.*

Alejandro, F.S., Ramos, M.M. and Masera, O.R. (2007). Assessing implications of land-use and land-cover change dynamics for forest conservation of a highly diverse tropical rain forest. *Biological Conservervation.* ***138****:131-145.*

Alfa-Gambari-Imorou, S., Mama, A., Tehou, A. and Sinsin, B**.** (2004). The human-elephant (*Loxodonta africana*) conflicts in the hunting zone of Djona (Benin) adjacent to the Regional Park of the W: the case study of the villages of Alfakoara. *In* P. Chardonnet, F. Lamarque & M. Birkan, eds. *Proceedings of the 6th International Wildlife Ranching Symposium*, Paris, France, 6–9 July 2004. *Game and Wildlife Science,* ***21(4):*** *553–569.*

Anderson, G.L. (1998). Classification and Estimation of Forest and Vegetation Variables In Optical High Resolution Satellites: A Review of Methodologies. Interim Report IR-98-085 /October, 1998. *International Institute for Applied Systems Analysis, Laxenburg, Austria.*

Aschbacher, J., Ofren, R., Delsol, J.P., Suselo, T.B. and Vibulsresth, S. (1995). An integrated comparative approach to mangrove vegetation mapping using advanced remote sensing and GIS technologies: Preliminary results. *Hydrobiologia* ***295****: 285–294.*

Austin, Z., Cinderby,S., Smart, J.R.C., Raffaelli,D. and White, P.C.L. (2009). Mapping wildlife: Integrating stakeholder knowledge with modelled patterns of deer abundance by using participatory GIS. *Wildlife Research,* ***36****:553-564.*

Aynekulu, E., Wubneh, W., Birhane, E. and Begashawl, N. (2006). Monitoring and Evaluating Land Use/Land Cover change using participatory geographic information system (PGIS tools: A case study of Begasheka watershed, Tigray, Ethiopia. *Electronic Journal on Information in Developing Countries:* ***25 (3)****: 1-10.*

Baaru, M.W. (2011). Improving small holder land productivity through promotion of sustainable soil and water conservation technologies in Machakos District. A case of vegetative macro contour lines. *PHD Thesis, University of Nairobi.*

Barnes, R.F.W. (2002). Treating crop-raiding elephants with aspring. Pachyderm **23**: 96-99.

Barnes, R.F.W. (1996). The conflict between humans and elephants in the central African forests. *Mammal Review, **26 (2)**: 67–80.*

Barnes, R.F.W., Boafo, Y., Nandjui, A., Umaru-Farouk, D., Hema, E.M., Danquah, E. and Manford, M. (2003). *An overview of crop-raiding by elephants around the Kakum Conservation Area*. Elephant Biology and Management Project, Africa Program. Washington, DC, USA, Conservation International.

Barnes, R.F.W., Hema, E.M., Nandjui, A., Manford, M., Dubiure, U.F., Danquah, E., and Boafo, Y. (2005). Risk of crop raiding elephants around the Kakum Conservation Area, Ghana. *Pachyderm **39**:19-25.*

Baruch-Mordo, S., Breck, S.W., Wilson, K.R. and Broderick, J. (2009). A toolbox half full: How Social Science can help Solve Human –wildlife conflicts. *Human Dimensions of Wildlife **14**: 219-223.*

Baruch-Mordo, S., Breck, S.W., Wilson, K.R. and Broderick, J. (2011). The Carrot or the Stick? Evaluation of Education and Enforcement as Management Tools for Human-Wildlife Conflicts. *PLoS One.* ***6 (1):*** *5-12.* http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0015681

Bauer, H. (2003b). *Lion conservation in West and Central Africa – integrating social and Natural science for wildlife conflict resolution around Waza National Park, Cameroon*. University of Leiden, Holland. (Ph.D. Thesis).

Bengis, R.G., Kock, R.A. and Fischer, J. (2002). Infectious animal diseases: the wildlife/ livestock interface. *Revue Scientifique et Technique (International Office of Epizootics), **21 (1):** 53–65.*

Beresford, M. and Phillips, A. (2000). Protected landscapes: A conservation model for the 21st century. *George Wright Forum **17**: 15–26.*

Berger, L.R. (2006). Predatory bird damage to the Taung type-skull of Australopithecus Africanus Dart 1925. *American Journal of Physical Anthropology, **131**: 166–168.*

Berger, D.J. (1993). Wildlife extension: participatory conservation by the Maasai of Kenya.

African Centre for Technology Studies. *ACTS Environmental Policy Series* ***4****: 5-45. Nairobi, Kenya.*

Berger, L.R. and Clarke, R.J. (1995). Eagle involvement in the accumulation of the Taung child. *Journal of Human Evolution,* ***29****: 275–299.*

Blasco, F., Gauquelin, T., Rasolofoharinoro, M., Denis, J., Aizpuru, M. and Caldairou, V. (1998). Recent advances in mangrove studies using remote sensing data. *Marine Freshwater Research,* ***49****: 15-22.*

Bojorquez-Tapia, L. A., Brower, L. P., Castilleja, G., Sanchez-Colon, S.,Hernandez, M. (2003). Mapping expert knowledge: redesigning the monarch butterfly biosphere reserve. *Conservation Biology* ***17****: 367–379.*

Brandon, R.B. (2001). Mapping Rural Land Use and Land Cover Change in Carroll County,Arkansas Utilizing Multi-Temporal Landsat Thematic Mapper Satellite Imagery. Thesis University of Arkansas. http://www.cast.uark.edu/local/brandon_thesis/index.html

Brown, G., Smith, C., Alessa, L., and Kliskey, A. (2004). A comparison of perceptions of biological value with scientific assessment of biological importance. *Applied Geography* ***24****: 161–180.*

Bruce, D.P., Samuel, M.K. Edwin, S. and Roland, W. K. (2003). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National Parks, Kenya. *Biological Conservation* ***119****: 507–516.*

Burkey, T. (1994). Faunal collapse in East African game reserves revisited. *Biological Conservation* ***7 (1):*** *107–110.*

Butler, J.R.A. (2000). The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. *African Journal of Ecology* ***38 (1):*** *23–30.*

Campbell, D.J. (1993). Land as ours, land as mine: Economic, Political and Ecological Marginalization in Kajiado District. In T. Spear & R. Waller (Eds). *Being Maasai: Ethinicity and Identity in East Africa (pp: 258-272).* London: James Currey.

Campbell, D.J., Gichohi, H., Mwangi, A. and Chege, L. (2000). Land use conflicts in Kajiado District, Kenya. *Land Use Policy* ***17****: 337–348*.

Campbell, D., Lusch, D., Smucker, T. and Wangui, E. (2003). Root causes of land use changes in the Loitoktok Area, Kajiado District, Kenya. Land use Change Impacts and Dynamics (LUCID) Project Working Paper 19. International Livestock Research Institute, Nairobi, Kenya, 37pp.

Campbell, D., Lusch, D., Smucker, T. and Wangui, E. (2005). Multiple Methods in the Study of Driving Forces of Land Use and Land Cover Change: A Case Study of South East Kajiado District, Kenya. *Human Ecology* ***33 (6)****: 763-795.*

Chakraborty, D. (2001). Characterization and spatial modeling for hydrological response behaviour of Birantiya Kalan watershed in western Rajasthan – remote sensing and GIS approach. *PhD. Thesis. IARI, New Delhi, India.*

Cheeseman, T. (2001). Conservation and the Maasai in Kenya: tradeoff or mutualism? On ''Policy failure in Kenyan conservation and Maasailands. *Cheesemans' Ecology Safaris, 18.*

Cinderby, S., and Forrester, J. (2005). Facilitating the local governance of air pollution using GIS for participation. *Applied Geography* ***25****: 143–158.*

Convention on Biological Diversity (CBD). (1992). The United Nations Convention on Biological Diversity. *Rio De Janeiro, 3-14 June 1992.*

Dahdouh-Guebas, Verheyden, F.A., De Genst, W., Hettiarachchi, S. and Koedam, N. (2000b). Four decade vegetation dynamics in Sri Lankan mangroves as detected from sequential aerial photography: a case study in Galle. *Bulletin of Marine Science* ***67 (2)****: 741–759.*

Danquah, E. Oppong, S.K., and Sam, M.K. (2006). Aspects of elephant crop-raiding behaviour in the Kakum Conservation Area, Ghana. *Nature et Faune* ***21 (2)****:15-19.*

DeFries, R., Krithi, K.K., and Sajid, P. (2010). Interactions between protected areas and their surroundings in human-dominated tropical landscapes. *Biological Conservation* ***143****: 2870–2880.*

De Vaus, D.A. (1996). Surveys in social research. 4th Edition. *Allen and Unwin. Pp. 76.*

Dovie, D.B.K., Witkowski, E.T.F., and Shackleton, C.M. (2005). Monetary valuation of livelihoods for understanding the composition and complexity of rural households. *Agriculture and Human Values* ***22****: 87–103.*

Ebua, V.B., Tsi E. A. and Fonkwo, S.N. (2011). Attitudes and perceptions as threats to wildlife conservation in the Bakossi area, South West Cameroon. *Biodiversity and Conservation* ***3 (12)****: 631- 636.*

Elwood, S. (2002) GIS Use in Community Planning: A Multidimensional Analysis of Empowerment. *Environment and Planning* ***34****: 905-922.*

ERMIS Africa, (2007). The Role of PGIS in safeguarding community resource rights: The case of Ogiek, Sengwer and Yiaku Indigenous people in Kenya.

http://www.ermisafrica.org/index.

Environmental Systems Research Institute (ESRI). (2009). *ESRI, Redlands, California. USA.*

EXELIS Visual Information Solutions(ENVI). (2012). ENVI 4.7 and ENVI EX. ITTVisual Information Solutions. ESRI, Redlands, California. USA.

http://www.exelisvis.com/portals/0/pdfs/envi/envi4.7

Fergusson, R.A. (2002). Living with a wild predator: managing human/crocodile conflict in Africa. A proposal for an IUCN/SSC Crocodile Specialist Group initiative to provide technical support for the investigation and alleviation of human/crocodile conflict in several African countries. *Crocodile Specialist Group Newsletter* ***21 (4)****: 17–21.*

Food and Agriculture Organization (FAO). (2009). Human- Wildlife conflicts in Africa; Causes, Consequences and management practices in Africa. *ISBN 0258-6150. Food and Agriculture Organization, Rome Italy*

Food and Agriculture Organization (FAO). (2005). *Strategies to mitigate human-wildlife conflict in Mozambique*, by J. Anderson and F. Pariela.

Food and Agriculture Organization (FAO). (1996). Forest resources assessment 1990. A survey of tropical forest cover and study of change processes. United Nations Food and Agriculture Organization, Rome.

Forest Governance Learning Group (FGLG). (2008). Draft Work Plan (Revised). Vietnam. 2008. http://www.recoftc.org/site/resources/Forest-Conflict. Accessed on 15th November 2012.

Fourli, M. (1999). Compensation for damage caused by bears and wolves in the European Union.Experience from *LIFE-Nature projects*. Directorate General XI "Environment, Nuclear Safety and Civil Protection" of the European Commission. Luxembourg, Office for Official Publications of the European Communities.

Frank, L. (2006). Living with lions. Laikipia Predator Project – Kilimanjaro Lion Conservation Project Annual Report. Berkeley, California, USA, Wildlife Conservation Society.

Gakahu, C.G. and Goode, B.E. (1992). Ecotourism and sustainable development in Kenya. The proceedings of the Kenya Ecotourism Workshop held in September 13-17, 1992. Published by Wildlife Conservation International.

Geist, H.J. and Lambin, E.F. (2002). Proximate causes and underlying driving forces of tropical deforestation. *BioScience* ***52****: 143–150.*

Githae, S.K. (2009). Taita Taveta District Drought Status Report. Drought monitoring bulletin, December 2009. Government of Kenya.

Githaiga, J.M., Red, R., Muchiru, A.N. and van Dijk, S. (2003). Survey of water quality changes withland use type in the Loitoktok Area, Kajiado District, Kenya: Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 35. International Livestock Research Institute, Nairobi, Kenya, 33pp.

Gobin, A., Campling, P.and Feyen, J. (2001). Spatial analysis of rural land ownership.

Landscape and Urban Planning ***55****: 185–194.*

Goodwin, H. J. (1996). *In pursuit of Ecotourism*. Biodiversity and Conservation, 5: 277-291. In: Wandaka J.K.M. (2006). Opportunities and challenges to community participation in ecotourism management in Kimana Communal Ranch, Kajiado District, Kenya. MSc Thesis, Kenyatta University.

Government of Mozambique. (2006). *Avaliação rápida e priorização do maneio das áreas de conservação em Moçambique.* Maputo, Mozambique, Ministério para a Coordenação da Acção Ambiental, Ministério do Turismo and Ministério da Agricultura.

Haikai, T. and Xiaojun, W. (2007). Participatory GIS for Sustainable Development Projects. Presented at SIRC 2007 – The 19th Annual Colloquium of the Spatial Information Research Centre University of Otago, Dunedin, New Zealand. December 6th-7th, 2007.

Hamissou, H.M.G. and di Silvestre, I. (2008). Conflicts between large carnivores and domestic livestock in the peripheral zone of the W transboundary Park in Niger. *In* B. Croes, R. Buij, H.H. de Iongh and H. Bauer, eds. *Conservation of large carnivores in West and Central Africa. Proceedings of an international seminar, Maroua, Cameroon, 15–16 November 2006. Leiden, the Netherlands, Institute of Environmental Sciences.*

Hardin, G. (1968). "The tragedy of the commons". *Science **162**: 1243-1248.*

Harris, M.T. and Weiner, D. (2002). Implementing a Community-integrated GIS: Perspectives from South African Fieldwork. In: Community Participation and Geographic Information Systems. Craig, J.W., Harris, T.M. and Weiner, D. (Eds.), New York, Taylor and Francis, 246-258.

Harris, M.T. and Weiner, D. (1998). Empowerment, marginalization and community-integrated GIS. *Cartography and Geographic Information Systems* **25 (2)**: 67-76.

Hoare, R. (2011). Lessons from 15 years of human-elephant conflict mitigation: Management considerations involving biological, physical and governance issues in Africa. *Pachyderm **51**: 60 – 74.*

Hoare, R.E. (1999). Determinants of human-animal conflicts in a land use mosaic. *Journal of Applied Ecology **36**: 689-700.*

Hoare, R.E., and Du Toit, J.T. (1999). Coexistence between people and elephants in African Savannas. *Conservation Biology **13 (3)**:633 – 639.*

iMap Africa. (2009). Resource mapping for development. Participatory Geographic Information System and Community Development: Unlocking New Frontiers in Geo-information.www.mapkibera.org.

IUCN (International Union for the Conservation of Nature). (2005). Benefits beyond boundaries *Proceedings of the Vth IUCN World Parks Congress*. Durban, South Africa, 1–17 September 2003. Gland, Switzerland and Cambridge, UK.

IUCN (International Union for the Conservation of Nature). (2013). Mammals. IUCN Red List of Threatened Species. Version 2011.2. http://www.iucnredlist.org/initiatives/mammals. (Accessed 14 June 2012).

Jaetzold, R. and Schmidt, H. (2005). Farm management Handbook of Kenya Vol II – Natural conditions and farm management information-Vol. II, East Kenya (Eastern and Coast). Ministry of Agriculture, Kenya, Nairobi

Jenson, J.R. (1986). *Introductory Digital Image Processing*. Prentice Hall: New Jersey

Kagiri, J.W. (2004). A resource planning strategy for resolving Human-wildlife conflicts: A case study for Laikipia District in Kenya. Unpublished MBA Thesis. University of Leicester, UK.

Kagoro- Rugunda, G. (2004). Crop raiding around Lake Mburo National Park, Uganda. *African Journal of Ecology* ***42****:32-41.*

Kamande, L.M. (2008). An evaluation of the contribution of Human-wildlife conflicts to poverty In Taveta division, Taita-Taveta District, Kenya. *MSc. Thesis, Kenyatta University, Kenya.*

Kamonjo, A.W., Sitati, N.W., Adano, W.R., Leader-Williams, N., and Stephenson, P.J. (2007). Assessing the economic costs and benefits of maize farming in elephant ranges in Transmara District, Kenya. In M. Walpole, and M. Linkie (Eds.), *Mitigating human-elephant conflict: Case studies from Africa and Asia* (pp. 71-82). FFI Cambridge publication series 2007 71 – 82. ISBN: 9781903703267.

Kathumo, V.M. (2011). Application of remote sensing and GIS in assessing land use and land cover changes and their impact on hydrological regime in river Gucha catchment, Kenya. *PhD Thesis, Department of Land Resource Management and Agricultural Technology, University of Nairobi, Kenya.*

Kathumo, V. and Gachene, C.K.K. (2012). Participatory GIS in Conserving Lower Tana River Forest (LTRF) Complex in Coastal Kenya: Participatory GIS Case study. Proceedings of a national workshop on Conservation of Lower Tana River Forest Complex held at Kenya Agricultural Research Institute on April 13th 2012.

Katrina, B. (1995). People, parks, forests or fields: A realistic view of tropical forest conservation. *Land use policy* ***12 (2):*** *137-144.*

Kellert, S.R. (1980a). Contemporally values of wildlife in American Society. In W.W. Shaw & E.H. Zub (Eds). Wildlife Values. Forest Service, Rocky Mountain Forest and Range Experiment Station, *Instructional Service Report*, 1:31-58.

Kellert, S.R. (1980b). American's attitude and knowledge of animals. *Proceedings of the forty-Fifth North American Wildlife Conference* **45:**111-124.

Kenya Wildlife Service (KWS). (2012). Problem Animal Management Unit (PAMU). http://www.kws.org/parks/community_wildlife_program/PAMU.html. Accessed 20th January 2013.

Kenya Wildlife Service (KWS). (2011). Reaching out to communities – KWS 2.0. Community Enterprise Strategy 2012-2017.

Kenya Wildlife Service (KWS). (2008). Conservation and Management Strategy for Lions and Spotted Hyenas 2009-2014.

Kenya Wildlife Service (KWS). (2007). Conservation and Management Strategy for Cheetahs and Wild dogs in Kenya 2009-2014.

Kenya Wildlife Service (KWS). (1996). Wildlife-human conflicts, sources, solutions and issues. Available at: www.safariweb.com/kwild/wildlife

Kenya Wildlife Service (KWS). (1994). Five men Review group. Wildlife –human conflicts. KWS, Kenya.

Kioko, J. and Okello, M.M. (2010). Land use cover and environmental changes in a semi-arid rangeland, Southern Kenya. *Journal of Geography and Regional Planning Vol.* ***3 (11):*** *322-326*

Kretser, H.E. (2008). *The exurban frontier*: Anticipating human-wildlife interactions where we Live, work and play. *PhD thesis Dissertation. Cornell University, Ithaca, New York, USA.*

Kretser, H.E., Curtis, P.D., Pendal, R.J., and Knuth, B.A. (2009). Factors affecting perceptions of Human-Wildlife interactions in residential areas of Northern New York and implications for conservation. *Human Dimensions of Wildlife* ***14****: 102-118.*

Kusena, K. (2009). Land cover change and its impact on human-elephant conflicts in the

Zimbabwe, Mozambique and Zambia (ZiMoZa) Transboundary Natural Resource Management Area. *MSc. Thesis. University of Uppsala.*

Kyem, P.A.K. and Saku, C.J. (2009). Web-Based GIS and the future of participatory GIS applications within local and indigenous communities. *Electronic Journal on Information Systems in Developing Countries (EJISCD),* ***38 (7)****:1-16.*

Kyem, P.A.K. (2006). Finding Common Ground in Land Use Conflicts Using PGIS. Lessons From Ghana. *Special Issue of PLA Notes.* ***54****: 36-40.*

Lahm, S.A**.** (1996). A nationwide survey of crop-raiding by elephants and other species in Gabon. *Pachyderm* ***21****: 69–77.*

Laituri, M. (2002) Ensuring Access to GIS for Marginal Societies, in: Community Participation and Geographic Information Systems. Craig, J.W., Harris, T.M. and Weiner, D. (Eds.), New York, Taylor and Francis 270-282.

Long, B.G. and Skewes, T.D. (1996). A technique for mapping mangroves with Landsat TM Satellite Data and Geographic Information System. *Estuarine, Coastal and Shelf Science* ***43****: 373–381.*

Long, B.G. and Skewes, T.D. (1994). GIS and remote sensing improves mangrove mapping, 7th *Australasian Remote Sensing Conference*, 1–4 March 1994, *Melbourne, Australia*, Vol. 1, pp. 545–551.

Lorent, H., Sonnenschein, R., Tsiourlis, G., Hostert, P. and Lambin, E. (2009). Land degradation and subsidies dependency and market vulnerability of stock breeding households in central crete. 7th International Science conference on the human dimensions of global change 26-30 April, 2009, Bonn, Germany.

Maass, P. (2008). The Cultural Context of Biodiversity Conservation: Seen and Unseen Dimensions of Indigenous Knowledge among *Q'eqchi'* Communities in Guatemala. *PhD. Thesis, University of Göttingen.*

Madhusudan, M.D. (2003). Living amidst large wildlife: livestock and crop depredation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. *Environmental Management* ***31(4)****: 466–475.*

Maïga, M.H. (1999). Les relations homme/éléphant dans le Gourma malien. *Flamboyant* ***50****: 20–27.*

Mama, A. (2000). *Problèmes de cohabitation entre les troupeaux d'éléphants et les populations riveraines de la ZCD au Bénin*. Cotonou, Bénin, Laboratoire d'Ecologie Appliquée, Faculté des Sciences Agronomiques, Université d'Abomey Calavi (LEA/FSA/UAC).

Manfredo, M.J. (2008). Who cares about wildlife? Social science concepts for exploring human-wildlife relationships and conservation issues. New York.

Mbau, J.S. (2006). Density, distribution and habitat utilization patterns by elephants in southern Aberdare Ranges, Kenya. *MSc Thesis, University of Nairobi.*

Mbile, P., Degrande, A., and Okon, D. (2003). Integrating Participatory Resource Mapping and Geographic Information Systems in Forest Conservation and Natural Resource Management in Cameroon: *A Methodological Guide*. *Electronic Journal on Information Systems in Developing Countries* ***14 (2)****: 1-11.*

McCall, M. K. and Minang, P. A. (2005). Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon. *Geographical Journal* ***171****: 340–356.*

McCarthy, M. (2006). The century of drought. *The Independent* (UK), 4 October.

McGregor, J.A. (2004). Crocodile crimes: people versus wildlife and the politics of postcolonial conservation on Lake Kariba, Zimbabwe. *Geoforum* ***36 (3)****: 353–369.*

McKinnon, J., Child, K. G. and Thorsell, J. (1986). *Managing protected areas in the tropics.* Gland, Switzerland: IUCN.

McConchie, A.J. and Mckinnon, M.J. (2002). Using GIS to Produce Community- Based Maps To Promote Collaborative Natural Resource Management. Asean Biodiversity, Thailand.

Millennium Ecosystem Assessment (MEA). (2005). Ecosystems and Human well-being (4) Volumes, Island Press, Covelo, CA.

Millennium Ecosystem Assessment (MEA). (2005a). Ecosystems and Human Well-being: Synthesis. Island Press: Washington, DC

Millennium Ecosystem Assessment (MEA). (2005b). Ecosystems and Human Well-Being: Island Press: Washington, DC. Current State and Trend, Vol. 1: 585–621.

Mundia, C.N. and Murayama, Y. (2009). Analysis of land use/cover changes and animal Population dynamics in a wildlife sanctuary in East Africa. *Journal of Remote Sensing* ***1****:952-970*

Muruthi, P. (2005). Human-wildlife conflicts; lessons learned from WWF's African heartlands. AWF working papers. Nairobi, Kenya, African Wildlife Foundation.

Mortimore, M. (2006). Managing soil fertility on small family farms in African drylands. In: Norman Uphoff. Andrew S Ball, E. Fernades, H Herren, Olivier Husson, Mark Laing, Cherry Palm, Jules Pretty, Pedro Sanchez, Nteranya Sanginga, Janice Thies (eds), Biological approaches to sustainable soil systems.

Moses K.S., Emmanuel, D., Oppong, K.S. and Enoch, A.A. (2005). Nature and extent of human-elephant conflict in Bia Conservation Area, Ghana. Pachyderm **38**: 49-58.

Musiani, M., Mamo, C., Boitani, L., Callaghan, C., Gates, C., Mattei, L., Visalberghi, E., Breck, S. and Volpi, G. (2003). Wolf depredation trends and the use of fladry barriers to protect livestock in western North America. Conservation Biology **17 (6)**: 1538–1547.

Mwakima, M.W. (2005). *Opportunities and constraints towards sustainable ecotourism*: The Case of II'Ingwesi communal Ranch and Sweet waters Game reserve, MSc Thesis, Kenyatta University.

Mwavu, E.N. and Witkowski, E.T.F. (2008). Land use and cover changes (1988-2002) around Budongo Forest Reserve, NW Uganda: Implications for forest and woodland sustainability. Land Degradation and Development **19**: 606-622.

Nabwire, B.B. and Nyabenge. M. (2006). Community resource mapping in sustainable natural resource management: A case study of SW Uganda. *Electronic Journal on Information Systems in Developing Countries.* ***25 (4)****: 1-8.*

National Environment Management Authority (NEMA). (2009). Special issue 51. Legal Notice No. 19. The environmental management and co-ordination (wetlands, River banks, lake shores and sea shore management) Regulations. Government Printers.

Newmark, W.D. (1993).The role and designing of wildlife corridors and examples from Tanzania. *Ambios* ***22****: 500–504.*

Ngene, S., Njumbi, S. and Omondi, P. (2011). Total aerial census of elephants and other large Mammals in the Tsavo-Mkomazi ecosystem. Technical Report. Kenya Wildlife Service.

Ogada, O.O. and Ogada, D.L. (2004). Factors influencing levels of carnivore-livestock conflicts In Samburu Heartland and proposed mitigation measures. Unpublished consultancy report for African Wildlife Foundation.

Ogada, M., Woodroffe, R., Oguge, N. and Frank, G. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. *Conservation Biology* ***17 (6)****: 1521–1530.*

Okello, M.M. (2005a). Land use changes and human–wildlife conflicts in the Amboseli Area, Kenya. *Human Dimensions of Wildlife* ***10****: 19–28.*

Okello, M.M. and D'Amour, D.E. (2008). Agricultural expansion within Kimana electric fences and implications for natural resource conservation around Amboseli National Park, Kenya. *Journal of Arid Environments.* ***72****: 2179-2192.*

Okello, M.M. and Kioko, J. (2010). Contraction of wildlife dispersal area in Olgulului-Ololorashi Group Ranch around Amboseli National Park, Kenya. *Open Conservation. Biology* ***4****: 28-39.*

Okello, M.M. and Wishitemi, B.E. (2006). Principles for the Establishment of Community Wildlife Sanctuaries for Ecotourism: Lessons from Maasai Group Ranches, Kenya. *African Journal of Business and Economics* ***1(1)****: 90 – 109.*

Okoumassou, K., Durlot, S., Akpamou, K. and Segniagbeto, H. **(**2004). Impacts humains sur les aires de distribution et couloirs de migration des éléphants au Togo. *Pachyderm* ***36****: 70–79.*

Omondi, P., Bitok, E. and Kagiri, J. (2004). " Managing human elephant conflicts – the Kenyan Experience". *Pachyderm* ***36****: 80-86.*

Oppong, S. K., Danquah, E., and Sam, M.K. (2008). An update on crop-raiding by elephants at Bia conservation Area, Ghana from 2004 to 2006. *Pachyderm* ***44****:59-64.*

Packer,C., Ikanda, D., Kissui, B. and Kushnir, H. (2005). The ecology of man-eating lions in Tanzania. *Nature et Faune* ***21 (2)****: 10–15.*

Palmer, M.A., Bernhardt, E.S., Chornesky, E.A., Collins, S.L., Dobson, A.P., Duke, C.S., Gold, B.D., Jacobson, R.B., Kingsland, S.E., Kranz, R.H., Mappin, M.J., Martinez, M.L., Micheli, F., Morse, J.L., Pace, M.L., Pascual, M., Palumbi, S.S., Reichman, O.J., Townsend, A.R. and Turner, M.G. (2005). Ecological science and sustainability for the 21st century. *Frontiers in Ecology and the Environment* ***3****: 4–11.*

Paradino, R.S. (2008). We are the custodians of the Salva; conservation, indigenous communities and common property in the Selva Lacandona, Mexico.

Parker, G.E and Osborn, F.V. (2006). Investigating the potential of chilli *Capsicum* spp. to reduce Human-wildlife conflicts in Zimbabwe. *Oryx, **40 (3)**: 1-4.*

Parker, G.E., Osborn, F.V., Hoare, R.E and Niskanen, L.S. (2007). Human-elephant conflict mitigation: A training course for community-based approaches in Africa. Participant's manual. Livingstone , Zambia, Elephant Pepper Development Trust and Nairobi, Kenya, IUCN Species Survival Commission, African Elephant Specialist Group, Human-Elephant Conflict Task Force.

Patterson, B.D. and Neiburger, E.J. (2000). Morphological corollaries of man-eating in African lions: the smoking gum. 81st Annual Meeting, American Society of Mammalogists, Durham, New Hampshire, USA.

Patterson, B.D., Kasiki, S.M., Selempo, E. and Kays, R.W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National Park, Kenya. *Biological Conservation **119 (4)**: 507–516.*

Perez costa Carmen, M. (2003). Participatory GIS approach for mapping land use change and assessing associated effects of those changes in a watershed: a case study in Laelay Wurko, Tigray Region , Ethiopia. MSc Thesis, National University of Ireland, Cork.

Petit, C., Scudder, T. and Lambin, E. (2001). Quantifying processes of land-cover change by remote sensing: resettlements and rapid land-cover changes in south-eastern Zambia. International Journal of Remote Sensing 22: 3435–3456.Piran, C. L.W. and Alastair, W.I. (2010) (Eds). Human–Wildlife Conflicts. Wildlife Research.
Special Issue **37 (8)**. 125pgs.

Pretorius, Y., Willem, F., Cornelis, V., Henjo, J., Rina, C., Nicky, M.K., Emmanuel, M., Bruce, R.P., Mike ,J.S., Andrew, S.K., Rob, S., Sipke, E.V., and Herbart, H.T.P. (2011). Soil nutrients status determines how elephant utilize trees and shape environments. *Journal of Animal Ecology **80**:875-883.*

Purnomo, H., Mendoza, G. A. and Prablui, R. (2004). Model for Collaborative Planning of Community-managed Resources Based on Quantitative Soft Systems Approach. *Journal of Tropical Forest Science* ***16 (1)*** *: 106-131.*

Republic of Kenya (ROK). (2012). Ministry of Forestry and Wildlife. Draft Wildlife Conservation and Management Bill, April 2012. Government printers, Nairobi

Republic of Kenya (ROK). (2011). Ministry of Forestry and Wildlife. Draft Wildlife Policy 8th July 2011. Government printers, Nairobi

Republic of Kenya (ROK). (2011). Taita-Taveta District Long rains assessment report 1st august – 5th august 2011.

Republic of Kenya (ROK). (2010). The Constitution of Kenya, 2010. Government Printers, Nairobi.

Republic of Kenya (ROK). (2009). Kenya National Bureau of Statistics (KNBS). Kenya Population and Housing Census, Nairobi, Kenya.

Republic of Kenya (ROK). (2007). Ministry of State for Planning. Kenya Vision 2030. Government printers, Nairobi, Kenya.

Republic of Kenya (ROK). (2005). Kenya Gazette supplement Acts, 2005. The forest Act 2005. Government Printers, Nairobi.

Republic of Kenya (ROK). (2002). Kenya National Bureau of Statistics (KNBS). Kenya Population and Housing Census, Nairobi, Kenya.

Republic of Kenya (ROK). (1999). Environmental Management and Coordination Act (EMCA). Government Printers, Nairobi.

Republic of Kenya (ROK). (1999). Kenya National Bureau of Statistics (KNBS). Kenya Population and Housing Census, Nairobi, Kenya.

Republic of Kenya (ROK). (1989). Kenya National Bureau of Statistics. Kenya Population and Housing Census, Nairobi, Kenya.

Republic of Kenya (ROK). (1969). Kenya National Bureau of Statistics. Population and Housing Census, Nairobi, Kenya.

Seno, S.K. and Shaw, W.W. (2002). Land tenure policies, Maasai traditions and wildlife conservation in Kenya. Society and Natural Resources **15**: 79–88.

Sherbinin, M. (2002). A guide to land use and land cover change (LULCC). A collaborative effort of SEDAC and The IGBP/IHDP LULCC Project.

Shota, M. and Takuhiko, M. (2011). Change in habitat selection by Japanese macaques (*Macaca fuscata*) and habitat fragmentation analysis using temporal remotely sensed data in Niigata Prefecture, Japan. *International Journal of Applied Earth Observation and Geo-information: **13 (4)**: 562-571.*

Sichali, E.R.M. (2000). The status of crocodiles in the southern segment of Shire river; A partial assessment of crocodile densities and age structure and their implications on mankind in some areas in Lower Shire. Report to Malawi Department of National Parks and Wildlife.

Sindiga, I. (1995). Wildlife based tourism in Kenya: land use conflicts and government compensation polices over protected areas. *Journal of Tourism Studies **6 (2)**: 45–55.*

Sitati, N.W., and Ipara, H. (2012). Indigenous Ecological Knowledge of a Human-Elephant Interaction in Transmara District, Kenya. Implications for research and management. *Advances in Anthropology **2 (3)**: 107-111.*

Sitati, N.W., Walpole, M.J., Leader-Williams, N. and Stephenson, P.J. (2012). Human-elephant conflict: Do elephants contribute to low grades in schools within elephant ranges?. *International Journal of Biodiversity and Conservation **4 (15)**:614-620.*

Sitati, N.W., Leader-Williams, N., Stephenson, P.J., and Walpole, M. J. (2007). Mitigating human- elephant conflict in a human dominated landscape: Challenges and lessons from Transmara District, Kenya. In Matt Walpole and Matthew Linkie (Eds). Mitigating Human-Elephant Conflict: Case Studies from Africa and Asia. FFI, Cambridge, UK. ISBN: 9781903703267.

Sitati, N.W., Walpole, M.J., and Leader-Williams, N. (2005). Factors affecting susceptibility of farms to crop raiding by African elephants: using a predictive model to mitigate Conflict. *Journal of Applied Ecology **42**: 1175–1182.*

Sitati, N.W. (2003). Human-elephant conflicts in the Masai Mara dispersal areas of Transmara District. Unpublished PhD Thesis, University of Kent, Centerbury, UK.

Smith, R. and Craglia, M. (2003). Digital Participation and Access to Geographic Information: A Case Study of Local Government in the United Kingdom. *URISA Journal **15**: 49-54.*

SPSS Inc. 2011. SPSS Base 20.0. Brief guide. USA. ftp://public.dhe.ibm.com/software/analytics/spss/documentation/statistics/20.0/en/client/Manuals/IBM_SPSS_Statistics_Brief_Guide.pdf

Stuart, T. and Stuart, C. (2006). Field guide to the larger mammals of Africa. Struik Publishers, South Africa.

Stuart, T. and Stuart, C. (2000). Field guide to the tracks and signs of Southern and East African Wildlife, Struik, Publishers, South Africa.

Tane, H. and Yu, X.B. (2002). Lake Poyang Watershed: Integrated Framework for Sustainable Development, Resource Management and Environmental Protection, *Mountain-River-Lake DO Jiangxi, Watershed Systems Twizel New Zealand, GFA Terra Systems, Hamburg Germany*. Nanchang Jiangxi China 2002.

Terry, A.M. (2009). Human-wildlife conflicts: emerging challenges and opportunities. *Human-wildlife conflicts* ***3 (1)****: 10-17.*

Thompson, M. and Homewood, K. (2002). Entrepreneurs, elites, and exclusion in Maasailand: Trends in wildlife conservation and Pastoralist development. *Human Ecology* ***30 (1)****: 107–138.*

Thornton, P.K., van de Steeg, J. and Herrero, M. (2008). The livestock-climate –poverty nexus. A discussion paper on International Livestock Research Institute research in relation to climate change. Discussion Paper No.11.

Tran, T. N. and Nguyen, K. D. (2007). Report of Survey on Community Forest Management in Dak Lak Province. Dak Lak, Forest Governance Learning Group (FGLG) Vietnam http://www.recoftc.org/site/resources/Forest-Conflict/. Accessed on 15th November 2012.

Treves, A. and Naughton-Treves, L. (1999). Risk and opportunity for humans coexisting with large carnivores. *Journal of Human Evolution* ***36****: 275–282.*

Treves, A., Naughton-Treves, L., Harper, E.K., Mladenoff,D.J., Rose, R.A., Sickley, T.A. and Wydeven, A.P. (2004). A spatial model derived from 25 years of data on wolf predation on livestock. *Conservation Biology* ***18 (1)****: 144-124.*

Tripathi, N. and Bhattarya, S. (2004). Integrating indigenous knowledge and GIS for participatory natural resource management: state-of-the-practice. *Electronic Journal of Information Systems in Developing Countries* ***17****: 1–13.*

Tsi, E.A., Ajaga, N. and Wiegleb, G. (2008). The willingness to pay for the conservation of Wildlife animals: case of the Derby Eland (*Taurotragus derbianus gigas*) and the African wild (*Lycan pictus*) in North Cameroon.

Turner, B.L. and Meyer, B.L. (1994). Global land use and land cover change: an overview. In Changes in Land Use and Land Cover: A Global Perspective, Meyer WB, Turner BL II (eds). Cambridge University Press: Cambridge; 3–10.

United Nations (UN). (2009). World population prospects: the 2008 revision. New York, NY: United Nations Population Division.

United Nations Economic Commission for Europe (UN/ECE). (2002). Forest conditions in Europe, 2001 Executive Report. Geneva and Brussels, 29.

United States Agency for International Development (USAID). (2012). Natural Resource utilization in the Boni- Lungi-Dodori forest areas of Lamu County, Kenya. www.usaid.gov

United States Department of Agriculture (USDA). (2006). The facts about Wildlife Services – wildlife damage management. Washington,DC, USA, United States Department of Agriculture, Animal and Plant Health Inspection Service.

USGS - Global Visualization Viewer (GLOVIS). URL: http://glovis.usgs.gov. Accessed 20th April 2012.

VACID-Africa. (2010). Mapping resources within the communities. The case of mapping *Melia volkensii* farmers in Kibwezi district of Kenya. KEFRI.

Vasagar, J. (2007). Safari Britons killed by charging elephant. *The Guardian*, 27 March.

Vernooy, R., Espinoza, N. and France, L. (2000). Participative mapping, analysis and monitoring of natural resources in a watershed.

Vien, H.T. (2009). The linkages between land reform and land use changes: A case of Vietnam. 7th International science conference on the human dimensions of global change. Bonn, Germany.

Wakoli, E.N. and Sitati, N. (2012). Analysis of temporal and distribution patterns of elephant attacks on humans and elephant mortality in Transmara District, Kenya. *Greener Journal* *of Environment Management and Public Safety* ***1 (1)****: 27-37.*

Walker, D.H. (2002) Decision Support, Learning and Rural Resource Management. *Agricultural Systems* ***73 (1)****:113-127.*

Wanjau, M.W. (2002). People/crocodile conflicts in Kenya: policy changes required to effectively manage the conflicts. Report to Kenya Wildlife Services.

Wilkinson, D., Smith, G.C., Delahay, R.J. and Cheeseman, C.L. (2004). A model of bovine tuberculosis in the badger *Meles meles*: an evaluation of different vaccination strategies. *Journal of Applied Ecology*, 41(3): 492–501.

Wishitemi, B. and Okello, M.M. (2003). Application of the protected landscape model in southern Kenya. *Parks* ***13 (2)****: 12-21.*

Woodroffe, R., Thirgood, S. and Rabinowitz, A. (Eds.). (2005). People and wildlife: conflict or coexistence? Cambridge, UK: Cambridge University Press.

World Commission on Environment and Development (WCED). (1987). *Our common future*. In:Wandaka J.K.M. (2006). Opportunities and challenges to community participation in ecotourism management in Kimana Communal Ranch, Kajiado District, Kenya. *MSc Thesis, Kenyatta University.*

WWF SARPO. (2005). Human wildlife conflict manual. Harare, Zimbabwe, WWF Southern African Regional Programme Office (SARPO).

Yamada, K., Elith, J., McCarthy, M. and Zerger, A. (2003). Eliciting and integrating expert knowledge for wildlife habitat modeling. *Ecological Modeling 165:251–264.*

Zar, J.H. (1996). Biostatistical Analysis. Third Edition. Prentice-Hall. New Jersey.USA.

Zondag, J and Borsboom, P. (2009). Driving forces of land use change: 49th ESRA conference. Lodz, Poland.

9.0 APPENDICES

9.1 Appendix 1 : Scientific names of animals mentioned in this thesis

Antelopes	*Antelopinae spp.*
Asian lion	*Panthera leo persica*
Baboons	*Papio spp.*
Bear	Family ursidae
Bush pig	*Potamochoerus larvatus*
Crocodile	*Crocodylus niloticus*
Cheetah	*Acinonyx jubatus*
Deer	Family cervidae
Dikdik	*Madoqua kirkii*
Eagle	Family Accipitridae
Elephant	*Loxodonta Africana*
Giraffe	*Giraffa camelopardalis*
Hippopotamus	*Hippopotamus amphibius*
Hyena	*Crocuta crocuta*
Hyrax	Family Procaviidae
Leopard	*Panthera Pardus*
Lesser Kudu	*Tragelaphus imberbis*
Lion	*Panthera leo*
Lynx	*Lynx spp.*
Mongoose	Family herpestidae
Monkeys	*Cercopithecus spp.*
Porcupine	*Hystrix crystata*
Red deer	*Cervus elaphus*
Rhinoceros	*Diceros bicornis*
Roe deer	*Capreolus capreolus*
Squirrel	*Xerus spp.*
Tiger	*Panthera tigris*

Wild boar	*Sus scrofa*
Wild dog	*Lycaon pictus*
Wolf	*Canis lupus*
Wood pigeon	*Columba palumbus*
Zebra	*Equus guagga*

9.2 Appendix 2: Scientific names of plants mentioned in this thesis

Banana	*Musa acuminata*
Beans	*Vulgaris spp.*
Cassava	*Manihot esculenta*
Cotton	*Gossypium hirsutum*
Green gram	*Vigna radiate*
Ground nuts	*Arachis hypogaea*
Maize	*Zea mays*
Mangoes	*Mangifera indica*
Millet	*Panicum sumatrance*
Onion	*Allium cepa*
Orange	*Citrus sinensis*
Paw paw	*Carica papaya*
Pegion pea	*Cajanus cajan*
Shea nuts	*Vitellaria paradoxa*
Sugar cane	*Saccharum officinarum*
Sunflower	*Helianthus annuus*
Tomatoes	*Lycopersicon esculentum*

9.3 Appendix 3: Questionnaire

An analysis of Human-wildlife conflicts in Taveta district:

Household questionnaire

The aim is to collect data to assess Human-wildlife conflicts in the study area (the spatial distribution of conflicts in the area, species involved and their impact, seasonality of raiding, growth stage of crops when raiding occurs, frequency of conflicts, crop preference etc)as well as the local community perspectives (attitudes and perceptions) towards wildlife. In addition the factors that predispose local communities to conflicts will be documented. of interest is also the factors that influence local community attitudes and perceptions such as age, sex, level of income, sources of income, level of education, community beliefs, how communities value the species, recent experiences with wildlife etc. The mammals involved in conflicts, local community support for their conservation and interactions with the wildlife authority.

NB: All information will be treated highly confidential and used solely for this research work.

1. Some Demographic Data

Date:

Instructions: Tick as appropriate

1.1 Individual Code/Name:……………………………………………….

1.2 Age: 1.18-35 [ ], 2. 35- 45 [ ] 3. 45-55 [ ] 4. 55 and above [ ]

1.3 Sex: 1.Male [ ] 2. Female [ ]

1.4 Marital status: 1. Married [ ] 2. Single [ ] 3. Divorced [ ] 4. Widow [ ]

1.5 Family size: [ ]

1.6 Level of education 1. None [ ] 2. Primary [ ] 3. Secondary [ ]
4. Tertiary [ ]

1.6 (a) Are you: 1. Resident [ ] 2. Immigrant [ ]

1.6 (b) If immigrant: 1) Seasonal [ ] 2. Permanent [ ]

1.6 (c) If immigrant how long have you lived in the area [ ] years

1.7 GPS: S:

E:

1.8 Village……………………………………..,

1.9 Sub-location…………………………….,

1.10 Location……………………………………..,

1.11 Division…………………………..................

2. Impacts of wildlife

2.1. What is your main source of livelihood/income? Tick as appropriate

1. Employed –state Profession [ ] 2. Business [ ] 3. Farmer [ ]

4. Livestock sale [ ] 5. Fish Farming [ ]

6. Others; e.g., Specify………………………………………………………….

2.2. What are your alternative sources of income? Tick as appropriate.

1. Cultivation [ ] 2. Livestock keeping only [ ] 3. Agro-pastoralism[ ]

4. Manual labour jobs [ ] 5. Aquaculture [ ]

6. Others (Specify) ………………………………

2.3 (a). Have you ever had any negative experience with wildlife? Eg damage to you or your property? 1. No [ ] 2. Yes [ ]

2.3 (b) if yes describe

…………………………………………………………………………………………………

………………………

2. 4. What problems do you have with wildlife? Tick as appropriate.

1. Livestock predation [ ] 2. Eating crops [ ] 3. Trampling crops [ ]

4. Access to water [ ] 5. Access to grazing [ ] 6. Spreading diseases [ ]

7. Killing [ ] 8. Bothering people [ ]

2.5. Rank your overall experience with wildlife in this area for the past 30 years? (Scale 1-5). Tick as appropriate

1. Very negative [ ] 2. Negative [ ] 3. Neither negative nor positive [ ]

4. Positive [ ] 5. Very positive [ ]

2. 6. What is the frequency of negative interactions with wildlife: Please tick as appropriate

1. Monthly (more than once per week [ ] 2. Once per week or less [ ]

3. Seasonally [ ] 4. Others: (Specify)…….………………………………

2. 7. What is your general attitude about wildlife? Tick as appropriate

1. Very negative [ ]   2. Negative [ ]   3. Not negative or positive [ ]
4. Positive [ ]   5. Very positive [ ]

2.8. Please fill in the following table

Animal species (e.g., Zebra, Elephant etc)	**Livestock attacked**	**Acreage of each crop in the farm (Acres)**	**Crops attacked**	**Acreage of each crop damaged. (Acres)**	**Ranking by crop/ livestock Preference**	**Frequency of attacks 1. Daily 2.Weekly, 3. fortnight 4. Monthly**	**Seasonality of attacks. 1.Early 2.Mid 3.Mature**

2.9. Can you rank the animal species named above by the degree of damage they cause?

……………………………………………………………………………………………………

2.10. How do you justify the above ranking? (Specify the species)

....

2.11. When did you start noticing the problem of crop raiding? State how many years ago)

....

2.12. Where do you think the animals come from?...

2.13 If in groups what is the group size and composition? Fill in the table below

Type of animal e.g., wildebeest	Group size (Number of animals in that particular group)	Group composition 1. Adults (A), 2.Sub-adults (SA) 3.Juveniles (J) 4. Male herd	Time they raid farms	Growth stage of crops attacked

2.14 (a). What time do elephants /primates raid farms?

1. Day [ ] 2. Night [ ]

2.14 (b) If day how frequent? 1. Once [ ] 2. Twice [ ]

2.14 (c) Is the raiding by the same group? 1. No [ ] 2. Yes [ ]

2. 15. What part of the crop do they use?

1. Cobs [ ] 2. Seedlings [ ] 3. Seeds [ ] 4. Seedling bulbs [ ]

5. Stems [ ] 6. Fruits [ ]

2. 16 (a). What time do wild animals attack livestock?

1. Day [ ] 2. Night [ ]

2.16 (b) If day how frequent? 1. Once [ ] 2. Twice [ ]

2.17 Name any animals that reside in your farms?

1. Bat roosting [ ] 2.Bird nesting [ ] 3.Rodent [ ] 4. Primate [ ]

5. Antelopes [ ]

6. Other ………..………..……………………………………………………………………

2. 18. Are there any carnivores that maraud around in the farms at night- in pursuit of their prey?

1. No [ ] 2. Yes [ ] if yes name them……………………………………

3. Community Perceptions on wildlife

3.1. What is your overall perception about wildlife in this area?

1. Very negative [ ] 2. Negative [ ] 3.Neither positive nor negative [ ]
4. Positive [ ] 5. Very positive [ ]

3.2 What is your attitude about each of these species named above in section 2.8? and why?

Animal Species name	**Attitude** **1.Very negative** **2. Negative** **3.Neither positive nor negative** **4. Positive** **5. Very positive**	**Value of the species and ranks** Values (e.g.,)	Ranks (in order of priority where 1 is most preferred.	**To what extent would you support its conservation** 1. Strongly agree 2. Agree 3. Not sure 4. Don't agree 5. Strongly disagree
		1. Economic		
		2.Educational		
		3.Existence		
		4.Aesthetic		
		5.Medicinal		
		6.Cultural		

3.3 (a). Where do you report animal conflicts?

1. Ministry of Agriculture [ ]

2. Kenya Wildlife Service [ ]

3. Chief/Assistant chief [ ]

4. Other (Specify)……………………………………………………………………………..

3.3 (b) Who reports?

1. Mother [ ] 2. Father [ ] 3. Employee [ ] 4. Children [ ]

3.4 How has the problem of Human-wildlife conflicts developed from 1970's to today?. Please fill the table below.

Time period	Type of conflicts e.g., crop damage, livestock depredation)	Species involved	Levels/frequency of conflict 1.Low (below 30%), 2. Medium (between 30 - 50%), 3. High (above 50%).
1970 -1980			
1980-1990			
1990-2000			
2000 – 2011			

4. Farm characteristics

4. 1. What is the size of all your total landholding Acres [ ]

4.2. What is the size of your cultivated land in Acres [ ]

4. 3. How much land is left fallow in acres [ ]

4. 4. Which crops do you grow?

……
……………………………………………

4. 5. What proportions (size of acreage occupied by various crops in the individual farmer's farm including those intercropped) e.g.,

Type of crop/s e.g.,	Acreage
Pure Maize	4
Maize, beans, cassava, bananas (intercropped).	3
Maize , arrowroots (intercropped).	2
Pure Bananas	6

Type of crop/s e.g.,	Acreage

4.6. Which parts of these plants are eaten by these animals? Tick as appropriate

1. fruits [ ]   2. Roots [ ]   3. Stems [ ]   4. Bark [ ]

5. Income

Level of income/month.

5.1. Less than ten thousand [ ]   2. Between 10-30 thousand [ ]

3. Above 30 thousand [ ]

6. Community/wildlife authority interaction.

6.1. Are you happy with response to your complains by the wildlife authority.

1. No [ ]   2. Yes [ ]

6. 2. Have you ever been compensated for your crops, animal or human attacks?

1. No [ ]   2. Yes [ ]

6.3. What are some of the ways KWS is trying to minimize Human-wildlife conflicts?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

6.4. What would you like to propose to KWS to ease human wildlife conflicts?

9.4. APPENDIX 4: Human-wildlife conflicts blamed on poor performance in schools in Taita Taveta County

Nairobi Star (Nairobi)

Kenya: Taita Taveta Leaders Decry Human-Wildlife Conflict

Raphael Mwadime 2 January 2012

LEADERS and residents of Taita Taveta county have attributed the dismal performance of the county in last years Kenya Certificate of Primary Education examinations to the persistent human wildlife conflict in the region.The county was the third last among 47 counties in the country.