ASSESSMENT OF FACTORS INFLUENCING HUMAN-ELEPHANT CONFLICT IN KAJIADO COUNTY

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A56/8598/2017

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN RANGE MANAGEMENT

DEPARTMENT OF LAND RESOURCE MANAGEMENT AND AGRICULTURAL TECHNOLOGY

FACULTY OF AGRICULTURE,

UNIVERSITY OF NAIROBI

2022

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

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DEDICATION

I dedicate this thesis to my father, Peter Kimani, for his relentless support during my entire studies and throughout my life.

ACKNOWLEDGEMENT

I would like to pay my special regards to my supervisors, Dr. Judith Mbau and Dr. Evans Chimoita for their intellectual guidance through every stage of the process, their patience and moral support. Without their persistent help, the goal of this project would not have been realized. My deepest appreciation goes to Professor Jesse Njoka, Former Director of African Drylands Institute for Sustainability (ADIS) for his support. My appreciation goes to Dr. Mbau and Professor Njoka who provided funds through ADIS, from the Institutional Canopy of Conservation which proved monumental for this research.

I would also like to thank the Gandhi Smarak Fund team for the partial scholarship fund for my tuition. I would also like to extend my utmost gratitude to the Kenya Climate Smart Agriculture Project for availing the much-needed funds for my research.

I would like to thank Dr. Henk Harmsen and Dr. Victor Mose for offering their knowledge into my work. My utmost appreciation to my colleagues Walter, Consolata, Lydia, Josephat, Edwin, Diana, and Grace for the motivation to press on even when it got difficult.

I would also like to acknowledge my gratitude for the support and great love from my family and friends. Their unfailing support and continuous encouragement kept me going on and this work would not have been possible without their input. I wish to thank all the people whose assistance was a milestone in the completion of this project. Finally, I must recognize God for providing all the strength, grace and favor I needed to complete my M.Sc. Program.

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LIST OF ABBREVIATIONS

ACP	Amboseli Conservation Program
AE	Amboseli Ecosystem
AET	Amboseli Ecosystem Trust
ANP	Amboseli National Park
ASAL	Arid and semi-arid land
AWF	African Wildlife Foundation
FGD	Focus group discussion.
GCP	Ground control points
GIS	Geographic Information System
HEC	Human elephant conflict
HWC	Human wildlife conflict
IUCN	International Union for the Conservation of Nature
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
LARMAT	Land Resource Management and Agricultural Technology
LULCC	Land Use and Land Cover Change
PA	Protected area(s)
SCP	Semi Automatic Classification Plugin
WWF	World Wildlife Fund

DEFINITION OF TERMS AS USED IN THE STUDY

Attitudes: a feeling toward or opinion concerning something ans someone which influences behaviour.

Geographic Information Systems: A method that captures, saves, operates, analyzes, manages, and presents all types of physical data.

Georeferencing: The procedure of linking a physical map or raster image of a map with spatial locations.

Human elephant conflict: Negative outcomes that result from interactions between elephants and humans like crop raiding as well as injuries and deaths to both humans and elephants.

Human wildlife conflict: An association between wildlife and humans and/or their goods, livestock, land, or property that bears negative impacts on one or both parties (WWF, 2017)

Land cover changes: The process by which human beings modify the biophysical aspects of the land surface which include water distribution, soil, vegetation as well as other land features, often resulting in the loss of such natural areas.

Land use changes: The process of altering the management of the land by people, usually associated with the alteration of the natural environment for economic benefits.

Perception: The manner in which someone regards or interprets something.

Remote Sensing: It describes the science and art of finding facts concerning an item, region, or occurrence by means of studying data attained by a tool not in contact with the item, region or occurrence under examination.

ABSTRACT

Increasing human populations and changes in land use have brought increased competition for space and resources between people and wildlife in the Amboseli Ecosystem. Among the large mammal species, elephants are one of the most vulnerable to land use change due to their home range and seasonal migrations. The ensuing interactions due to sharing resources are frequently negative and the individuals involved progressively develop negative attitudes towards elephants, viewing them as a risk to their survival. The aim of this research was to assess some of the factors driving human-elephant conflict in Imbirikani Group Ranch for improved management and coexistence of elephants and local communities. The specific drivers analyzed were land use and cover (LULC) changes as well as human perceptions toward human-elephant coexistence. LULC changes were analyzed in a 32-year epoch from 1981 to 2019 from Landsat images for 1987, 1999, 2013 and 2019. The data was analyzed through supervised classification with QGIS 3.12 using the maximum likelihood classification algorithm. Percentages of land area were computed to make comparisons of the changes in LULC over time. In addition, a multi-stage sampling design was applied whereby the study area was divided into strata based on the administrative sub-locations. Household survey was conducted on 320 sampled households selected through a multistage sampling design and primary data gathered by interviewing selected households through semi-structured questionnaires. The households were interviewed on the held attitudes and perceptions on the nature and extent of human elephant conflicts. Further, field visits and observatory data were gathered to unveil farms and property damages caused by Elephants. Focus group discussions were also carried out to gain more insights on available resources mapping and human elephant conflict. Collected data were summarized by descriptive statistics including frequencies and arithmetic means and results presented based on thematic areas such as types of conflict, seasonality of attacks, crops affected, and costs of HEC incidences. A logistic regression model was generated to assess explanatory power of variables while Pearson's chi-squared tests were computed to establish associations between hypothesized independent variables and the dependent variable of attitudes toward elephant conservation. Shrublands experienced the highest change with a steady decrease of almost 30% over the study period. Bareland increased by 16%. Grassland increased by 7.51%. Woodlands experienced a decline of 11.2%. Irrigated agriculture showed an increase of 12.48%.

Crop raiding was the most prevailing form of HEC with the behaviour of raiding elephants being described as habitual from specific elephant groups and nocturnal. The type of crop grown was the most significant predictor for HEC. Education level, gender and location had a significant influence on perceptions and attitudes toward human-elephant coexistence ($p = 0.0132$, $p = 0.0037$ and $p > 0.0001$, respectively). Age ($p = 0.1377$) and type of livelihood ($p = 0.1272$) had no significant relationship with the participants' perceptions and attitudes. Additionally, 61% believed elephants were beneficial but 82% felt bad about free roaming wildlife while the majority, 61%, had a negative attitude toward wildlife authorities. Understanding the spatio-temporal distribution of conflicts, cost implications and nature of crop raiding behaviour in addition to community knowledge, attitudes, and perceptions on the same, should be integrated into management decisions to guide planning of conservation interventions. Integrated spatial planning and land use zoning should be executed in collaboration with the community. Moreover, elephant repellent crops should be grown in HEC hotspot areas and mechanisms to disincentivize agricultural expansion in wildlife habitats and movement corridors established for improved conflict mitigation.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

People and wild animals have exhibited unaltered inter-relationships throughout human history. However, with the advent of domestication of plants and animals, many human wildlife conflicts ensued. Habitat fragmentation and destruction have been attributed to agricultural development, infrastructural development and increasing settlements. Analyzing the existing land use forms and the reasons associated with the uses gives a proper perspective of prevailing conflicts between people and wild animals. Few studies provide quantitative data on the level of crop damage which impedes on better official response to these conflicts. This scenario is true of one of the most valuable mega-herbivores, the elephant (FAO, 2015).

Human elephant conflicts (HECs) arise wherever people and elephants share resources. These complex challenges occur across Africa and Asia. African elephants are increasingly brought into contact with communities residing in the fringes of protected areas as they range over a large area for food. The ensuing interactions are frequently negative and the individuals involved progressively view elephants as a risk to their survival (Smith & Kasiki, 2015). Increasingly, it is recognized that the realization of elephant conservation programs is dependent upon the attitudes of communities living in neighboring places. Ever more, local people will only tolerate elephants if they perceive them as bearing some monetary value (Van & Matteson, 2018).

Wildlife areas are experiencing land use and cover changes, as evidenced typically by conversion to human settlements, croplands, urban areas, industrial and water development (Viana *et al.*, 2019). Globally, an appraised 4.7 million square kilometers of savanna and 6 million square kilometers of woodland have been transformed to farmlands since 1950 (Tsegaye *et al.*, 2010). Habitat conversions continue to reduce the availability of key resources such as energy, water and nutrients for wildlife (Zeh et *al.,* 2019). Within Kenya, sedentarization by pastoral communities as well as migrant communities, have been the leading cause of land use changes due to population growth and partially to the formation of protected areas since the 1940s (Morara *et al.* 2014).

Land use denotes the activities to which land is deployed for and is often attributed to socio-cultural practices, public policies, economic returns and ecological zones. Land cover on the other hand, refers to the land in its physical state while describing the amount and type of vegetation (natural or planted) or constructions, occurring on the earth surface. Water, sand, ice, bare rock, and similar surfaces are also considered to be land cover. The terms land use and land cover are interrelated by anthropological activities that openly modify the physical environment like vegetation burning, irrigated agriculture, deforestation and the use of fertilizer (Lands Sessional Paper number 1, 2017).

In Kajiado County, wildlife refuge zones have been transformed into settlements, resulting in fragmented habitats , increased farmlands, and decline in riverine vegetation (Morara *et al*., 2014). In particular, the Amboseli ecosystem, located within Kajiado County, epitomizes the changes Kenya's rangelands are experiencing loss of woodlands, a reduction in habitat diversity, and the resultant decline in range productivity being among the key resource changes (Western *et al*., 2015).

In the 1970s, grazing areas for the Maasai community of Kenya deteriorated and reduced through instituting wildlife protected areas (Western & Wright, 1994) as well as land fragmentation. Following the establishment of Amboseli National Park and the increased alterations in land tenure systems, ecosystem use by the people intensified. It is this change that fashioned a pastoral landscape comprising free ranging livestock, wildlife conservation, rain-fed and irrigated crop husbandry as well as permanent settlements (Atieno, 2000). The materialization of group ranches in the 1960s concentrated the movement and grazing of Maasai livestock into lesser sections (Graham, 1989). Increased subsistence demands of a burgeoning population led to further subdivision within the group ranches, subsequently leading to interference with major wildlife migration routes and reduction of wildlife dispersal areas (Wayumba & Mwenda, 2006). The recent past has seen the group ranches in Amboseli

Ecosystem subdivide land among members, a move which conservationists fear will push out wildlife (Western, 2020).

Increasing human population and changes in land use have led to increased competition for space and resources between people and wildlife (Clements *et al.* 2010). Among all large mammal species, elephants are one of the most vulnerable to land use change due to seasonal migrations (Saaban *et al.* 2011; Billah *et al.*, 2021) and large feeding ranges. It has been suggested that, even if all forests within an elephant's range would be completely cleared for agricultural purposes, elephants still follow their traditional migratory routes and may cause considerable damage to agricultural fields (Rood et al. 2008). While loss of habitat is one of the main problems facing elephants, consequent human-elephant conflicts (HECs) are considered a major issue affecting elephant populations in Africa (Gubbi, 2012). The resultant conflict from continuous conversion of elephant habitats, particularly to agriculture, has been a significant threat to their successful conservation (IUCN, 2021).

Elephants tend to use wildlife corridors to track resources such as food and water, which vary in space and time. Corridors act as dispersal areas connecting habitat covers for the interchange of resources in the form of genetic resources and food (Muriuki, 2018). Within the Amboseli ecosystems (AE) of southern Kenya, Imbirikani Group Ranch acts as one such wildlife corridor. The group ranch connects Amboseli National Park and Chyulu Hills National Park. This research analyzed the nature and extent of HEC as well as evaluated the perceptions and attitudes of the local community towards human elephant interactions within Imbirikani Group Ranch. An understanding of these factors that influence HEC within this landscape plays an important role in taking the appropriate actions in mitigating HEC. The outputs of this research are also important for informing policy to improve implementation of community-based conservation.

1.2 Problem Statement

Human elephant conflict is at an all-time high in the Amboseli Ecosystem (AE) as reported by the Amboseli Conservation Program (ACP), 2017. This is evidenced by the growing overlap of elephant habitats and land use practices incompatible with wildlife conservation. Owing to intensification in land use and land tenure transformation in the Amboseli ecosystem dispersal areas, elephant conservation has become a key challenge. Habitat transformation, environmental degradation and eventually human-wildlife conflicts are among the threats stemming from land use changes within this ecosystem (Ekisa & Victor, 2016) further exacerbated by land subdivision, primarily due to the desire to own personal (Kariuki *et al.*, 2021).

In Imbirikani Group Ranch, land use transformation has changed land cover to agricultural land, urban centers and settlements, causing the deterioration of wildlife habitats. These changes contribute to wildlife losses, land degradation, habitat destruction, and obstruction of wildlife corridors (Kitina & Kihima, 2014). Of notable concern has been the steady decrease in elephant habitats and their quality in Imbirikani, resulting in the frequenting of elephants around settlement areas further escalating HEC. This situation has been associated with incompatible human activities revealed by habitat degrading land use practices (Okello *et al.*, 2014) such as deforestation, unplanned urban sprawl, overgrazing and unsustainable irrigation (Malaki, 2018).

The collective effects of augmented temperatures and reduced rainfall have further resulted in shrinking wildlife habitats and aggravated competition for food and water resources between people and wildlife. Climate change as well as the broadening climatic variability, impact HEC through their effects on the supply of food and water for both elephants and people (Shen & Ma, 2014). Actually, periodic droughts and escalating temperatures (Bartzke *et al.*, 2018) lead to regular food and water scarcities, subsequently causing greater movements in addition to the increased probability of interactions among elephants, people and livestock. This further aggravates HEC even as people resort to alternative land use options such as agriculture in an endeavor to adapt to climate change effects.

Within the AE, and as observed by Okello (2012) wildlife dispersal areas contracted down to 77 percent due to human structures and activities with the consequential intensification of HWC in Imbirikani Group Ranch. Such high levels of loss of habitats have consequences to wildlife conservation, key among them being an escalation of negative human- wildlife interactions. Human elephant conflicts and the extent to which they are linked to LULCC have been subject to scanty research in Imbirikani Group Ranch.

HWC management is often devoid of community involvement while land use planning has predominantly been an expert-driven process. This can undermine community perspectives and ownership of mitigation strategies. This research provides an integrated land use change assessment approach by means of remote sensing, GIS and participatory mapping to reinforce conventional methods by incorporating collaboration and exchange of knowledge with the community as key stakeholders in conservation, an approach that has recently started gaining momentum. The evaluation of trends in HEC impacts is necessary to identify and formulate effective management approaches. This research also aimed to evaluate local community perceptions towards human-elephant coexistence for improved community-based conservation.

1.3 Justification of the study

Conservation of wildlife dispersal areas not only requires knowledge of species habitat requirements but also knowledge of past and current land use practices that alter land cover. Imbirikani provides connectivity between Amboseli National Park, Chyulu Hills National Park and Tsavo National Park. Essentially, this strategic connection is vital to the survival of Amboseli's elephants and other wild animals. Consequently, an assessment of the extent and the nature of HEC as well as the evaluation of its influence on conservation efforts are crucial if the threats related to wildlife conservation and loss of biodiversity in this area are to be met. There is a need for conservationists to have this data at a fine spatio-temporal scale more so in areas where these threats prevail in the Amboseli Ecosystem for the purpose of improving interventions.

A Human Wildlife Conflict mitigation group was set up in 2016 by research and conservation agencies in the Amboseli Ecosystem with a goal to create a database that would capture the seasonal burdens at the basis of conflicts as well as the rapid response. The results from this study will go a long way in providing content in this database on the prevailing prominence of land use changes and the resultant conflict for improved conservation management. The documentation of land use/cover changes and their contribution to human elephant conflict will help in monitoring human activities for improved land use planning with the goal of improving coexistence between people and wildlife.

So far, human elephant conflicts have only been reviewed on a wider scope of human wildlife conflicts within Imbirikani Group Ranch. In this respect, this research offers more insights on HEC in one among the critical elephant conservation areas in the country. As a result, this will assist the Kenya Wildlife Service (KWS), Kajiado County Government, conservation agencies and local communities contributing to wildlife conservation make knowledgeable decisions on suitable practices that will heighten elephant conservation besides their harmonious living with the neighboring local communities.

This study contributes to knowledge that will improve land use planning in Kajiado County with the ultimate aim of facilitating harmonious coexistence between humans and wildlife. The results of this study help illuminate livelihood problems such as decreasing food security and increasing poverty levels arising from HEC. The study also suggests policy direction on HEC mitigation while generating new knowledge about the study area.

Evaluating trends in HEC is critical for formulating efficacious management plans in addition to conservation planning and hands-on intervention at the human-elephant interface at the local level. Data from this project will inform community-based land use planning at the group ranch level. This study will correspondingly aid policy makers and other stakeholders in conservation to develop strategies and action plans for sustainable management of elephant dispersal areas. In addition, it will also inform climate smart farming that’s resilient to elephant destruction in Kajiado County.

The African elephant is a species of global importance as these pachyderms play a crucial role as flagship and keystone species helping to maintain biodiversity of their ecosystems and contribute to overall global conservation goals. This study will be helpful in contributing to the larger goals of elephant conservation, an endangered species according to the IUCN Red List (IUCN, 2021). The study will also enhance habitat management thus contributing to biodiversity protection.

1.4 Objectives

1.4.1 Broad objective

To assess some of the factors driving human-elephant conflict in Imbirikani Group Ranch for improved management and coexistence of elephants and local communities.

1.4.2 Specific objectives

The specific objectives of the study are to:

1. Determine land use and cover changes in Imbirikani Group Ranch for the last 32 years.
2. Evaluate the nature and extent of human-elephant conflict within Imbirikani Group Ranch.
3. Assess community perceptions and attitudes towards human-elephant conflicts in Imbirikani Group Ranch.

1.4.3 Research questions

1. To what extend has land use and cover changed within Imbirikani Group Ranch in the last 32 years?
2. What is the nature and extent of human elephant conflict within Imbirikani Group Ranch?
3. What are the attitudes and perceptions of the local community towards human-elephant conflicts in Imbirikani Group Ranch?

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction to Human Elephant Conflict

The deterioration in the numbers and available range for elephants due to expanding anthropogenic activity in Africa is acknowledged as one of the continent's most severe conservation challenges (Hoare, 2015).Extension of settlements and cultivated areas across Africa has given rise to widespread decline of elephant habitat, degraded food resources, condensed landscape connectivity, in addition to a substantial decrease in the species' populations compared to their size as well as overall range historically(Calabrese *et al.*, 2017). In the process of their territories dwindling, elephants are increasingly compelled to move closer to people, where more recurrent and severe conflict ensues over resources with consequences stretching from crop raids to reciprocal death (Liu *et al.*, 2016). HEC has posed a challenge to biodiversity conservation, and a principal goal for elephant conservation is its effective management.

For years, high levels of poaching have occasioned a decline in elephant numbers. However, with the enhanced capacity of elephant management organs and the international ban on ivory trade, the level of poaching has significantly reduced enabling their population recovery leading to a gradual return of elephants to their former range. Nevertheless, the human population has also developed intensely over this period, and the problem of conserving elephants in Kenya today is quite unlike the case 20 to 30 years ago. Settlements in addition to cultivation within elephant ranges and the consequential HEC are some of the key threats to the future of elephant populations in Kenya (WWF, 2019).

2.1.1 Amboseli Ecosystem Elephant Population Trends

Elephants are keystone species playing an important part in ecological processes such as influencing vegetation composition and structure. They also represent one among many of the main tourist attraction species. Nevertheless, being one of the main prey for poachers, they have become a species of global protection and concern (Omondi & Ngene, 2012). Over the last century, the African elephant has declined gravely due to illegal ivory trade as well as drought.

Estimations show that elephant numbers plummeted to 20,000 in 1990 from about 167,000 in 1973.As indicated in the 2014 KWS census, the species were appraised at 38,000 in Kenya whereas in Africa they were approximated to be between 410,000 to 250, 000, representing more than 50 percent drop from 1985 (KWS, 2014). Today, elephant numbers stand at 415,000 spreading over a range of 37 countries in Sub-Saharan Africa (AWF, 2019). Furthermore, their numbers have increased progressively in Amboseli within the last two decades. This is more disturbing since forested vegetation, their main food, has been exhausted within AE (Ochwangi, 2014).

In 1972, Amboseli Elephant Research Project, the main research division of AET, estimated the elephant population stood at 800. Due to improved protection and management, over the course of three decades, in 2008, the number had risen to an impressive 1,600. Regrettably, the drought of 2009 saw the loss of over 300 families, approximately 967 elephants (Okello *et al.*, 2016). According to a report by Amboseli Trust for Elephants, the elephant population comprised 1657 individuals (792 males, 865 females) by 31st December 2017 in the AE. Far fewer births in the rainfall year of 2017 than in preceding years were observed. The same year also recorded a lower rate of production relative to years after the major 2009 drought. Similarly, the interval between births has correspondingly extended with the current average being close to five years. This trend suggests that elephant populations are at a weaker capacity to recover after deaths of natural or induced nature. Current elephants' numbers are slightly over 1,600 in the Amboseli Ecosystem, a figure that differs depending on the availability of feed and water which causes them to migrate to surrounding wildlife areas.

Elephant population in Amboseli Ecosystem declined between 2000 and 2007 at a rate of 1.17% after which the population grew at the annual rate of 3.72% between 2010 and 2018. This is illustrated in figure 4.4 below.

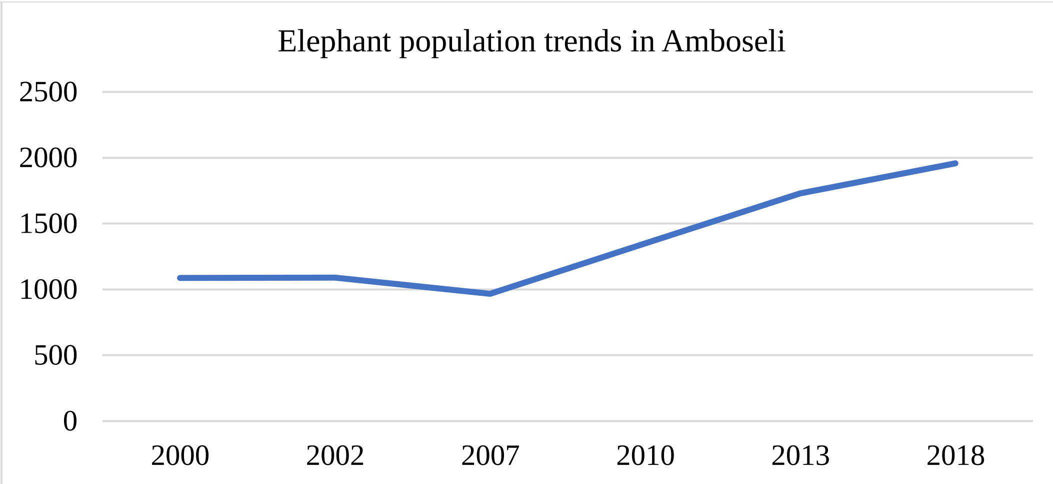

Figure 2. 1: Elephant population changes between 2000 and 2018.

Source: Kenya Wildlife Service

2.1.2 African Elephant Ecology and status

While most elephant range occurs outside protected areas, their local distribution varies over space and time. For example, in the dry season when water is limited their density is higher around rivers, swamps or generally within the vicinity of surface water sources. Elephant diet includes pasture, bark, herbs, browse and fruits. These pachyderms are extremely adjustable and proficient in inhabiting a diversity of environments. Natural influences that affect their movement and dispersal include diet, home range, group size and composition, as well as migration patterns (Ochwangi, 2014). Elephants are environmental engineers and keystone species since they greatly alter the structure of their habitats. Additionally, they seek areas with high quantities of forage and generally avoid residential areas (Grant *et al.*, 2008).

The African bush elephant (*Loxodonta africana*) is currently on the endangered grade on the Red List of the International Union for Conservation of Nature (IUCN). The IUCN lists the following as threats to elephants: agriculture and aquaculture, commercial and residential development, livestock farming and ranching, biological resource use, transport and related service corridors, people’s intrusions and habitat disruption, alien/invasive and other problematic species, natural system modifications, genetic factors and diseases in addition to climate change and extreme weather conditions (IUCN Red List, 2019).

2.1.3 Human Wildlife Conflict in the Amboseli Ecosystem

HWC poses a challenge to livelihoods and conservation throughout Africa in that it causes destruction of crops and livelihoods, animosity towards wildlife, and occasionally human injuries and death. There exists an inextricable link between the abundance and distribution of African elephants and that of the human population (Mmbaga *et al.*, 2017).

In the period 2013 to 2016, 300 injuries and 40 human deaths attributed to wild animals were conveyed in Kajiado, besides 1,700 farm raiding incidents. Compared to 24 to 30 elephants that died from retaliatory killings, there was only a single elephant lost to poaching in Amboseli throughout 2016 (Western, 2017). These statistics point to the biggest threat to elephant conservation today i.e. human elephant conflict.

In ANP, elephants move far and wide and therefore, their survival is determined by the ability of local communities to coexist with them. However, population growth in these group ranches has resulted in more direct contact with wildlife and expansion into and around protected areas. The resulting increase in land use and land tenure transformation in the dispersal areas of the AE has made elephant conservation a prominent challenge. In this ecosystem, the principal types of human-elephant conflicts are human injury and loss of life, crop raiding, damage of property and occasionally livestock injuries (Ekisa and Victor, 2016). In Imbirikani Group Ranch, the number of reported HEC related incidences was highest in 2016 and has been on a downward trend upto 2020 as shown below.

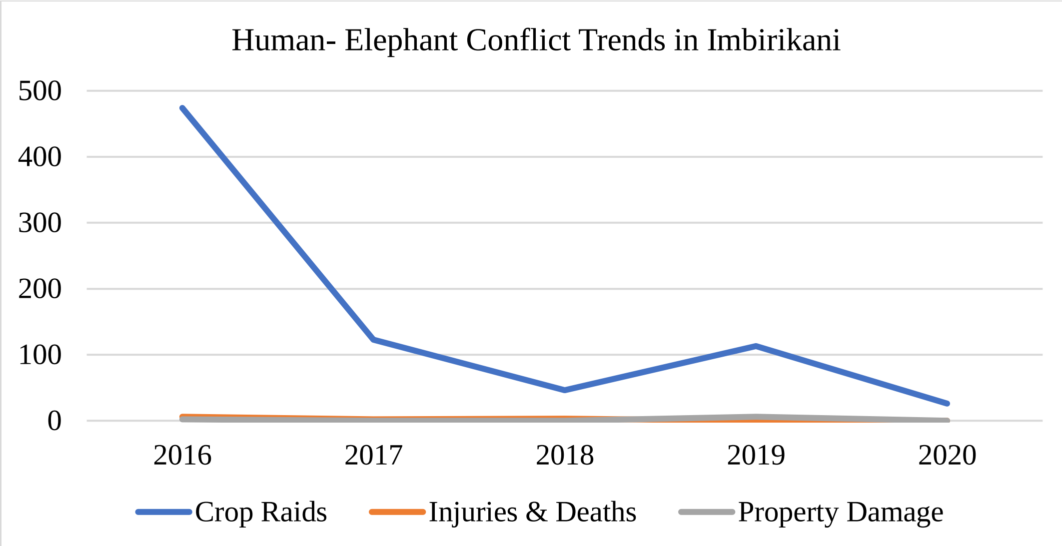

Figure 2. 2 Human elephant conflict reports in Imbirikani Group Ranch.

Source: BigLife Foundation

2.2.0 Factors Influencing Human Elephant Conflicts

2.2.1 Human Demographic Factors

Social and demographic dynamics increasingly put more people in direct exchange with wildlife: as human populations rise; settlements inflate into and about protected areas. This growth in human population and the resultant demand for settlements as well as socio-economic activities have occasioned increase in human activities up to the boundaries of protected areas and marginal land that were wildlife dispersal areas (Esiromo, 2012). Protected areas are beneficial for rural development, particularly in Africa and Asia, however, increasing human populations often are detrimental to biodiversity (Kariuki et al., 2021).

In Sub-Saharan Africa, many of the elephant range countries are subjected to human population rises of 1 to 3.5 percent each year (World Bank 2018). Being some of the marginalized communities, these people more and more compete with other wild animals, like elephants, for survival (Shaffer *et al*., 2019).

The Kenyan population has expanded to 47.6 million people from 38.6 million in 2009 according to the 2019 census (KNBS, 2019). In Kajiado County, the population has grown to approximately 1.2 million in 2019 compared to 687,000 in 2009 and 406,000 people in 1999. The county has posted a 5.5 percent population growth rate compared to the average Kenyan growth rate of 2.2 percent. The implication of this is increased contact between humans and elephants as competition for food, water and space heightens (Nyhus, 2016).

Between 1989 and 1999 the human population grew by 3.89% in Imbirikani Group Ranch. This growth shot up from 1999 to 2009 by 6.77% which was followed by an increase of 4.96% between 2009 and 2019 as depicted in figure 4.3. This is above the national growth rate of 2.2% (KNBS, 2019) between 2009 and 2019.

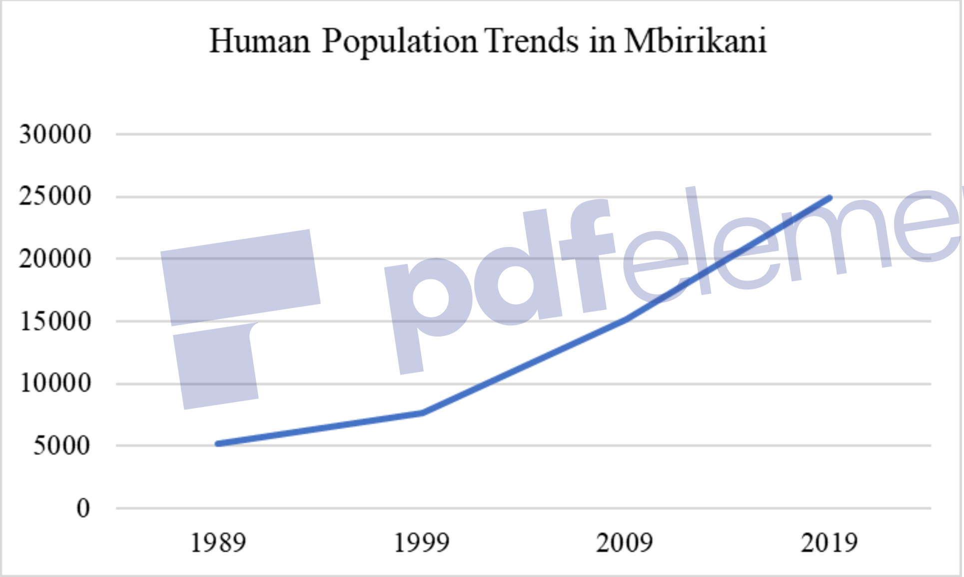

Figure 2.3: Human population trends from 1989-2019 in Imbirikani Group Ranch.

Source: Kenya National Bureau of Statistics

2.2.2 Elephant Factors

2.2.2.1 Individual Elephant Characteristics

Often there is significant disparity among individual animals or groups in terms of the regularity of the negative interactions between people and wildlife. Certain individuals within elephant populations may at no time or rarely get involved with HEC, some irregularly involved, while others consistently involved (Hoare, 2015). Stage of life is one factor that may play a role in the probability of a conflict happening. Injured, old or sick animals may be more expected to participate in farm raids, or other risky endeavors. In other instances, young animals may be more likely to engage in high-risk behavior (Chiyo *et al*, 2012).

Sex is another factor. African elephants (*Loxodonta africana africana*), in particular male species, disproportionately indulge in crop raiding behavior (Nyhus, 2016). For instance, in the Amboseli elephant population, Chiyo *et al.*, 2012 estimates that 1/3 of all male elephants after dispersal raid crops while seemingly no females engage in this behavior. On the other hand, all the male species and most elephant family groups have access to farmlands. Social learning has also been attributed to crop raiding. Elephants form social networks which influence spread of learned behavior in populations (Hoare, 2015).

2.2.2.2 Elephant Migratory Behaviour

The migratory habit of elephants increasingly puts them into contact with human beings who encroach upon their migratory corridors. People have established settlements and farms along elephant migratory routes. This results in modification of the natural environment that supports elephant survival, as well as curtailing their seasonal movement into and out of the Amboseli National Park (Kageni, 2018).

2.2.2.3 Elephant Population

Kenya witnessed a 30 percent drop in poaching cases in 2018 compared to 2017. In 2018, the country suffered the loss of 396 elephants owing to diverse factors, including natural causes such as drought, disease, drowning, territorial fights and old age; HWCs, poaching and accidents in comparison to 727 that died in 2017. Nationally, the elephant population has stayed healthy currently being estimated at 35,000 having grown by 119 percent over a 29-year period from 16,000 in 1989 (KWS, 2018). This implies that elephant populations are on the rise owing to increased surveillance among other factors. Upto 2015, elephant numbers have been on the rise in AE, despite the human population pressure, limited resources, and competition for these resources (Eric & Ochwang, 2014).

In 1999, there were 1087 elephants in the Amboseli Ecosystem (Moss, 2001). In 2005 the population had increased to 1300 (Kioko *et al.,* 2006). In 2010, the elephant population in the ecosystem was 1,500 (Croze & Lindsay, 2011). By 2019, the population was estimated at over 1600 (AET, 2019). Generally, the elephant population has risen by about 300 percent since the 1970s, or at a growth rate of 2.4 percent annually (Aduma *et al.,* 2018). These pachyderms have a tendency to occupy nearly 80 percent of their time in habitats outside protected areas and using a landscape almost 20 times larger compared to the park (Okello *et al.*, 2016). Therefore, an increasing elephant population tends to intensify human-elephant conflict.

2.2.3 Competition for Resources

Despite measures to increase water sources in rural areas, most households still rely on natural water sources for domestic consumption. Food and water distribution in addition to other ecosystem factors are postulated to influence the abundance and distribution of HEC (Nyhus, 2016)**.** Furthermore, several pastoral communities migrate nearer to more permanent water sources in the course of dry seasons to guarantee constant access of water for their household requirements, livestock and crops. Thus far this perpetuates competition for more and more limited water sources as well as other resources in the course of and/or after droughts which further aggravates the risk of HEC (Mariki, 2015).

Poverty similarly weakens household coping adaptive capacities to recover from harvest damages by crop-raiding behavior of elephants that additionally impedes conservation efforts by provoking hostility and negative attitudes toward elephants (Nsonsi *et al.*, 2017). Confrontations arise between the animals and human beings as they try to defend their lives. Increasingly, elephant conservation faces the constant threat of human population growth and the consequential expansion of settlements as well as abstraction of resources which exert pressures on environments and wildlife populations (Ojuka, 2016).

2.2.4 Inadequate compensation

An elephant herd will normally enter a field and eat a whole season's crop in only a few hours. Following such an event, residents experience food shortages and the subsequent pain of the loss. Out of obligation they are forced to spend less on necessities like their children's education or on health expenses, while prioritizing food purchases. Undeniably, communities' quality of life meaningfully deteriorates due to the elephant raids. Additionally, encounters with these species can occasionally be deadly leading to human death (Naidoo *et al*., 2016). Although tourism revenue has been growing steadily, a lot of the communities living around protected areas are fraught by the costs and negative effects of wildlife tourism, without tangible benefits (Naidoo *et al*., 2016).

2.2.5 Perceptions and Attitudes towards elephant conservation

Perception denotes the combination of processes used by individuals to make sense of the different stimuli they are exposed to. Such processes arise with reception of stimuli from our surroundings and our interpretation of the same stimuli. Perceptions help us provide meaning to our environment. An attitude on the other hand is a feeling, thought or opinion about a situation or someone. Our attitudes encompass beliefs, views, and actions. They determine how we perceive situations as well as how we behave when exposed to these situations. They are learned over time rather than innate. Understanding such anthropological factors (attitudes and perceptions of local communities) provide an outline of the sociopolitical and cultural context of HWCs. They are important since they determine the success of any wildlife management initiative (Mir *et al*, 2015) by determining people's tolerance to wildlife. Factors influencing perceptions and attitudes towards wildlife include age, sex, education level, distance of homestead to protected areas (PA), economic benefits from conservation, previous encounters with wild animals whether positive or negative, compensation for loss as well as the livelihood activity a household engages in, depending on its compatibility to conservation or lack thereof (Tilahun *et al*, 2017).

The magnitudes and extent of HEC can be different among communities subject to type of crops, farm husbandry practices, environmental conditions, variations in crop season of growth, habitat features, obtainability of resources for both wildlife and human populations, as well as local deviation in elephant behavior like learnt reactions to management. Similarly, the perception of local communities towards HEC can also differ as influenced by cultures and traditions (Sampson *et al*., 2019).

Crop destruction and human casualties (injuries and death) are the most frequently conveyed and revealed costs of HEC (Nath, 2015). However, hidden costs in terms of lessened psychosocial security and interrupted social activities raise added concerns. Such physical and unseen costs increasingly make it hard, even unbearable, for communities to cultivate positive attitudes for and forbearance of elephants living in their region (Shaffer *et al*., 2019).

2.3 Land Use and Land Cover Changes

Land use and cover are two basic terms referring to the terrestrial environment in association with both anthropogenic activities and natural processes (Mendoza *et al*., 2011). Moreover, the combined term land use and land cover (LULC) encompasses both classifications of LU and LC. The examination of changes is of principal importance to comprehend many economic, social and ecological problems (Pelorosso *et al.,* 2008). The analysis of LULCC is crucial to understanding numerous environmental phenomena in addition to social issues since these changes reflect key alterations of the Earth's land surface (Verburg *et al*., 2011)

2.3.1 Types of Land use changes

The interface between human activities and physical processes brings about land cover changes or adjustments of the constructions of the land surface, being either in the category of a transformation or modification leading to secondary ecological impacts (for instance micro climatic fluctuations, soil erosion and changes in the quality of water among others) while it echoes human objectives represented on land use and cover changes. Mainland uses in Kenya which include rain-fed and irrigated farming, commercial, industrial, human settlements, infrastructure, leisure areas, rangelands, wildlife conservation, mining, fishing, woodlands, among others range across the high, moderate and low rainfall areas (Lands Sessional paper, 2017).

2.3.2 Drivers of Land use changes

LULCC is a key matter of concern with respect to change in the worldwide environment (Qian *et al.*, 2007). The rapid human population growth, swift development and expansion of urban centers, shortage of land, the necessity for more construction and production, altering technologies are some of the various drivers of land use/cover changes globally today (Barros, 2004).

The threats to East Africa's outstanding savannas arise in several kinds and Amboseli suffers from most of them. To a large extent, the severest threat lies in the disintegration of the ecosystem and breakdown of the migrant herds of wildebeest, zebra, elephants as well as pastoral livestock (Amboseli Conservation Program, 2017). Like urban areas, the ASALs have seen a very high rate of immigration from other parts of the country. While the ASAL of the AE were traditionally inhabited by the nomadic pastoralist Maasai, many different tribes are now in this area, practicing differing livelihoods, with more emphasis on agriculture (Ekisa & Okello, 2016).

Over the past millennia, the AE has played a fundamental part in subsistence pastoralism besides wildlife conservation through provision of significant biotic resources for pastoral communities, their livestock and wildlife. Conversely, following the gazettement of ANP in 1974, influx of farmers, and the resultant modifications in land ownership systems, people's use of the biome has increased over time. In consequence, a mixed agro-pastoral landscape has been created with rain-fed and irrigated crop cultivation, livestock ranging, wildlife conservation, and a diversity of other land use and cover forms comprising significant development of market centers (LUCID, 2017).

Further key elements that have propagated land use change in the AE include an increasing human population, fragile communal leadership as well as the aspiration to acquire land title deeds presented as warranty for loan solicitations from financial institutions (Campbell *et al*., 2003b). Collectively, these factors produce resource rivalry while disregarding historical grazing patterns for wet and dry seasons (Ntiati, 2002; Kimiti *et al.*, 2016).

2.3.2.1 Agricultural Expansion and Intensification

A confluence of factors has led to expansion of farming activities in the Amboseli Ecosystem. Key among these is the high demand for food produce owing to a growing human population and climate change impacts that have occasioned the occurrence of periodic droughts rendering pastoralism an increasingly risky venture among pastoralists. Pastoralists have thus had to adjust by diversifying their livelihoods. Crops planted on the periphery of the park, particularly maize, attract elephants that stray outside the park boundaries (UNEP, 2019). Crop destruction is the most widespread form of HWC across Africa. The rate and regularity of crop-raiding events depends upon a host of circumstances including the accessibility, variability and kind of food sources existing in the range, the degree of human activity on a cropland, and the kind of crops as well as their maturation time in comparison to natural feed sources (Shaffer *et al.*, 2019).

A study done in Kuku Group Ranch in the Amboseli Ecosystem by Okello (2006) showed that the number of people practicing agropastoralism was larger than those involved only in farming or rearing livestock. Crop farming was perceived to be more beneficial compared to both conservation or pastoralism. This is attributed to a range of reasons including direct monetary profits to households, the shortage of markets for beef in addition to deteriorating livestock numbers and growing costs of pastoralism, as well as dwindling water and land resources for livestock. Every single one of these factors renders pastoralism less financially lucrative. Accordingly, the Maasai community has tended to diversify their revenue sources as opposed to depending on pastoralism alone. In addition, the local community considers wildlife conservation less beneficial (Homewood *et al.*, 2019).

2.3.2.2 Human population Growth

Human population growth has been associated with the struggle for natural resources between communities and wildlife. According to United Nations (2017); the then global population of 7.6 billion is projected to stretch to 8.6 billion by 2030, 9.8 billion by the year 2050 and 11.2 billion by 2100, with approximately 83 million people being the increase to the world's populace annually. This will likely lead to an increased human population overlap with established wildlife territories (Ogutu *et al.*, 2016). The eventual detrimental consequences will be *inter alia*, habitat destruction and fragmentation, overexploitation of natural resources in encroached areas as well as the resulting increase in poaching and human wildlife conflicts. The designation of land as PAs notwithstanding, wildlife habitats are at the brink of loss due to escalating local human population.

Interactions between rural communities and wildlife are inevitable on account of the fact that they depend on natural resources for daily needs such as fuel, food, fibre or water. Therefore, a critical evaluation of local human population growth is necessary in addressing livelihood development and biodiversity loss. Kajiado South Sub-County where Amboseli Ecosystem lies, bears a human population density of 23.04 per kilometer square with a population growth rate of 5.5% (KNBS, 2019). Kutatoi and Waweru (2017) carried out research on the causes of HWC in Kajiado South Sub-County and observed that 15 percent of the respondents reported human population growth as the main cause of HWC. The high population growth was attributed to urbanization and the resultant immigration of non-local communities into the area.

2.3.2.3 Economic Development

Economic diversification and international influence on national policies further stirs up the changing land use in the rangelands. This has a negative impact on biodiversity and the different territories which are very crucial for the continued existence of pastoralists who rely on the natural resource base for livestock production. In addition, the sprawling of urban centres increasingly observed in Amboseli rangelands has over the years reduced land for grazing over the years (Kariuki *et al.*, 2018).

The observed rise in business centres and marketplaces in the rangelands is a clear indication of increased trade in pastoral areas. Business centers have created market days where pastoralists who subsisted on livestock now get involved in buying and selling of their livestock to purchase other commodities including agricultural products. Through capacity building, pastoralists have diversified their economies through formal and informal employment. The tourist facilities both within the protected, unprotected, and private areas have provided alternative livelihood options to the local communities in rangelands (Sakimba, 2016).

2.3.3 Impacts of land use and cover changes

Most HWCs occur in areas where land uses are not compatible with wildlife conservation. Some of these problems postured by land use/cover changes around protected areas include the intensification of HWCs (FAO, 2009). HWCs have been on the rise posing a major challenge to conservationists and wildlife managers in several countries, Kenya included (FAO, 2009; Kenya Wildlife Service, 2012).

At Kenya's independence in 1963, the total national population was approximately 7 million people. The population had increased to 15.5 million people by 1979. In 1989, it rose to nearly 21.5 million people and shot to 29 million by 1999 (GoK, 2013). Over that same era, the economy in Kenya performed below average with no notable industrialization that could help cope with the stresses of the cumulative population. Currently, it stands at about 48,000,000 (KNBS, 2019). This trend in human population has unavoidably occasioned extreme burden on the existing natural resources, with implications of a growing demand for settlements and a need to feed a burgeoning population. The effects of these are evidenced by both increased agriculture and economic activity of industrialization and urbanization. Humans encroach into wildlife habitats bringing them into closer contact with wild animals (AWF, 2017).

2.3.4 Land Tenure

Following years of independence in Kenya, the lack of a clearly definite land use policy has given rise to an arbitrary method to restricting the various land use activities as well as policy responses (National Land Sessional paper, 2017). The semi-arid rangelands of southern Kenya traditionally sustained pastoralist lifestyles, frequently practiced by the Maasai and various other tribes in the area (Western & Nightingale, 2003). In recent years, the region's inhabitants have undergone a land use shift from primarily pastoralist to an agro-pastoralist or agriculturalist lifestyle, putting an immense strain on the environment's already limited resources (Kimiti, 2018). Changes in resources over the long-term have brought about several problems, including limited livestock movement, deterioration in feeding areas besides increased resource competition (Egeru *et al.*2014).

In Kenya, terrestrial wild animals are protected principally in national parks, sanctuaries and reserves. Yet most of these animals exist outside protected areas (Kariuki *et al.,* 2021). Therefore, wild animals utilize wildlife corridors to sustain their food and water needs. Terrestrial wildlife dispersal areas can be described in terms of: a) functionality as regions used by animals to move from one "habitat patch" to another and b) structurally as regions joining two covers of suitable habitat by transiting through a matrix of less suitable ones (Hilty *et al.*,2006). However, a proliferation of settlements, crop cultivation and fencing of land threatens to block these movements. Therefore, the progressive alteration in land use and its subdivision is a key threat to long-term sustainability of Imbirikani as a dispersal area and has led to its ecological isolation (Mbane *et al.*, 2019). Ecological isolation in most cases is damaging to animals requiring vast home ranges as elephants as well as to those possessing complex needs at various stages in their seasons or life cycles (Kideghesho *et al.*, 2006).

Initially, land in the Maasailand was owned communally or in group ranches (Ntiati, 2002). Nonetheless, a policy ratified by the Kenyan Government to encourage the subdivision of the land from group ranches to privately owned parcels patented the start of an alarming change in land tenure (Mbote, 2005). Inevitably, there has been increased habitat fragmentation and degradation of the Imbirikani corridor. Rangeland fragmentation, and the consequent land cover changes, represents a very real threat to both wildlife conservation and local pastoralist livelihoods. Traditional grazing management structures have largely disintegrated, and a growing human and livestock population are adding extra pressure to a stressed system (Big Life, 2016).

Needless to say, if the land use changes are not controlled the Amboseli and Chyulu National Parks may lose their connectivity which is critical to the survival of elephants in this ecosystem

2.4 Community attitudes and perceptions towards elephant conservation

When humans and elephants compete for food, water and space, the resultant impacts are usually negative on human goals or vice versa. Negative impacts include crop destruction, livestock injury, damage of structures, effect on school going children and socialization and even loss of life including retaliatory killings to elephants. These negative experiences lead to increasingly negative attitudes towards elephants which are as a result considered destructive and a nuisance (Postigo, 2014). This implies that assessing local communities' attitudes toward HEC is a prerequisite for successful elephant conservation. This presents the social context of HEC which is a result of unregulated expansion of economic activities. Attitudes and perceptions are considered individual traits which are stimulated by education level, wealth status, personal values, benefits accrued (or not accrued) from wildlife conservation and the extent of costs associated with wildlife. These factors have informed research as well the mitigation strategies for HEC management for instance through education and awareness or provision of incentives from wildlife to generate benefits to communities (Quiroz *et al.*, 2017).

Further, what researchers refer to as the 'hidden costs' of HEC, progressively influence community tolerance for elephants. These include decreased nutritional status, increased night watches, increased mental stress, disruption of school and daily chores and amplified socio-political inequalities (Bond, 2015). Human perceptions vary in space and time because factors affecting attitudes are heterogenous (Mir *et al.*, 2015). The regular assimilation of local perspectives into wildlife conservation research and implementation is valuable for capturing indigenous knowledge, leveraging local community capacity to conserve wildlife and offers them a sense of collective ownership in conservation goals (Larson *et al.*, 2016).

Browne *et al.*, *(*2013) showed that a slight majority of 53 percent of residents in the Greater Amboseli Ecosystem, supported elephant conservation while the remaining 48 percent were opposed to it. Those who support elephant conservation believed that the species was beneficial in that it attracted tourists to the group ranches increasing economic opportunities to the communities. On the other hand, those who were opposed believed that it was the antecedent for conflicts, increasing precarious human-elephant interactions.

Diverse schools of thought surround the underlying attitudes towards wildlife. Political ecologists have posited that negative attitudes are a result of displacement due to conservation, constraints on livelihoods and limitations to resource access (Lunstrum, 2016). Cultural anthropologists attribute the attitudes to culturally- ingrained wildlife dimensions which are fashioned by customs of various African societies (Dickman *et al.,* 2015). Conservation psychologists have also attempted to examine the cognitive mechanisms underpinning attitudes towards wildlife (Lute *et al.,* 2016). Based on the three theoretical approaches, Fernandez *et al.* (2020), examined shifts in attitudes of local communities towards wildlife in the Amboseli Ecosystem. Although there exist efforts to help communities generate income from conservation, HWCs undercut its significance in the AE due to limited community involvement in the decision-making process and in the conflict mitigation strategies (Fernandez *et al.,* 2020).

2.5 Compensation mechanisms

Kenya Wildlife offers compensation for crop raiding, human injury or livestock predation (Kenya Wildlife Conservation and Management Act, 2013). Moreover, there are programs which offer locals within close range of high-risk areas stipends for education. Because of the current policy and frequent crop damage, many residents have a negative view of wildlife, the KWS and even wildlife conservation efforts as they perceive wildlife as the responsibility of the government (Mbau, 2013; Ekisa and Okello, 2016).

However, conservation organisations have come in to correct the situation. Amboseli Trust for Elephants (ATE) consolation scheme, for example, addresses the loss of cattle, sheep-goats, and donkeys as a result of interactions with elephants outside the protected area of Amboseli National Park. ATE paid out a total of 720,000 KES in 2017, however the number of events (48) has increased substantially. Although part of this increase could be due to greater dispersal away from the National Park, i.e., more elephants distributed over a larger area of the ecosystem, it is likely that increased livestock numbers coupled with a very harsh and prolonged dry season exacerbated the overlap between elephant and livestock needs for forage and water causing a greater number of livestock deaths (Amboseli Trust for Elephants, 2017).

Additionally, ATE fosters livelihood development among young women and men by funding primary, secondary and university students from the Group Ranches surrounding Amboseli National Park. This represents one of the many organisations engaging in capacity building activities to empower the livelihoods of the local residents who coexist with elephants.

Critics of compensation programs have however questioned the financial sustainability of these approaches in the long run. While the programs have been significantly successful in curbing retaliatory killings in the AE (Shaffer *et al.*, 2019) they have perpetuated a culture of compensation amongst the local communities, often seeing wildlife conflict as an economic loss rather than a natural component of the ecosystem. Therefore, they have not necessarily produced more positive attitudes towards wildlife or conservation (Anyango-Van Zwieten *et al.*, 2015; Wilson-Holt and Steele, 2019).

2.6 Land use and wildlife governance in Amboseli Ecosystem

Kenya's Vision 2030 acknowledges the need for a Conservation Connectivity Framework to secure wildlife spaces. The Wildlife Conservation and Management Act was signed in 2013 for wildlife protection, conservation and management. The law established guidelines for community- based conservation for benefit sharing of resources from wildlife. The Act was amended in 2019 which served to introduce new offences and penalties, clarify some offences that were initially ambiguous and setting more stringent terms on some offences (Kenya Gazette, 2019). The National Wildlife Strategy 2030 provides the vision and framework for the implementation of Kenya's Constitution (Article 69) and the Wildlife Act (2013). Additionally, the Conservation and Management Strategy for the Elephant in Kenya (2012 – 2021) lays down the framework for harmonized and concerted effort for the conservation of elephant populations in Kenya.

The Amboseli group ranches and stakeholders developed a comprehensive Amboseli Ecosystem Management Plan (2008-2018) to serve as a roadmap for land use management, natural resource utilization, urbanization, tourism and economic growth in the entire ecosystem (ATGRCA, & KWS, 2008). The plan was renewed in the newly ratified (AEMP 2020-2030) that was launched in December 2020. Amboseli Group Ranch land use plans have also been incorporated into the new AEMP (ACC, 2020). Through the AE zonation scheme of the plan, Imbirikani GR was marked as a livestock production zone and a low use area. Nonetheless, increased farming, settlements and the loss of woodlands still threaten ecological connectivity between AE and adjoining ecosystems fragmenting key wildlife habitats while exacerbating human-elephant conflict.

2.7 The use of GIS and Remote Sensing Tools

Geographic Information System (GIS), in contrast to the orthodox ground surveys, has presumed an increasingly significant part in conservation biology and wildlife management by offering means for modeling possible distributions of animals and their habitats (Prasad *et al*, 2011). In recent years, remote sensing procedures have ascertained to be accurate in the generation of land use and cover maps which aid in revealing changes. Satellite Remote Sensing (SRS) has a relative advantage over traditional surveys in that apart from saving time and cost for regional scale, it similarly runs large scale data on land use and cover changes with details regarding their spatial spread (Yuan *et al.*, 2005). In this regard, GIS and remote sensing have been demonstrated to be beneficial tools for evaluating the spatio-temporal details of these changes (Serra *et al*., 2008).

High-resolution satellite images must undergo a geometric rectification process to be used for metrical purposes, an operation called orthorectification. This process is necessary because of deformations mainly due to camera distortions and acquisition geometry (Baiocchi *et al.*, 2020). Following this orthorectification is image classification which involves categorizing the pixels of a digital image into land cover classes or themes. Most image processing techniques are based on hard logic, utilizing both spectral and temporal spatial pattern (Khorram *et al.*, 2013). Image classification based on hard logic is divided into supervised classification and unsupervised classification as defined by Hester *et al.*, (2008). Unsupervised classification methods generally use no or minimal analyst supervision to develop the resultant land use/land cover maps. This is a computerized process whereby each pixel is iteratively assigned to a class based on the similarity of the spectral properties of pixels in multiple bands. The analyst assigns the categorical information to the classified data after classification.

In supervised classification the user or image analyst "supervises" the pixel classification process. The user specifies the various pixels values or spectral signatures that should be associated with each class. This is done by selecting representative sample sites of a known cover type called training sites or areas. The computer algorithm then uses the spectral signatures from the ground truthing points to classify the whole image (Killeen, 2015). Three algorithms are used in supervised classification namely maximum likelihood, minimum distance, and spectral angle mapper (SAM). Maximum likelihood classification is a method for determining a known class of distributions as the maximum (San *et al.*, 2013). It assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood).

Minimum Distance uses the mean vectors for each class and calculates the Euclidean distance from each unknown pixel to the mean vector for each class. The pixels are classified to the nearest class. SAM is a physically based spectral classification that uses an n-Dimension angle to match pixels to training data. This method determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands. This technique, when used on calibrated reflectance data, is relatively insensitive to illumination and albedo effects (Sisodia *et al.*, 2014). Maximum likelihood classification is by far the most common supervised classification method used with remote sensing image data because it is intuitively appealing due to the most probable outcome designation, it is statistically desirable and has been proven to perform well over a range of land cover types (Phiri, 2017).

GIS has offered versatility and a wide range of applications in enhancing wildlife management and conservation such as wildlife tracking for movement and behavioural analysis, wildlife research, ecological monitoring, land cover change analysis and mapping conflict hotspots (Acharrya, 2017). GIS and remote sensing provide reliable tools for spatial analysis of human-elephant conflict patterns which is essential in prioritizing highly prone areas during formulation of mitigation plans (Tripathy *et al.,* 2021). Numerous studies have been conducted on land use and cover changes and the resulting impacts on human-wildlife conflict. For example, in Bangladesh, satellite imagery has been used to monitor land cover changes as well as in Chunati and Fashiakali Wildlife Sanctuaries (Islam*et al.,* 2016; Billah *et al.,* 2021).

In Africa, GIS applications have been robust in conservation including a recent pan-African spatial analysis of HWC, in particular lions and elephants (Di Minin *et al.,* 2021). The study aimed at assessing the potential of high-quality fences for conflict mitigation across the continent. In Ethiopia Landsat imagery was similarly used for classification and monitoring of spatio-temporal patterns of land cover changes between 1977 and 2017 and the implications of these changes for elephant population, distribution and seasonal migration in Babile Elephant Sanctuary (Sintayehu & Kassaw, 2019). At a national level, GIS and remote sensing techniques have been adopted for natural resource management and conservation especially in key biodiversity areas. In the Mara-Serengeti ecosystem to the Mau Forest Complex, GIS has been instrumental in the protection of vulnerable ecosystems through mapping population growth, human encroachment and habitat conversion to enhance sustainability (Magige *et al.,* 2020).

2.8 Participatory Mapping

For effective land use planning, multi-stakeholder participation is inevitable. Participatory mapping has developed to be a present-day spatial planning model that promotes stakeholder involvement as well as providing a channel for participants to contribute their opinions in a simple and understandable graphical format. At the indigenous community level, participatory mapping provides a means to; a) extract local information on resources, b) evaluate how people perceive, regard, and use resources, c) discuss land use issues at a focal point, and d) support decision-making (Mundia, 2015).

Participatory mapping has gained prominence over the years as a tool for community interventions from Participatory Rural Appraisal allowing for improved information exchange between communities and outsiders (Cochrane & Corbett, 2020). International Fund for Agricultural Development (FAD), for example, deployed several participatory mapping tools such as ground or paper sketch and three-dimensional modelling which has facilitated community-based natural resources management and increased adaptive capacity to climate change (Laganda *et al.*, 2013). Community maps are important in that besides displaying geographical features, they also present information usually left out in conventional GIS maps (Mbau, 2013) like indigenous environmental knowledge, cultural heritage and household characteristics (Laganda *et al.*, 2013).

A broad work of literature has recognized the effectiveness of participatory mapping as a mechanism for amplifying community voices and participation in a range of initiatives including advancing community land rights and land use zoning decisions (Stocks, 2003; Parker, 2006; Zhang *et al.*, 2013), improving spatial information for emergency response (Shekhar *et al.*, 2012; Camponovo & Freundschuh, 2014) and climate change communication (Piccolella, 2013). In Kenya participatory mapping has also been used in several ways. In Taita Taveta county of Southern Kenya, Mbau (2013) found that participatory GIS was a useful tool in community land resource mapping as well as enhancing wildlife management by integrating key stakeholders for HWC mitigation strategies. Similarly, Okande (2018) intimated the importance of participatory communication in de-escalating HWC in Transmara, Narok County. Participatory mapping has also been applied in Koibatek Forest Complex with reported positive results in creating a sense of ownership of the forest within the community thus enhancing its conservation (Trivellini, 2018). In Chyulu Hills, the community was involved in identifying and mapping severely degraded areas for potential restoration activities which led to the implementation of a restoration project targeting 11,000 hectares (Ajamah, 2021).

2.9 Human Elephant Conflict and Climate Smart Landscapes

Land use characterizes the leading climate mitigation potential for many countries since approximately a third of global greenhouse gas emissions originate from land use practices (Smith *et al.,* 2007). Pressures from wide land use and degradation, variations in frequency and magnitude of extreme phenomena and interactions with other factors impede on the sustainability of terrestrial ecosystems (Kupika *et al.,* 2018). In particular, elephants' home range requirements make them susceptible to climate change effects that include high temperatures and dwindling water supplies and food resources. HEC has the potential of proliferation due to the impacts of climate stressors on people and subsequently causing livelihood changes. As such, community choices and human tolerance will shape the success of conservation in the Amboseli Ecosystem (Boult *et al.*, 2019).

The two key conservation concerns for African drylands include habitat damage or deterioration and fragmentation, mostly due to cultivation, production of charcoal, as well as infrastructural expansion. A crucial interrogation for their management is how such lands can preserve their vital ecosystem services and functions, while concurrently enhancing resilient incomes for communities (Githiru *et al.* 2017).Undeniably, with intensifying permanent agriculture, human-elephant conflicts seem to be growing in various African bionetworks as the cropland interaction with elephant range increases (King *et al.,* 2017).

In climate-smart landscapes, that is, those that at the same time support climate, conservation and agriculture purposes (Scherr *et al.,* 2012), wildlife barely takes focus. In essence, there is hardly any mention of human wildlife conflicts and their part in determining land use results in these human–natural biomes and landscapes (Minang *et al.,* 2015). Key components of climate-smart landscapes include protection of natural habitats for biodiversity conservation, restoration of degraded watersheds and rangelands, enrichment of carbon within the soil, farming with perennials and employment of climate-tolerant livestock systems (Githiru *et al.*, 2017). Although climate-smart landscapes are highlighted as where wildlife territories or migration routes are preserved in an otherwise agronomic matrix, there is little mention of the negative influence HWCs have on such diverse landscape objectives. This study will illuminate the extent to which HECs influence integrated landscapes and hence the livelihoods of local communities. For elephants, there are numerous financial and social losses to local communities connected with living adjacent to them. Prominent among these are economic (mainly agricultural-related) losses, health and sometimes death.

2.10 Knowledge Gap

There exist numerous studies on human wildlife conflict in Amboseli Ecosystem as a whole. Little research work on individual group ranches pertaining to the extent of land use changes and socio-economic dynamics as underlying factors for HEC has been reported. Imbirikani Group Ranch has received little consideration in the documentation of these factors and the resultant trends in HEC. This is despite the Imbirikani Land Use Plan that was documented in 2017 to curb the spiraling land subdivision as well as the consequential impediments to wildlife conservation.

HEC cases are inherently unique for each group ranch as well as each household and thus effort should be made to detail this information for planning interventions. This is attributed to the fact that HECs affect people's livelihood in different ways depending on the economic and socioeconomic costs related with the destruction leading to detrimental repercussions to elephant conservation. The community, along with Non-Profit Organizations in the Amboseli Ecosystem, is constantly coming up with creative strategies and innovations to bar elephants from human settlements and farms. This is credited to the adoption of a community-based natural resource management method. There is, therefore, a need to continually update data on HEC, in light of such changes that have a bearing on the perception of the local community on conservation.

In addition, Imbirikani serves as a critical drought refuge for the elephant population in Amboseli Ecosystem as they migrate to Chyulu National Park and Tsavo Ecosystem. There has been a growing interest over the area by conservationists as it also stands as one of the least subdivided group ranches. Involvement of the community in the assessment of LULCC has been minimal which has undermined long-term conservation planning. To this end, it is important to evaluate the community's perception/ knowledge of the prevailing resource changes and the associated HEC dynamics. This study attempts to elucidate the nature and extent of HEC in light of changes in land use/cover as well as community perceptions and attitudes to improve land use planning as well as elephant conservation in Imbirikani.

CHAPTER THREE: MATERIALS AND METHODS

Study Area

Imbirikani Group Ranch, stands within 2°22 S and 2°44 S, and 37°24 E and 37°52 E. The ranch is under communal ownership by registered members and not subdivided. Imbirikani Group Ranch is one of the remaining communal land holdings within the Maasai Amboseli Ecosystem in the largely semi-arid Kajiado County.

The Group Ranch, which measures 1,352.2 Km^2, is adjoined to the South by the now sub-divided Kimana Group Ranch, Olgulului and Eselengei Ranches to the West, the Kaputei community to the North, Kuku Group Ranch Southwards and the Chyulu National Park Eastwards. Imbirikani was the second most expansive of the communal group ranches formed in Kajiado district in the 1970s (*Imbirikani Grazing Plan*, 2017). Figure 3.1 below shows the study area in the Amboseli-Chyulu Ecosystem.

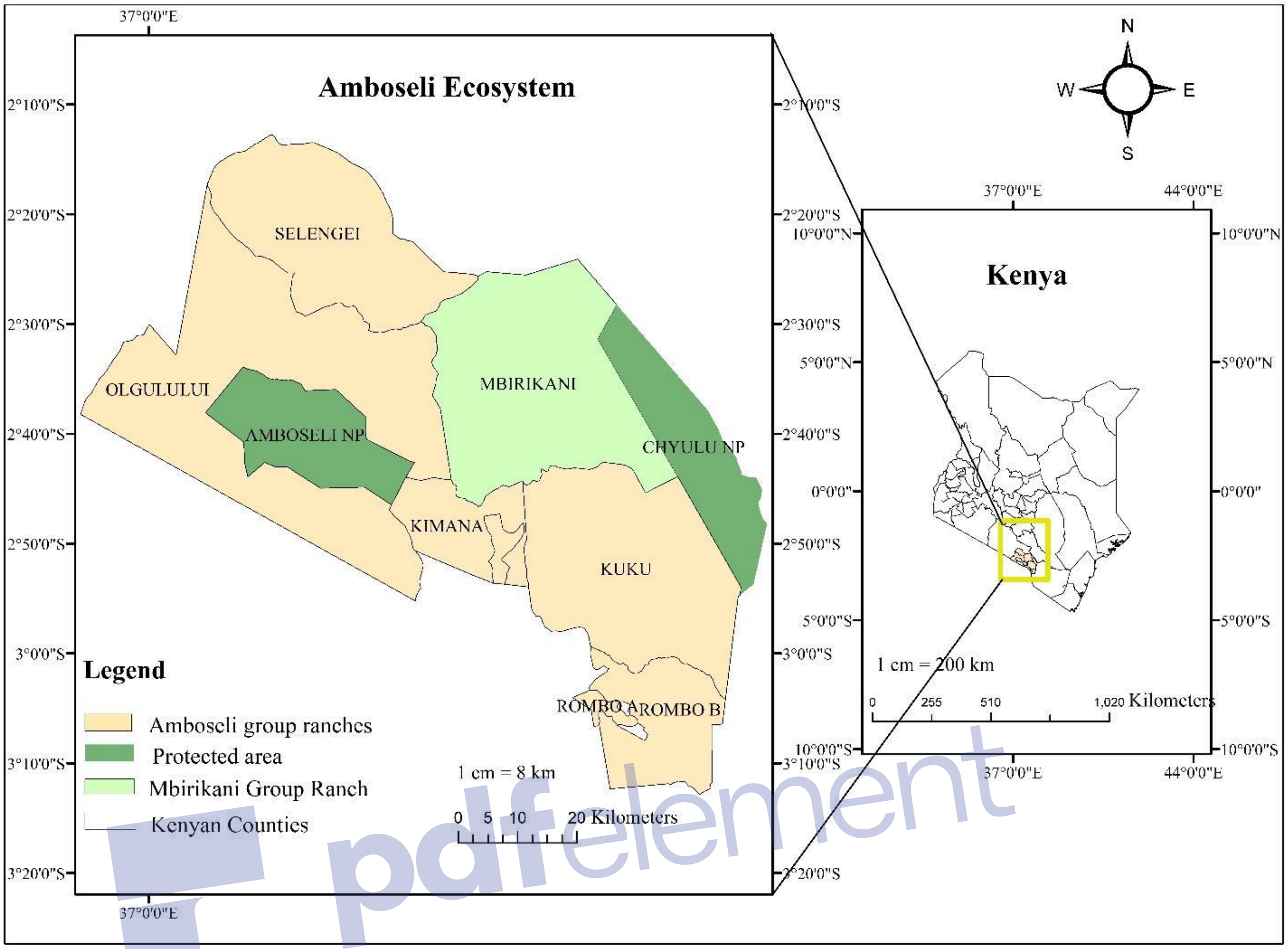

Figure 3. 1 Map of the Amboseli Ecosystem showing Imbirikani Group Ranch

3.2 Biophysical aspects of study area

3.2.1 Climate

3.2.1.1 Rainfall

Imbirikani Group Ranch is a semi-arid area, categorized into agro-climatic zones 4 and 5 (Groom, 2005). The frequent volatile and intermittent droughts make conventional farming hard (Campbell *et al*., 2003). Rainfall exhibits bimodal patterns where the long-wet season occurs between March and May and the short-wet season between October and December. It ranges between 350mm and 500 mm per year depending on the elevation. The high elevation regions of Chyulu Hills get roughly 800 millimeters of rain annually (Campbell *et al.*, 2003). On the other hand, the lowland regions only receive 500 mm of annual rainfall owing to the rain-shadow influence from the Chyulu Hills and Mt. Kilimanjaro (Ntiati, 2002).

3.2.1.2 Temperature

Imbirikani is typified by a warm and dry climate and the temperatures range from 14 degrees celsius to 30 degrees celsius with two rainy spells in the average of 350 to 500 millimeters yearly (Kioko *et al*., 2012).

3.2.2 Soils

The soil of the area changes with the altitude. The soils of Chyulu Hills are volcanic in nature and rich enough for woodland vegetation to thrive. The lower altitude areas have complexes at the base and alluvial soils in the marshy areas and swamps. There are several soils across the Ecosystem including Cambisols, Luvisols, Volcanics, Pleistocene Volcanics, Saline and Sodic Lacustrine. The Pleistocene volcanic are located at the foot of Mt. Kilimanjaro which supports maize production (BurnSilver, 2009). A sequence of all-year-round swamps are sustained by below ground aquifers from the Kilimanjaro and the run-off during wet seasons within the ecosystem (Mose *et al.* 2013).

3.2.3 Flora

The community of Imbirikani relies on the rangelands for their livelihoods. Three types of forest are found in this rangeland i.e. lava, dryland and cloud forest. The permanent water sources occur rarely and are limited to a small number of swamps, the Kikarangot River which runs laterally along the southern edge of the ranch in addition to a water pipeline in the western quarter of the ranch running south to north. The ranch is a dry woodland savannah dominated by *Acacia xanthophloea*, *Acacia tortilis*, *Balanites aegyptiaca*, *Acacia drepanolobium*, *Acacia mellifera*, *Commiphora* sp and *Eragrostis superba*. This type of vegetation promotes the pastoralist regime of the indigenous Maasai community in addition to a broad range of savannah wildlife species, which forms the keystone of tourist attractions in the ecosystem (Amboseli Ecosystem Management Plan, 2018).

3.2.4 Fauna

The Amboseli ecosystem boasts of a wholesome birdlife, with more than 400 species documented, 40 of which are fowls of prey. Globally, the ecosystem has endangered bird species such as Lesser Kestrel (*Falco naumanni*), restricted-range ones found primarily in a very narrow range like the Taveta golden weaver (*Ploceus castaneiceps*), others that inhabit only a precise type of vegetation like the Grosbeak weaver (*Amblyospiza albifrons*), as well as regionally endangered bird species like the Martial eagles (*Polemaetus bellicosus*). Evidently, the avian life is varied due to the different habitats (Amboseli Ecosystem Management Plan, 2018).

Portions of Imbirikani offer an essential wet season refuge area for massive numbers of herbivores from Amboseli National Park and Tsavo West National Park plus the surrounding ranches (Groom and Harris, 2008). Imbirikani provides an important dispersal area to wild animals including elephant (*Loxodonta africana africana*), cheetah (*Acinonyx jubatus*), lion (*Panthera leo*), buffalo (*syncerus caffer*), leopard (*Panthera pardus*), giraffe (*Giraffa Camelopordalis*), impala (*Aepyceros melampus*), gazelle (*Eudorcas thomsonii*), , jackal (*Canis aureus*) and hyena (*Crocuta crocuta*) (KWCA, 2018).

3.2.5 Demographic aspects

The human population of Imbirikani has risen speedily from the time when it commenced in 1981. Membership within the group ranch has grown to 4,585 members in 2001 from 922 in 1981 (Campbell *et al.*, 2003). In total, the resident population is approximately 25,000 people in the ranch with there being 11,500 households (KNBS, 2019). Additionally, the average human population density for Loitoktok District where Imbirikani lies, is 43 people per square kilometer (Githaiga *et al.*, 2003). Similarly, the Loitoktok population is rapidly increasing owing partially to huge immigrants' numbers into the group ranch who also reside within Imbirikani, mainly of Kikuyu and Kamba communities in Kenya as well as Tanzanian communities (Ntiati, 2002). The individuals in this area are principally Maasai predominantly practicing pastoralism and their livelihoods are founded largely on the natural resource base (Campbell *et al.*, 2003) with some 60,000 to 90,000 heads of livestock.

3.2.6 Livelihoods

The community in Imbirikani is predominantly the Ilkisongo Maasai. They rely primarily on pastoralism for sustenance. Permanent water sources are scarce while rainfall patterns are erratic. These conditions, in turn, make it hard for the local communities to create income from other avenues besides pastoralism. They rear a diverse herd of livestock including indigenous, sometimes improved cattle breeds, goats and sheep.

Tourism has had a growing bearing on the livelihoods of the community on account of the Amboseli National Park. Several lodges, such as the Ol donyo Wuas and Satao Elerai Lodges have sprung up due to the ballooning demand for accommodation by tourists in Imbirikani. In addition, the beading industry in the area, a traditional practice the Maasai are famed for, has benefited grossly from the tourism activities. The Amboseli management advocates for cultural tourism and keeps a list of cultural bomas that tourists will visit besides taking game drives. In Imbirikani Group Ranch, some of these bomas include Siana and Osiram cultural bomas. These are women-led manyattas founded for the primary purpose of empowering local women economically. From the proceeds, the women are able to buy livestock, educate their children and even practice small scale farming.

Similarly, following the infiltration of the ranch by non-Maasai communities, agriculture has emerged as an important source of livelihood with most farmers practicing horticulture along the piped water system. Common horticultural crops are tomatoes (*Solanum lycopersicum*), water melon (*Citrullus lanatus*), capsicum (*Capsicum annuum*) and onions (*Allium cepa*).

The presence of non-governmental agencies (like Big Life Foundation, Born Free Foundation, Amboseli Conservation Program and Amboseli Ecosystem Trust) in the area has provided job opportunities for the local community. This is a case attributed to the adoption of community-based conservation. Imbirikani members serve mainly as game scouts, rangers, forestry personnel, radio operators. The lodges and agencies pay conservation fees as well as land rents to the group ranch committee in addition to financing education for high school and tertiary level students. They also provide learning institutions with resources and remunerate teachers' salaries.

A thriving trade center has developed in Imbirikani town. Retailers sell all kinds of household items and foodstuffs. Bio-enterprises including medicinal plants, honey production and snake venom production likewise play a great role in supporting community incomes (Njuguna, 2017).

3.3 Methodology

This study employed a combination of satellite imagery, participatory mapping and questionnaire data to evaluate the links between land use and cover changes and human elephant conflicts. Remote sensing, GIS, qualitative and observational techniques were applied.

3.3.1 Conceptual Framework

This study sought to evaluate land use and cover change as a driving factor for human elephant conflicts. It also sought to understand the nature and extent of human elephant conflicts as well as assessing the perceptions of local communities towards their coexistence with elephants. A conceptual framework is defined as a system of inter relationships of variables in a phenomenon under study. In addition, it is also an assortment of interrelated thoughts that guides the study and controls what variables will be investigated and relationships to be analyzed (Esiromo, 2012). The illustrated conceptual framework diagram in Figure 3.2 below demonstrates the manner in which the independent variables (elephant variables and anthropogenic or human variables) play a role in influencing the dependent variable (human elephant conflict).

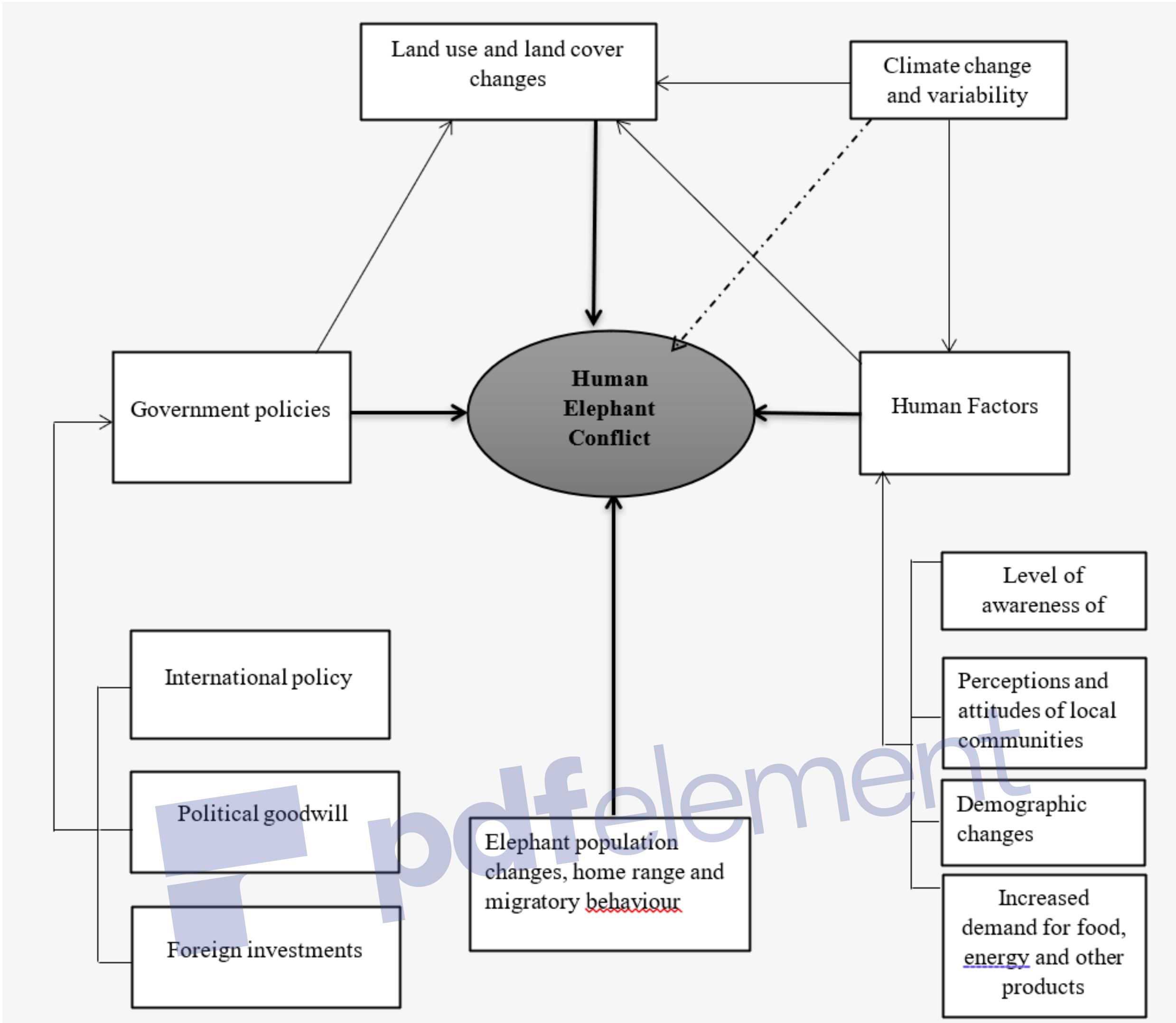

Figure 3. 2 Conceptual framework showing interlinkages between dependent and independent variables in the study.

3.3.2 Assessment of land use and cover changes

3.3.2.1 Conventional GIS

GIS refers to a digital system for capturing, saving, probing, analyzing, and presenting geospatial data. This geospatial data describes equally the location and characteristics of a spatial feature (Chang, 2016). The use of remotely sensed data has enabled studies on land cover change possible and less time-consuming, at reduced cost as well as improved accuracy in connection to GIS which provides an ideal platform for data exploration, update and revival/recovery (Karsidi, 2004).

To analyze LULCCs, maps of these changes in the area of study were created from Landsat TM imagery for the period from 1981 when the inception of Imbirikani Group Ranch occurred to 2019. Data was acquired from Landsat 5 MSS (Multispectral Scanner) for 1981, Landsat 7 ETM+ (Enhanced Thematic Mapper) for 1999 and Landsat 8 OLI (Operational Land Imager) for 2013 and 2019.The raw Landsat images were acquired from the USGS Earth Explorer website. The images coincided with the dry season to ensure a cloud cover of less than 20 percent. Ancillary data for boundary shapefiles of Imbirikani Group Ranch were acquired from Big Life Foundation. The satellite images were clipped using the polygon shapefiles for boundary demarcation of the study area. Table 3.1 below shows the features of the satellite data. Figure 3.3 shows a step-by-step flowchart of the methods used.

Table 3. 1: Characteristics of satellite imagery used for land use and cover analysis.

Satellite	**Year**	**Spectral band**	**Path and row**	**Date of acquisition**	**Resolution in metres**
Landsat 5 MSS	1981	4,3,2	167/062 168/062	02/18/1981	30
Landsat 7 ETM+	1999	4,3,2	167/062 168/062	10/25/1999	30
Landsat 8 OLI	2013	5,4,3	168/061 168/062	08/06/2013	30
Landsat 8 OLI	2019	5,4,3	167/062 168/062	09/22/2019	30

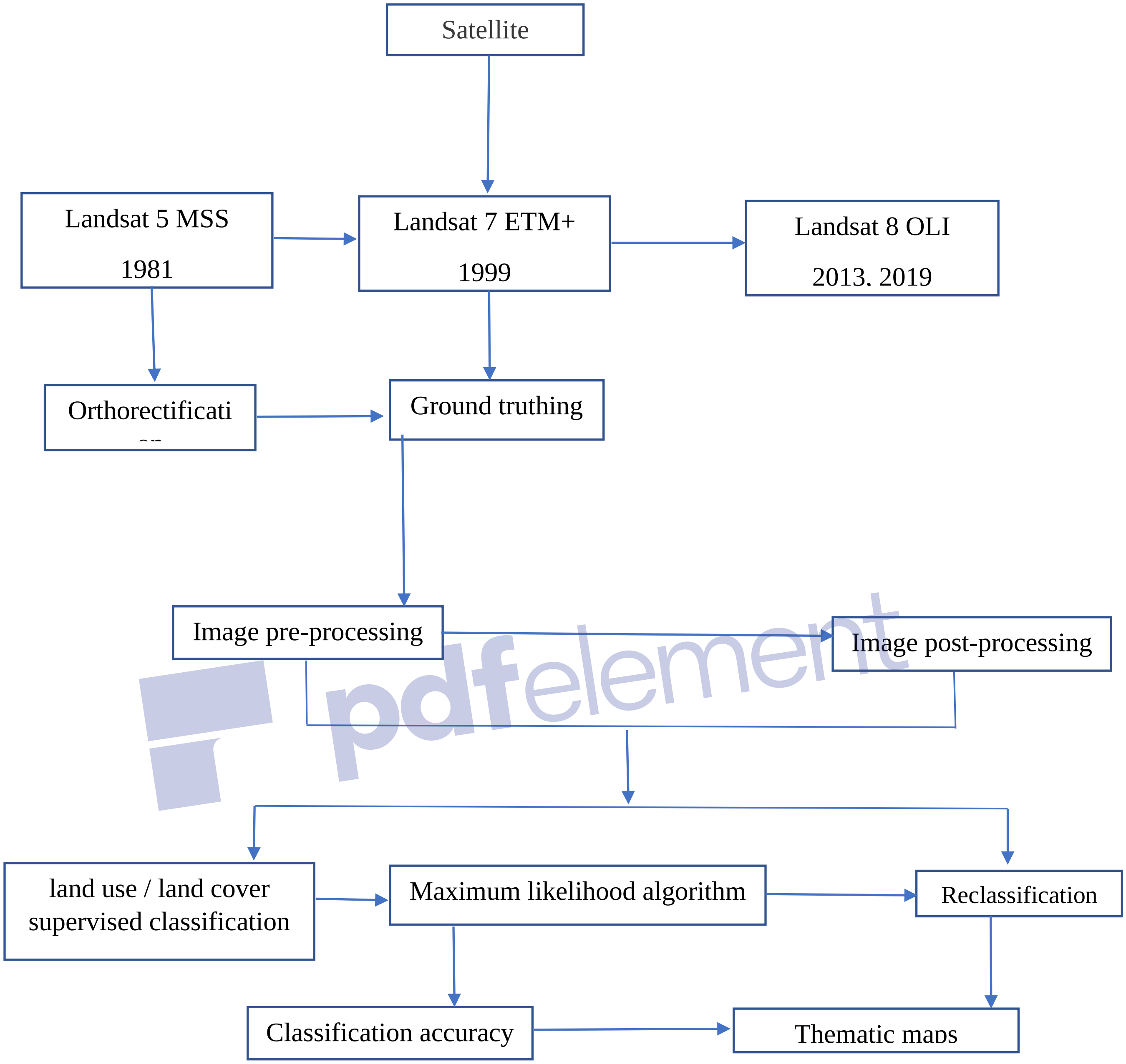

Figure 3. 3 Diagrammatic representation of land use classification

GPS points were taken within this area for every single land use and cover type for geo-referencing as ground truthing data. Supervised classification for the various land use types were then carried out using maximum likelihood classification (MLC). The MLC algorithm was selected based on its ability to considerably reduce data necessities while also providing comprehensive information from images (Hassan 2017; Billah, 2021). Classification denotes the process of acquiring information from remotely sensed imageries. These images were then developed into inferred maps of several land use and cover types (Waithaka, 2010). Land use and cover maps were generated to display the changes analyzed between the study periods. During the interval periods, changes in natural vegetation cover, water resources, infrastructure, urban centers, settlements, cultivated fields and bareland were established. The Accuracy Assessment Plugin of QGIS was also used to generate error (or confusion) matrices computation for the remotely sensed data.

3.3.3 Nature and extent of human elephant conflicts

This objective was achieved by use of qualitative and descriptive research design. Multistage sampling approach was used to select the study sites and respondents. In the first stage, preliminary surveys were carried out to acquaint with the community and the area of study. The target populations for this study were the residents of Imbirikani Group Ranch. Data on the population of study was collected from the Kenya National Bureau of Statistics (KNBS).

A multi-stage sampling design was carried out. In the first stage Imbirikani Group Ranch was to divided into administrative units based on locations then into sub-locations. Samples were then drawn from the 7 sub-locations: Imbirikani, Isinet, Oltisika, Oldonyo Wuas, Ichalai, Inkoroshwa, Orng'oswa. Within the sub-locations stratified random sampling was applied. This sampling method follows when a population out of which a sample of interest is to be selected does not comprise a homogeneous collection, for one to obtain a characteristic or representative sample. When using stratified sampling the universal set is distributed into several sub-populations referred to as strata which are discretely more homogeneous. The items from each stratum are then picked to comprise a sample (Kothari, 2006).

Imbirikani Group Ranch was divided into strata based on the 7 sub-locations. The sample size for each sub-location was determined depending on the number of households. Three transects were used in each of the sublocations. Systematic sampling methods of households were then carried out along transects with 300m intervals. The first household to be sampled was picked at random while the next households were selected systematically. Selection of the households in this way ensured adequate and unbiased representation of the target population. The transects were also used to make observations for elephant crop raids or property damage. Following Mugenda and Mugenda (2003) when the universal set of elements is more than 10,000 the sample size (denoted as 'n') was derived in equation 1:

$$n_o = \frac{(z)^2 * pq}{(d)^2} = \frac{(1.65)^2 * 0.5 * 0.5}{(0.05)^2} = 272 \text{..............................equation 1}$$

Where:

n= sample size that is desired

z=standard normal deviation at the preferred confidence level (90%).

p= the quantity in the target universal population projected to have the characteristics under measure.

q =1-p

d=level of statistical significance set

As stated by Cochran (1977) and Bartlett (2001), since this sample size surpasses 5 percent of the population a correction formula was used to determine the final sample size in equation 2:

$$n_1 = \frac{n_o}{1+n_o/\text{population}}$$

n_o=required samplesize

n_1=final samplesize

$$n_1 = \frac{272}{1+272/11,500} = 267 \text{ households ....equation 2}$$

Thus, the expected sample size was 267 (equations 3 to 9). In accordance with Mugenda and Mugenda (2003), if the selected sample size is big enough, any sample that is greater than or equal to 30 is expected to be representative enough of the population under study. To adjust for non-response, a total of 320 households were interviewed. In addition, according to Kothari (2006), a formula of proportional allotment is followed whereby the quantities of the samples from the individual strata are made proportionate to the population sizes of the strata where:

$P_i = n(N_i/N)$

P_i = the quantity of the population in stratum i

n = the total sample size

N= population

Given the population, N_i for the strata is:

Imbirikani(N_1)- 1,535

Isinet (N_2)- 1,442

Oltisika (N_3)- 1,211

Oldonyo Wuas (N_4)- 2,075

Ichalai (N_5)- 1,842

Inkoroshwa (N_6) – 1,750

Or ng'oswa (N_7)- 1,643

and the total number of households in Imbirikani Group Ranch is 11,500. Then the proportional allocation for each strata was:

P_1= 1535/11500(320) = 43 …………………………………….equation 3

P_2= 1442/11500(320) = 40 …………………………………….equation 4

P_3= 1211/11500(320) = 34 …………………………………….equation 5

P_4 =2075/11500(320) = 58 …………………………………….equation 6

P_5 = 1844/11500(320) = 51 …………………………………….equation 7

P_6 = 1750/11500 (320) = 49…………………………………….equation 8

$P_7 = 1643/11500\ (320) = 46$ ……………………………………equation 9

Total =321

The interviews were administered to the household heads who have lived in the area for the period under study. In the event they were unavailable, any other senior member of the household was interviewed. Data was collected by means of semi-structured questionnaires purposed for the household. Information to be captured included land use practices, presence of wild animals on the various land use types, types of HEC experienced, season of elephant raids, size of farm affected and affected area of the farm, crop types affected, estimated losses of crop raiding, proximity to the PA (protected area) and awareness of respondents on population change patterns. Moreover, the mitigation practices adopted by the community were also documented. Data from the questionnaires was combined with field visits and observations of elephant damage on farms and property calculated per household.

3.3.4 Perceptions of the local community towards human-elephant coexistence

This data was collected using household questionnaires and focus group discussions. The survey questionnaire included fixed response questions, that is, “yes” or “no” questions as well as five-point Likert scale questions ranging from “strongly agree” to “strongly disagree”. These questions were followed up by open ended explanatory questions to understand prevailing attitudes. Data on perceptions of the community towards interactions with elephants were described according to how members of the community interpret encounters with elephants as influenced by factors such as age, attitudes, experience with wildlife and location (Mbau, 2013). Overall perception and attitudes about elephants, benefits received from elephant conservation and rate of response to conflicts by government authorities was also documented.

Participatory resource mapping was done in Imbirikani Group Ranch to capture local knowledge on resource changes over time. Participatory mapping is a great tool that increases community contribution and provides a way for participants to convey their ideas in an easily comprehensible visual arrangement. It helps provide facts on how populations identify, value, and consume resources while acting as a focal point for discussions on land use issues (Mundia, 2015). A focus group discussion of 10 members, comprising the youth, elderly women and men, was conducted (Mundia, 2015). This involved 10 participants with 2 elderly (above 70years) people (male and female), 2 middle aged men (above 55 years), 2 middle aged women (above 55 years), 2 young women and 2 young men above 18 years. The participants were involved in sketching mental maps of resource changes over different times during the period of study in Imbirikani. This helped to assess the spatio-temporal resource changes over time with regards to how the community perceived them. The time periods were divided into 1981, 1996 and 2020. Physical features like schools, roads, springs, and boreholes were used as reference points to examine the extent of various land use and land cover types for the different time periods. A discussion was then held on how the changes in resources over time have contributed to human-elephant conflicts as perceived by the community. The maps were uploaded into QGIS software where they were georeferenced.

3.3.5 Secondary data

Census data for Imbirikani for the years 1989, 1999, 2009 and 2019 was collected from the Kenya National Bureau of Statistics library. This data was used to establish any relationship between human population and land use changes. Data on elephant census was also obtained from KWS from 2000 to 2018. Human-elephant conflict data was retrieved from Big Life Foundation and KWS from 2011 to 2019. Reports of HEC occurrences for individual farmers as reported were obtained to show trends in HEC within Imbirikani. This data was reinforced with information collected from the community through interviews pertaining to elephant conflict events.

3.4 Data analysis

Data for objective one on land use and cover changes was analysed as follows: Satellite images were subjected to supervised classification using maximum likelihood algorithm. All scenes at the USGS website are level 1 terrain corrected, georeferenced products (L1T) and no georectification was required. Preprocessing included atmospheric correction through conversion to reflectance values by dark object subtraction (DOS) 1 atmospheric correction method and pansharpening using the Semi-Automatic Classification plugin (SCP) in QGIS (Congedo, 2018). The composite of bands 4, 3, 2 and 5, 4, 3 were used to classify different land uses. The study area was covered by two Landsat scenes across the time series used. Thus, the satellite images were mosaicked into one raster for each year under study. Estimated land area cover in square kilometres was obtained for the different land use classifications. Percentages of land area were computed using Ms Excel to make comparisons.

To assess whether independent variables under study had a predictive impact on HEC in Imbirikani for the second objective, a logistic regression analysis was performed using R version 4.03. The analysis inquired whether residents had experienced any elephant attacks against hypothesized predictor variables including crops preferably destroyed by elephants, seasons when they experienced these attacks (dry season/wet season) and level of crop maturity during the attacks. The response variable was a binary (presence or absence) event. That is, HEC occurrence or no occurrence. The logistic regression function provided the probability of HEC occurrence as a function of the explanatory variables. In other words, HEC occurrence as a function of seasons, type of crop and growth stage of crops.

Objective three data was also analyzed using R software. Questionnaire results were summarized and cross-tabulated for analyses and interpretation using Ms Excel and R version. Pearson's Chi-square statistics were computed to test relationships between categorical variables. Independent variables included age, education level, location, type of livelihood and previous experiences with elephants. These variables were used to test for relationships with perceptions and attitudes toward elephant conservation.

CHAPTER FOUR: RESULTS

This chapter presents the findings of the analyses on land use and land cover changes between 1981 and 2019. It also describes the results from socio-economic data depicting the nature and extent of HEC as well as the human perceptions and attitudes toward human- elephant interactions in Imbirikani.

4.1 Land use and land cover changes in Imbirikani Group Ranch

4.1.1 Multi-temporal thematic maps

The supervised classification captured six classes that were categorized as bareland, grassland, shrubland, woodland, irrigated farmland and rainfed farmland as demonstrated in figure 4.1 below.

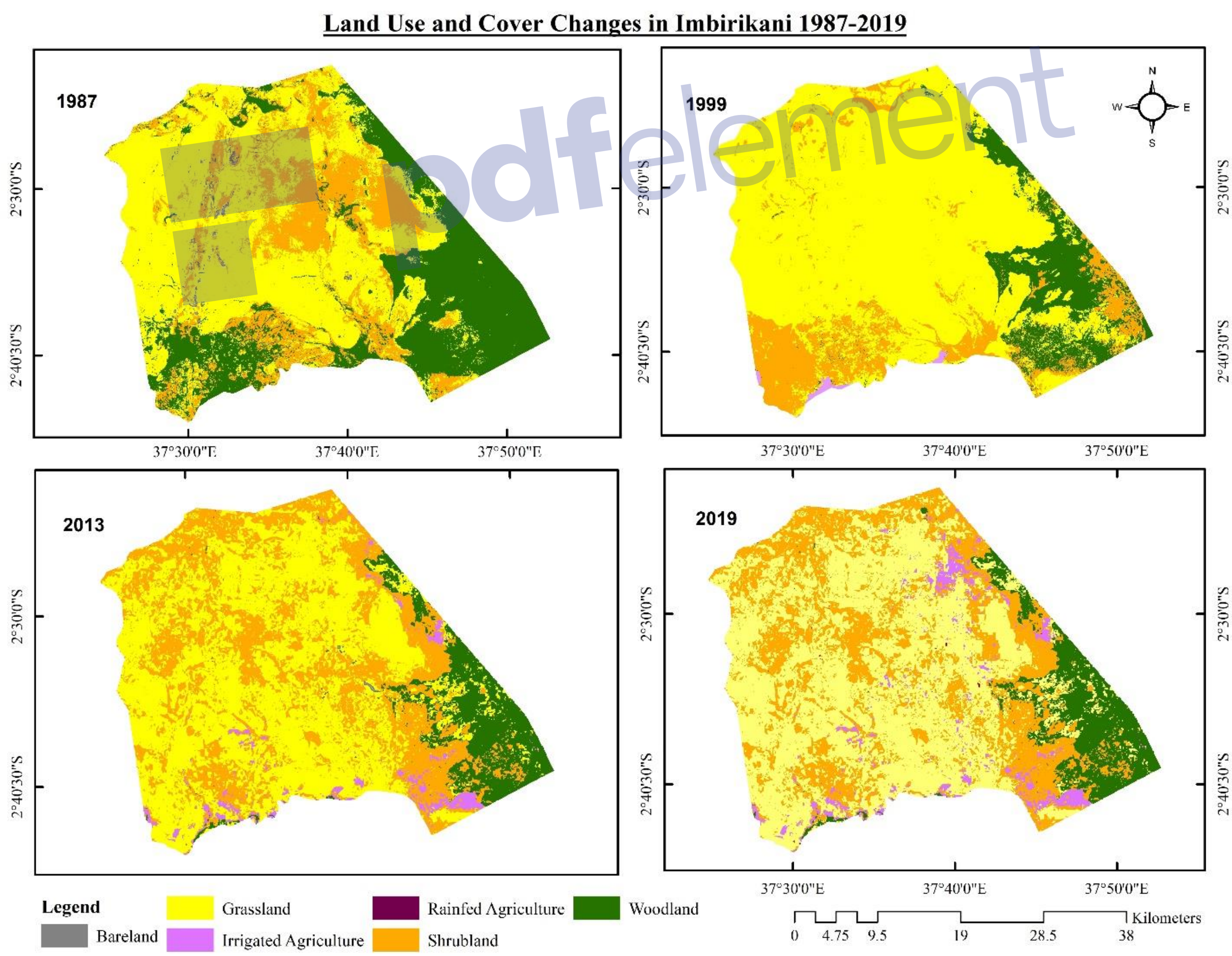

Figure 4. 1: Imbirikani group ranch land use and cover a)1987, b)1999, c)2013 and d)2019

In 1987 four classes appear in the classification: bareland, grassland, shrubland and woodland. This is also the case for the year 1999. However, in 1999, a few pixels of rainfed agriculture appear but their area was not computed owing to the negligible area under rainfed agriculture. In the years 2013 and 2019, all the classes are clearly visible. Throughout the 4 periods, shrublands remained the most dominant, followed by grasslands, woodland then bareland. There was a general decrease in shrubland, grassland and woodland over the years while bareland and farmlands increased as shown in Table 4.1. Table 4.2.

Table 4. 1: Land cover area (sq. km.) 1981-2019

	1987	1999	2013	2019
Bareland	6.511	15.99	54.25	21.47
Grassland	201.83	294.66	330.24	401.52
Irrigated Farmland	0	0	111.86	166.79
Rainfed Farmland	0	0	1.057	4.6
Shrubland	661.50	787.65	567.10	428.02
Woodland	468.13	366.93	238.33	217.22

Table 4. 2: Land Cover Change 1981-2019 (%)

	1987- 1999	1999- 2013	2013- 2019	1987- 2019
Bareland	3.7	2.23	-9.93	16.08
Grassland	-3.51	-1.68	27.81	7.51
Irrigated Farmland	0	8.37	4.11	12.48
Rainfed Farmland	0	0.34	0.26	0.07
Shrubland	9.63	-16.5	-17.88	-24.95
Woodland	-2.26	-9.64	-3.82	-11.2

The analysis revealed changes in all land cover types except rainfed agriculture. Shrublands experienced the most significant change with a steady overall decrease of 24.95% over the period 1987 to 2019. There was a 9.63% increase in shrublands between 1987 and 1999. The area declined steadily between 1999 and 2019 with a change of 16.5% followed by 17.88%. Bareland increased by 16% from 1981 to 2019. Grassland increased by 7.51% between 1981 and 2019.

However, the area declined by 3.51% between 1981 and 1999 and declined by a further 1.68% in the subsequent period between 1999 and 2013 before increasing by 27.81% in 2019. Irrigated agriculture showed substantial changes with a cumulative increase of 12.48% between 1987 and 2019. The greatest increase was detected between 1999 and 2013 with a 8.37% change followed by a 4.11% change between 2013 and 2019. Overall, rainfed farmlands showed no change. There was a 0.34% increase between 1999 and 2013, before increasing by 0.26% between 2013 and 2019. Woodlands also experienced a decline over the 32-year period with a general decrease of 11.2%. The period between 1987 and 1999 shows a 2.26% decrease in woodland cover. The following periods also display a decline in woodland cover with the 1999-2013 period witnessing the highest decline of 9.64% and a 3.82% decrease between 2013 and 2019.

4.1.2 Land cover change detection

4.1.2.1 Land cover change detection between 1987 and 1999

In this period, there was significant loss of shrubland to other classes with grassland being the largest gaining class with 136.52 sq. km. Grasslands were mostly lost to shrubland as well, with 153.96 sq. km lost to shrublands. Bareland did not lose much to other classes except grasslands which gained 5.96 sq. km. On the other hand, woodland lost most of its area to shrublands by 158.92 sq. km.

Table 4. 3 Land cover change detection cross-tabulation 1987-1999 (sq. km.)

Land Cover	Bareland	Grassland	Shrubland	Woodland
Bareland	0.01	5.96	0.09	0.45
Grassland	21.39	92.96	153.96	33.16
Shrubland	23.53	136.52	474.55	26.82
Woodland	11.06	19.17	158.92	177.63

4.1.2.2 Land cover change detection between 1999 and 2013

This period displayed an increased cover by bare land, rainfed agriculture and irrigated agriculture. On the contrary, there was a significant conversion of grassland, shrubland and woodland to other classes. Between 1999 and 2013, areas under bareland remained fairly the same apart from 24.53 sq. km. which were converted to shrubland while 10.01sq. km were converted to woodland. 208.94 sq. km. of shrubland, 94.05 sq. km. of grassland and 34.45 sq. km. of woodland were lost to bareland. Grassland lost to other classes but mostly to shrubland by 112.65 sq. km. Gains in irrigated and rainfed farmland were notably made from grassland, shrubland and woodland. Woodland was mostly transformed into irrigated farmland, followed by bareland, shrubland then grassland and rainfed agriculture as depicted in Table 4.4 below.

Table 4. 4: Land cover change detection cross matrix 1999-2013 (sq. km.)

Land Cover	Bareland	Grassland	Irrigated Farmland	Rainfed Farmland	Shrubland	Woodland
Bareland	16.75	1.45	2.57	0.68	24.53	10.01
Grassland	94.05	18.97	5.93	1.04	112.65	21.97
Shrubland	208.94	7.6	64.11	2.51	406.76	97.58
Woodland	34.45	2.22	39.23	0.42	23.09	138.64

4.1.2.3 Land cover change detection between 2013-2019

The period between 2013 and 2019, as is apparent in Table 4.5, saw marked changes in several classes including grassland, bareland, shrubland and woodland which lost to other classes. Irrigated and rainfed agriculture gained areas from other classes. Areas under grassland were converted to shrubland, bareland and irrigated agriculture, respectively. Shrublands were transformed into grassland, bareland and irrigated agriculture with 317.29 sq. km. lost to these classes in total. Additionally, woodlands lost 143.81 sq. km. to bareland, shrubland, grassland, irrigated agriculture and rainfed agriculture, in that order. There was also a notable gain in area under irrigated agriculture from other classes including bareland, woodland and shrubland.

Table 4. 5: Land cover change detection cross matrix 2013-2019 (sq. km.)

Land cover	Bareland	Grassland	Irrigated Farmland	Rainfed Farmland	Shrubland	Woodland
Bareland	75.15	128	62.14	0.04	38.41	50.43
Grassland	15.77	87.9	8.42	0	20.95	0.2
Irrigated Farmland	4.75	21.15	39.13	0.14	6.76	39.9
Rainfed Farmland	1.23	2.43	0.1	0.18	0.69	0.02
Shrubland	92.68	204.78	19.68	0.15	247.51	2.2
Woodland	43.81	27.52	44.27	0.56	27.65	124.41

4.1.2.4 Land cover change detection between 1987 and 2019

Long term changes for the period 1981 and 2019 revealed significant gains in bareland, rainfed and irrigated agriculture while losses were experienced in grassland, shrubland and woodland.

Grasslands were mostly lost to irrigated agriculture, shrubland, bareland and woodland, respectively with 147.25 sq. km. lost in total. Similarly, 394.09 sq. km. of shrubland were converted to other land cover types. This loss was mainly to grassland, followed by bareland, irrigated farmland and woodland. The most significant loss in woodland occurred from irrigated farmland, bareland, grassland, shrubland and then rainfed farmlands totaling to 179.96 sq. km. area loss. These changes are shown in the table 4.6 below.

Table 4. 6 Land cover change detection cross matrix 1987-2019 (sq. km.)

Land Cover	Bareland	Grassland	Irrigated Farmland	Shrubland	Rainfed Farmland	Woodland
Bareland	5.34	0.98	0.01	0.18	0	0
Grassland	33.59	154.21	69.84	35.25	0.01	8.57
Shrubland	135.72	214.31	22.25	267.21	0.08	21.81
Woodland	46.76	32.27	74.63	25.34	0.96	186.8

Figures 4.2 a) and b) below show the location and extent of agricultural conversion on the wetter areas of Imbirikani in Isinet and Namelok areas respectively in the year 2019.

Figure 4. 2: Irrigated farms in Isinet

Figure 4. 3: Irrigated farms in Namelok

4.1.3 Accuracy Assessment

In the classification process, there were some potential sources of error. First, historical cloud-free satellite image data was difficult to acquire as little long-term land use change analysis studies have been done in the area. Secondly, the area is hilly which has a particular impact on the satellite image pixel value. Nevertheless, the datasets were within the acceptable accuracy range of >75% (Bratic *et al.*, 2018). This shows good classification quality of the model used. Table 4.7 below shows the accuracy assessment results.

Table 4. 7: Confusion matrix for satellite image datasets (%)

Index	**1987**	**1999**	**2013**	**2019**
Overall accuracy	83.31	80.75	90.33	94.5
User's accuracy	84.56	80.48	92.42	93.54
Producer's accuracy	81.6	78.44	89.24	89.98
Allocation disagreement	9.68	12.6	5.09	3.57
Quantity disagreement	4.03	6.99	0.81	0.93

4.2 Nature and extent of human elephant conflicts in Imbirikani Group Ranch

4.2.1 Demographics

There was a successful response rate on this research project where 319 out of 320 households participated. There were more responses from female (53%) house heads compared to the males (47%). The average age distribution was 36 to 55 years with 47% of the respondents with fewer respondents being above the age of 55years. More than half of the respondents had not gone to school, only 13% have secondary level education. People with tertiary level education represented only 10% of the sample. The average number of persons per household was 8 with the biggest household having 36 members. Furthermore, a typical household had 5 children with 4 of them enrolled in school.

4.2.2 Land use practices

Majority of participants own the land they are currently residing in amounting to 97% with only less than 4% being on a lease/rent agreement. Owning land in this context means land that was allocated by the group ranch committee to registered individuals. Across all land ownership choices, most individuals own (as allocated by Imbirikani Group Ranch Committee), lease or rent land sizes of upto 5 acres. More than three quarters of the residents are longtime residents having lived for more than 10 years at their current homesteads. Notably, most individuals (88%) have not subdivided their land. 65% of the residents cited livestock rearing as their main source of livelihood followed closely by crop production. Only 3.4% have a business or formal employment as their main income source. In terms of land use by residents, 82% mentioned livestock production and 70% reported crop production as well. Livestock production was rated the most profitable venture in the area whereas only 25% agreed to benefiting more from crop production exclusively.

4.2.3 Nature and extent of human elephant conflict

Residents in Imbirikani Group Ranch mentioned that they often experience invasions from wild animals into their farms and homesteads. Majority of the residents (69%) reported that elephants are the most prevalent invaders in the area with their opinions towards their interaction with elephants being generally negative.

A total of 88% of respondents agreed to having problems emanating from elephant invasions with crop damage reported by 37% of them. Following closely in rank was damage to water structures and disruption of school going students. Important to note also is that around one in five elephant invasions resulted in human injury and loss of lives (Figure 4.6)

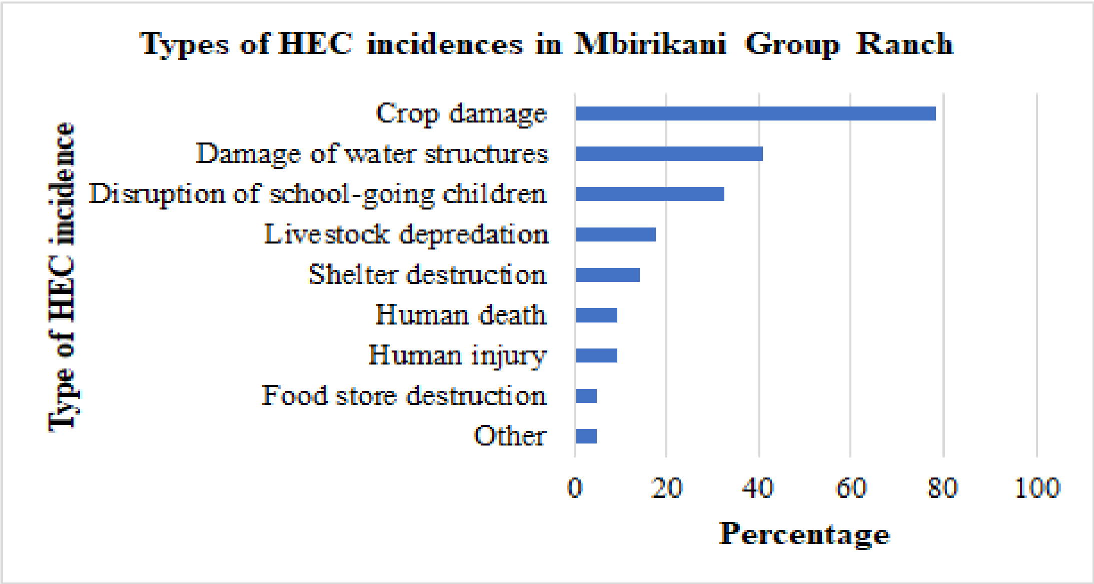

Figure 4. 4: Types of human elephant conflict experienced in Imbirikani Group Ranch.

4.2.4 Farm attributes

39% of the respondents practice livestock production while 35% practice crop production. Notably, most residents preferred grazing their animals in the woodlands, on communal land or range them freely on their farms. Very few people (2%) practiced zero grazing. Among the crops planted, maize (*Zea mays*), tomatoes (*Solanum lycopersicum*) and beans (*Phaseolus vulgaris*) are the top three crops cultivated in the area. Other crops grown include kales (*Brassica oleracea*), capsicum (*Capsicum annuum*), sweet potatoes (*Ipomoea batatas*), spinach (*Spinacia oleracea*), cassava (*Manihot esculenta*), chilli (*Capsicum frutescens*), bananas (*Musa sp*), pumpkin (*Cucurbita sp*) among others. Maize (*Zea mays*) was reported to be the most preferred by elephants by 78% of the respondents followed by tomatoes (*Solanum lycopersicum*) 55%, beans (*Phaseolus vulgaris*) 32%, onions (*Allium cepa*) 25%, watermelons (*Citrullus lanatus*) 13%, cabbage (*Brassica oleracea var. capitata*) 13%, pastures 10% and other crops 9% respectively. Figure 4.7 below represents this data.

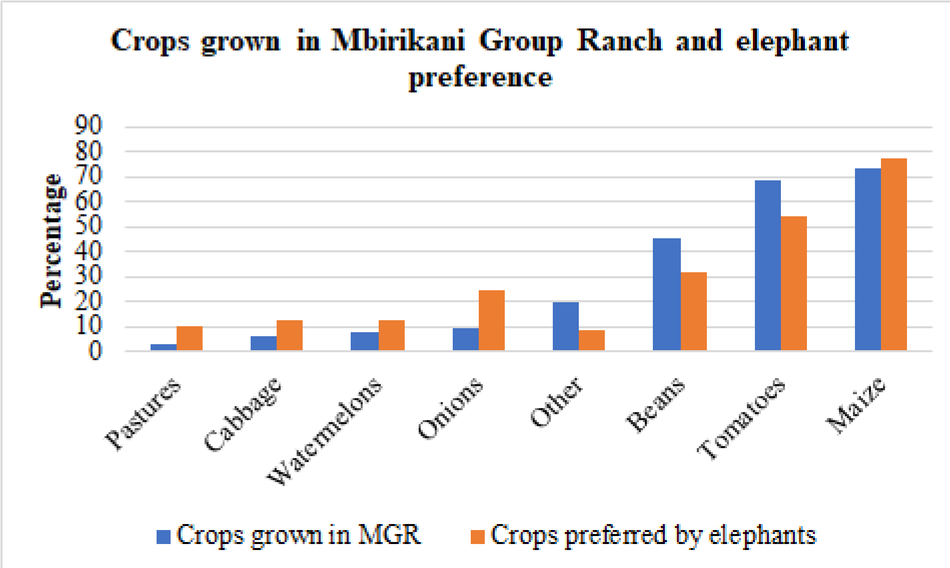

Figure 4. 5: Types of crops grown in Imbirikani Group Ranch and elephant preference

4.2.5 Frequency and severity of elephant invasions

Food store destruction, human death and human injury were the least mentioned forms of HEC while damage to crops, water structures and disruption of school going children were the most frequent. The frequency of each type of HEC within the last one year is presented in Table 4.8. 36.25% of respondents had experienced crop damage over 10 years ago while 26.25% experienced it 2-5 years ago. Of the respondents that had experienced crop raiding incidences, a majority (55%) had such experiences within the last 10 years. The results suggest that crop damage was the most frequent form of HEC.

Majority of the households had not experienced (not applicable) livestock depredation, human death, human injury, as well as destruction of shelters and food stores (Table 4.8). Other HEC incidents that emerged from the interviews included disruption of herding, destruction of indigenous trees, restriction of movement and road accidents.

Table 4. 8a Regularity of human elephant conflict incidences

	Crop damage	Livestock depredation	Human death	Human injury	Shelter destruction	Food store destruction	Damage to Water structures	Disruption of school-going children
This Year (2020)	9.69	3.12	0.94	1.25	4.06	1.88	6.88	0.94
2-5 years ago	26.25	11.25	5	2.81	8.75	4.06	14.69	10
6-10 years ago	7.81	4.69	3.44	2.81	2.81	1.56	7.19	5.31
over 10 years ago	36.25	11.88	7.5	7.81	7.81	6.88	28.75	26.88
Not applicable	8.12	57.19	71.25	73.44	64.69	73.75	30.62	45

Table 4.8b Last experience of HEC incidences

	Crop damage	Livestock depredation	Human death	Human injury	Shelter destruction	Food store destruction	Damage to Water structures	Disruption of school-going children
Once	7.81	10.94	6.56	5.62	6.25	4.06	0.94	1.56
Twice	10.62	5.31	1.56	2.5	3.75	3.75	2.81	4.69
Thrice	3.75	3.44	0.62	1.25	1.88	0.31	3.12	0.94
Four times	3.75	1.25	0.62	0.94	2.5	0.62	2.19	1.88
More than four times	55	10.31	5.62	5.62	10	6.56	46.56	32.5
Never	19.06	68.75	85	85.31	75.62	84.69	44.38	58.44

The respondents reported that most HEC incidences began after they took on farming as a livelihood option. After a farm invasion event, 33% of the participants reported to have lost 50% of their farm produce, 31% experienced complete loss (100%) of their produce, 15% lost nothing at all, 11% lost 30% while 10% estimated an 80% loss of their yields.

4.2.6 Seasonality of attacks

To determine whether seasons had any influence on HEC occurrences, respondents were queried on when these incidences frequently occurred, whether the dry or wet season, using a five- point Likert scale which was collapsed into a three- point scale during analysis for better representation. 92.19% reported invasions occurred during the dry season while 34.69% reported invasions in the wet season. 42.5% disagreed that elephants frequent during the wet season. With regards to the time of day when HEC incidents occur, almost all (96.56%) respondents conveyed that elephant attack in the night. Additionally, the results revealed that elephants will normally attack when the crops are mature as reported by 90% of the research participants.

4.2.7 Cost implications of human elephant conflict

Farmers experienced great losses to elephant invasion. Estimated total costs of these losses by the respondents during the survey was reported to amount to Kenyan shillings 39,583,810 in total in the year 2019. The highest amount of loss was experienced by tomato farmers followed by maize (*Zea mays*), beans (*Phaseolus vulgaris*), onions (*Allium cepa*) and pastures as illustrated in Table 4.9. Economic losses were also experienced through damage of assets, human injury and loss of human life. While these losses were not of greater magnitude in comparison to crop damage, respondents indicated losses of over Kenyan shillings 50,000 at a household level as shown in table 4.10.

Table 4. 9: Crop losses experienced from depredation by elephants

Type of crop	**Quantity destroyed**	**Market value per unit in USD (2019)**	**Total amount in USD**
Tomatoes	9145.5 (90kg) crates	25	228,637.50
Maize	3875 (90kg) bags	30	116,250.00
Beans	829 (90kg) bags	25	20,725.00
Onions	952 (20kg) nets	17	16,184.00
Pastures	3,752 bales	3	11,256.00
Cabbages	3,482 pieces	0.8	2,785.60
Total			**395,838.10**

Table 4. 10 Extent of damage for other forms of human elephant conflict in percentage

	Below 10,000	10,001 to 20,000	20,001 to 30,000	40,001 to 50,000	Above 50,000	No damage
Food store damage	2.5	7.81	3.44	3.44	15	65.62
Human injuries	0.31	0	0.31	0.62	6.88	91.25
Water structures damage	0.94	2.19	5.94	7.81	24.38	50.94
livestock depredation	2.5	1.56	4.06	5.31	5	77.5

4.2.8 Characteristics of raiding elephants

Respondents approximated the average herd size of elephants during a raid as 10. Generally, the composition of a raiding herd included 3 mature males, 5 mature females, 5 sub adults, and 5 juveniles on average. 52% contended that raids are always from the same group of elephants. It was also reported that elephants will normally raid crops during the lactating season. To explain this, respondents relayed that elephants are mostly seen accompanied by their calves during most crop raiding events. Elephant encounters that resulted in human injury or death were reported to be from lone elephants, particularly males.

From the community, it emerged that there are particular elephants that are problematic crop raiders. The elephants are identified by their colours which they acquire from soils in their primary habitats. Black ones are believed to come from Chyulu forest because of the black volcanic soils around the area. They are also said to have worn out soles due to the coarse nature of these volcanic soils. The short red types are believed to come from Taita Taveta and Makueni counties while the tall, white ones are apparently associated with the Amboseli National Park. Respondents, especially those who guarded their farms expressed that understanding elephant behaviour helps them manage raiding elephants and thus respond appropriately. For example, the black elephants have been observed to detest noise and to be aggressive. Therefore, people drive them out more cautiously than the others.

While most elephants will raid in the nighttime, elephants from Chyulu are reported to raid even in the day and are habitual raiders. It was also revealed that males are notorious for raiding community landscapes. Tim, an iconic Amboseli tusker who died out of old age in 2020, was allegedly a habitual raider, often accompanied by a group of other younger males, according to residents. This explains why he was fitted with a tracking collar in 2016 by the Elephant Protection Initiative. On the other hand, females will most often raid when lactating.

4.2.9 Distribution of human elephant conflict incidences by location

The analysis on distribution on HEC by location revealed that Imbirikani location had the highest cases of crop damage followed by Isinet and Oltiasika locations. Imbirikani's primary land use is livestock production followed by crop production. Isinet, on the other hand is dominated by built up areas and farmlands. However, it was noted that members of Imbirikani also owned some of the agricultural land in Isinet. This is the case because the area is a group ranch where members are allocated land by the group ranch committee. This partially explains why members of Imbirikani mentioned higher crop damage cases. Most members of Oltiasika location practice livestock production with little crop production. This explains why their most reported cases were livestock depredation. Pearson's Chi-squared test showed a strongly significant difference in the HEC among locations (χ^2 = 63.523, df = 14, p- value< 0.0001). This implies that HEC is unevenly distributed within Imbirikani Group Ranches shown in table 4.11.

Table 4. 11: Number of human elephant conflict incidences according to location in the year 2019

	Crop damage	Livestock damage	Human Death	Human Injury	Shelter	Food store Damage	Damage to water structures	Disruption of school going children
Isinet	67	20	9	3	19	4	55	33
Imbirikani	122	12	8	7	5	4	49	36
Oltiasika	61	24	13	19	21	6	27	34

4.2.10 Trends in human elephant conflict from 1981 to 2019

The community noted that HEC has been on the rise since 1981, the year of inception of the group ranch. According to the respondents, the period between 1981 and 1981 experienced very low HEC incidences, the period 1988 to 2007 was characterized by moderate HEC cases while the 2008 to 2013 epoch experienced a high incidence of HEC cases. Between 2014 and 2019, there has been an exponential rise in HEC as shown in figure 4.8.

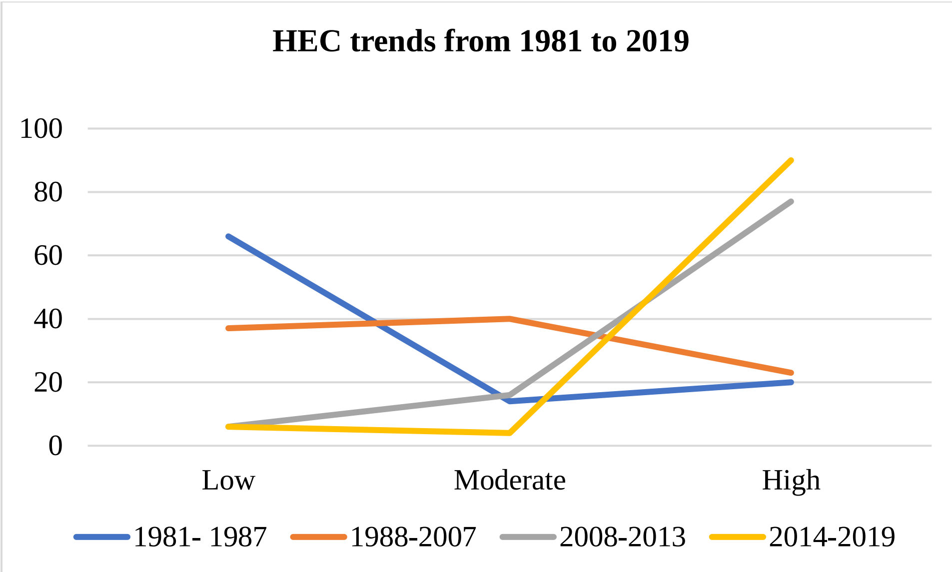

Figure 4. 6: Respondents' opinions on human elephant conflict trends from 1981 to 2019.

4.2.11 Logistic regression analysis

The results of the full logistic model show that the type of crop grown is the most significant predictor for HEC. Specifically, presence of tomatoes, maize and beans were the most significant in influencing occurrence of HEC in Imbirikani Group Ranch.

The full logistic model formulated is as shown below:

P(Elephant attacks) $=\beta 0+\beta 1x1+\beta 2x2+\ldots+\beta 11x11$

Where;

x 1 = Season

x2 = Crop_stage3

x3 = Crop_stage4

x4 = Crop_stage5

x5 = Maize

x6 = Beans

x7 = Tomatoes

x8 = Onions

x9 = Cabbage

x10 = Pastures

x11= Watermelons

β = the resultant changes in Y in response to a unit increase in x_n

Y = dependent variable

P= Probability

The results were as shown in table 4.12

Table 4. 12: Full regression model for causes of human elephant conflict incidences

	Estimate	Error	z value	Pr(>|z|)
Intercept	17.4504	1038.566	0.017	0.98659
Maize	1.0477	0.4605	-0.104	0.00917*
Beans	0.2873	0.4863	0.591	0.03546*
Tomatoes	1.0797	0.4172	2.588	0.00966*
Onions	0.1483	0.5551	0.267	0.78939
Cabbage	1.0311	1.0767	0.958	0.33826
Pastures	1.4204	1.0904	1.303	0.19269
Watermelons	0.9107	0.7979	1.141	0.25373
Season	-0.8899	0.8734	-1.019	0.30825
Crop stage 3	-16.895	1038.566	-0.016	0.98702
Crop stage 4	-16.3199	1038.566	-0.016	0.98746
Crop stage 5	-14.8775	1038.566	-0.014	0.98857

Null deviance: 232.98 on 318 degrees of freedom

Residual deviance: 190.39 on 307 degrees of freedom

AIC: 214.39

4.2.12 Climate smart agriculture practices

Respondents were aware of existing climate change impacts. They explained this observation by increased temperatures, frequency of drought events and unpredictable rainfall patterns. Only 12% admitted they were not aware of climate change. 81% of the respondents reported that climate change impacts were visible, 3% did not observe any such impacts while 16% did not know. The study also investigated which climate smart technologies the community in Imbirikani practiced. Rainwater harvesting seemed to be the only practice in use among the respondents who harvested water from their roof catchments. Others used dams which had been constructed by the government for household consumption. Destocking was the main practice among those who practiced climate informed livestock farming. For adapted breeds, most households had replaced the traditional breed with higher quality Sahiwal (*Bos taurus indicus*) and Boran (*Bos indicus*) breeds which fetch better prices and are early maturing. Very few of the respondents know about or are practicing forage development. This venture was only found to be adopted by women groups who had received support from NGOs as an alternative source of income. Soil water conservation was the least common technology among the respondents. Figure 4.9 shows climate smart agriculture technologies practiced in Imbirikani Group Ranch.

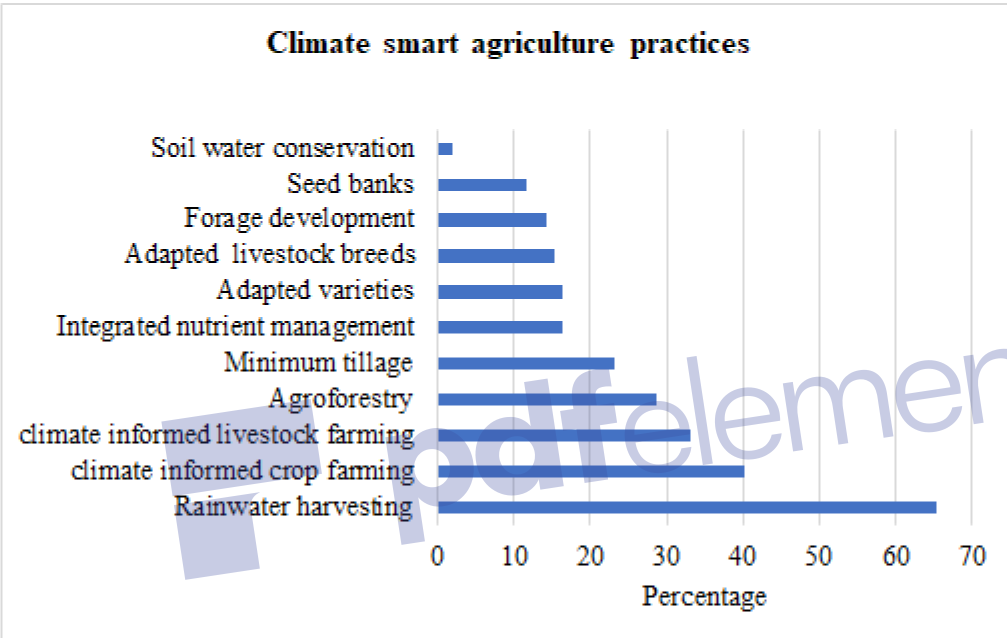

Figure 4. 7: Climate smart agriculture technologies practiced in Imbirikani Group Ranch

With regards to HEC, 64% of the participants felt climate change had influenced the frequency and severity of elephant raids in Imbirikani. 22% disagreed with this statement while 15% did not know whether there was any relationship between climate change and HEC. The link was made from increased droughts which have driven elephants to always look for water and food. Since elephants raid mostly during the dry season, longer dry seasons have increased the frequency by which these raiding events occur as well as their magnitude.

4.3 Community perceptions and attitudes towards and human-elephant coexistence

4.3.1 Perceived changes in land use and land cover

95% of residents mentioned they had observed changes in land use over the past forty years. Of these, 77% noted an increase in bare land in the region in the past recent years with 61% declaring this increase to be greater than 50% compared to historic times. A majority 76% noted there had been a decrease in grassland with 53% citing a decrease of more than 50%. Majority of the respondents (85%) noted an increase in irrigated farmlands with 70% citing a more than 50% increase. Rainfed farmlands were said to have decreased by 59% of the respondents while 39% of these said the decrease was by more than 50%. 54% cited a decrease in water sources and volume while 39% noted increased water probably due to increased water access through boreholes and piped water. Woodland cover had decreased according to 75% of the participants, 47% among whom noted this change to be more than 50%. Land covered by settlements had experienced the largest expansions according to 91% of the population as more than 62% explained a more than 75% increase in settlements. These results are depicted in table 4.13 below.

Table 4. 13: Local community perceptions on changes in land use and land cover

	Bareland	Grassland	Water sources	Irrigated farmlands	Rainfed farmlands	Woodland	Settlements
Decrease	72.79	76.25	54.38	7.81	58.75	75	7.19
Don't know	3.44	2.81	2.81	1.88	10.94	4	1.25
Increase	20.94	18.12	38.75	85	10.31	13	90.94
No change	3.44	2.81	4.06	5.31	20	4	0.62

Percentage changes in land use and land cover as perceived by the community

	Bareland	Grassland	Water sources	Irrigated farmlands	Rainfed farmlands	Woodland	Settlements
<25%	4.69	3.12	5.62	1.88	8.44	9	0.62
26-50%	27.5	38.12	20.94	20.6	30.94	31	3.75
51-75%	52.81	48.12	48.44	46.9	24.38	40	31.88
>75%	8.12	5	18.12	23.4	5.31	8	61.88

4.3.2 Attitudes towards human-elephant coexistence

Asked how they felt regarding free roaming wildlife, 82% percent admitted they felt bad, 14% were positive while 4% were indifferent. 51% of the respondents considered the conservation of elephants important, 20% said it was very important, 16% believed it was not important at all, 8% claimed it was barely important while 4% were indifferent. Some reported their disenfranchisement as, "*I do not support it, but it does not matter because my opinion doesn't count"* while some termed elephants as a nuisance that endanger human life. Others expressed their appreciation for elephant conservation; *"tourism is only enabled by wildlife. Those manyatttas around the park only depend on tourism and livestock. Even those who live away from the park like me sell their livestock to those getting money directly from tourism"*.

Among the respondents, 80% responded positively towards protecting elephants and accepted the need to protect elephants. However, 86% would not support conservation where their lives and livelihoods were threatened. This was evident from the responses that endorsed the needs of people and their livelihoods (livestock and crops) over saving elephants. Even so, the general notion was that poachers should be punished as evidenced by 72% of the respondents. People's perception of national parks and conservation as a land use showed a majority support and awareness for conservation benefits as shown in table 4.14.

Table 4. 14: Frequency (%) of responses on people's attitudes towards elephants and conservation.

	Elephants should be protected	People who poach should be punished	National parks are of value	Conservation is a waste of land	What people and their livestock/crops need are more important than saving elephants
Agree	80	71.56	85.63	20	85.94
Neutral	10	11.56	6.88	13.44	7.19
Disagree	10	16.88	7.5	66.56	6.88

4.3.3 Influence of age, gender, education level, livelihood and location on attitudes toward human-elephant coexistence

There was a significant relationship (χ^2= 16.087, df = 6, p-value =0.0132) between level of education and perceptions towards elephant conservation. Negative perceptions towards elephant conservation were skewed to members of the community who had no formal education compared to those who had received formal education. Those who had received no education at all formed the majority of the population sampled (58%). There was a significant relationship between participants' education level and elephant conservation with education level promoting and instilling conservation skills. The results showed literacy contributed to tolerance and appreciation of elephants and their conservation as in table 4.15 below.

Table 4. 15: Perceptions towards elephant conservation as influenced by level of education and age in Imbirikani (%).

Education level	Positive	Neutral	Negative	Total
Illiterate	5	12	40.9	57.9
Primary	4.3	2.5	11.9	18.7
Secondary	2.8	0.9	9.7	13.4
Tertiary	2.1	0.9	6.9	9.9
Total	14.4	16.3	69.3	100
Perceptions towards elephant conservation as influenced by gender				
Female	4.7	7.9	40.8	53.4
Male	9.7	8.5	28.5	46.7
Total	14.4	16.3	69.3	100

No significant relationship existed between age and perceptions towards elephants (χ^2 = 9.7036, df = 6, p- value = 0.1377). Similarly, type of livelihood did not seem to have a significant influence on perceptions towards elephant conservation (χ^2= 9.9401, df = 6, p-value = 0.1272). There was a significant difference between females and males in their perceptions towards elephant conservation (χ^2= 11.191, df = 2, p-value = 0.0037). The results show that women generally had negative perceptions towards elephant conservation as illustrated in table 4.16.

Table 4. 16: Factors influencing perceptions towards elephants and their significance

	Chi-square statistic χ^2	degrees of freedom	P- value
Age	9.7036	6	0.1377
Livelihood	9.9401	6	0.1272
Education	16.087	6	0.0132
Gender	11.191	2	0.0037
Location	63.523	14	<0.0001

Opinions on whether elephant conservation was important was also influenced by the location (χ^2= 63.523, df = 14, p-value <0.0001). Imbirikani emerged as the location with the majority of residents with negative perceptions towards elephant conservation followed by Oltiasika and Isinet respectively. Imbirikani also had the largest number of people with positive attitudes towards elephants. Figure 4.10 gives a graphical representation of these findings.

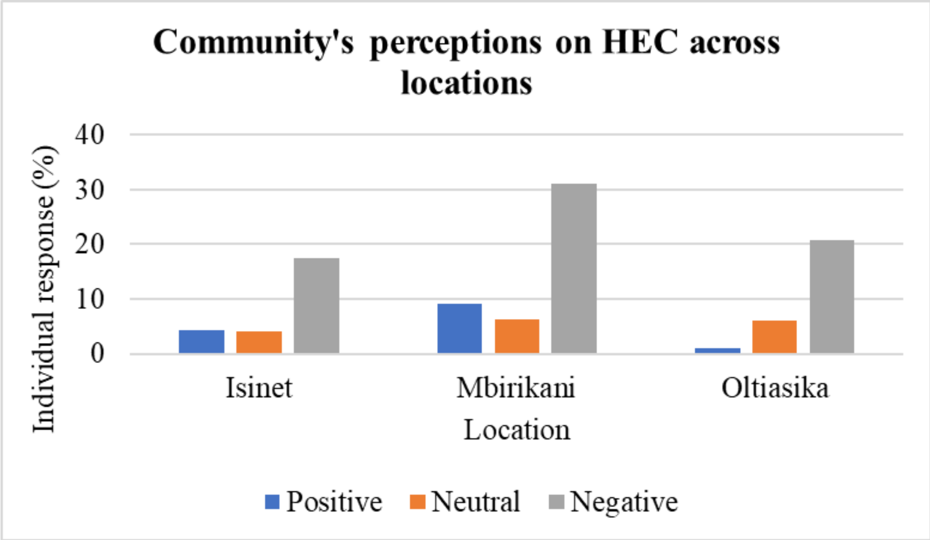

Figure 4. 8: People’s perceptions on human elephant conflict as influenced by location

4.3.4 Perceived value of elephant conservation by the local community

The general perception was that elephants had value as reported by 61% of the respondents. Nevertheless, the community perceived elephants to be of beneficial value so far as school bursaries and projects from conservation were concerned. The community reported that KWS provides scholarship bursaries to the tune of Kenyan Shillings six million annually to the Imbirikani community. However, according to the community "it is not much compared to the costs of wildlife". Moreover, conservation has apparently created jobs for the local community. Cultural bomas have also been constructed in Imbirikani location for cultural tourism and to sell beadwork by local women. On the other hand, the majority did not perceive elephants to have any aesthetic, monetary, ecological, educational or medicinal value.

Following damage from elephants, a consolation fee of Ksh 3,000 is given for depredation of shoats and Ksh 25,000 for cattle as mentioned by the community members. Similarly, the Great Plains Eco-lodge has provided employment for community members and leased land from Imbirikani Group Ranch providing a source of income for the group ranch. However, members cited misappropriation of funds by committee members of Imbirikani Group Ranch. On the other hand, vehicles from the BigLife Foundation were reported to benefit the community in times of crisis such as hospital emergencies and funerals. In addition, BigLife Foundation also helped guard farms in the night where incidents had been reported. The benefits of elephants according to the community are shown in table 4.17 below.

Table 4. 17: Benefits of elephants as perceived by the community (%)

	Aesthetic value	Bursaries	Cash benefits	Ecological value	Educational value	Medicinal value	Other benefits	Projects from conservation
No	83.08	12.31	74.87	95.9	68.72	91.28	87.18	42.56
Yes	16.92	87.69	25.13	4.1	31.28	8.72	12.82	57.44

4.3.5 Perceptions towards trends in human elephant conflict

Respondents noted an increasing trend in HEC incidences since 1981. Between 1981 and 1981, the trend was described as very low. In the period 1988 to 2007 it was termed as moderate, between 2008 and 2013 it was high while between 2014 and 2019, it was perceived to be very high. Some of the reasons described to be behind these trends were a sharp increase in crop cultivation (22%), stringent protection of elephants by wildlife authorities which had led to an increased elephant population (40%), reduced pastures and water (6%), proximity of the farms to the sanctuary due to encroachment into elephant corridors (3%), increased settlements (14%), human population increase (3%) and increased water points which attracted elephants around human settlements (6%). Those who reported reduced HEC cases attributed this fact to the Kimana-Namelok electric fence (8%) Figure 4.11 shows this.

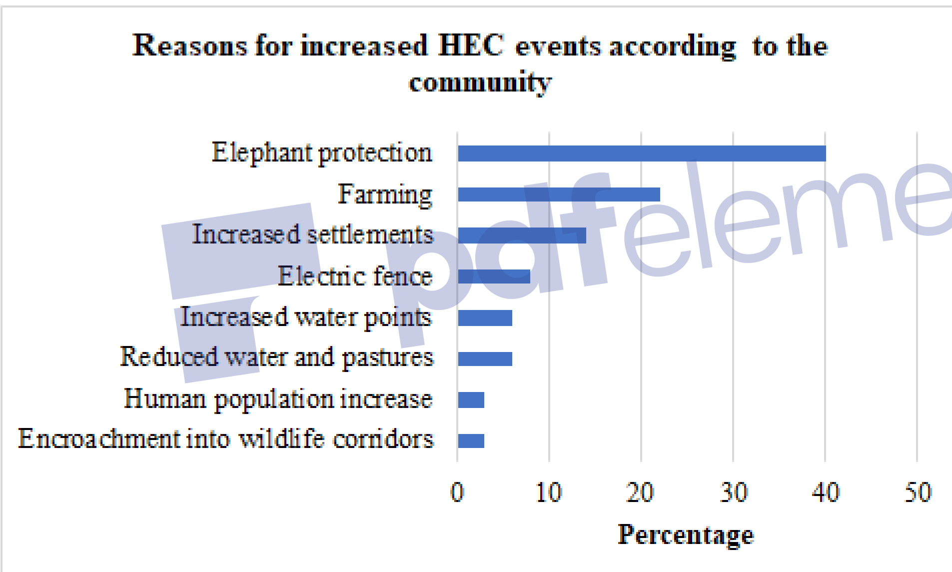

Figure 4. 9: Causes of increased human elephant conflict incidents as identified by the community.

4.3.6 Local community's perceptions of wildlife management authorities

Most of the respondents (68%) conveyed that they report HEC incidences unlike 32% of their counterparts. Among those who reported conflict cases, a majority made reports to Big Life rangers (77%) while a minority made their reports to KWS officials (18%). Only a negligible number reported incidents to other authorities such as the chief.

In response to how fast authorities responded, 43% conveyed that the authorities they reported to never responded to their calls, 39% said wildlife authorities responded within a day, 16% reported response in less than a week while 2% reported response took over 2 weeks. Of those who had experienced crop damage, 100% reported no compensation while 14% of those who had experienced livestock depredation and human attacks reported some form of compensation totaling to approximately Kenyan shillings 13,300 on average. The average period for disbursement of the compensation funds was 13 weeks. Residents were of the notion that this amount was not satisfactory and only served as a consolation fee for damages caused. The prevailing attitude was that wildlife authorities, particularly KWS, cared more about elephants than they did, people.

4.3.7 Resource mapping

During the resource mapping, the participants identified resources in 1981 as water resources including swamps and rivers, woodlands dominated by *Acacia tortilis* and *Acacia xanthophloea*, shrublands, grasslands, urban areas and farmlands. The resource changes were represented in maps for Isinet location, Imbirikani location, Oltiasika location and Imbirikani Group Ranch.

4.3.7.1. Resource change maps for Isinet between 1981 and 2020

Isinet location was reported to have experienced significant changes in urban area, farmlands, woodland, shrublands and grasslands. The participants represented the resource changes in Isinet from 1981 to 2020 during three time periods as shown in figure 4.12 below.

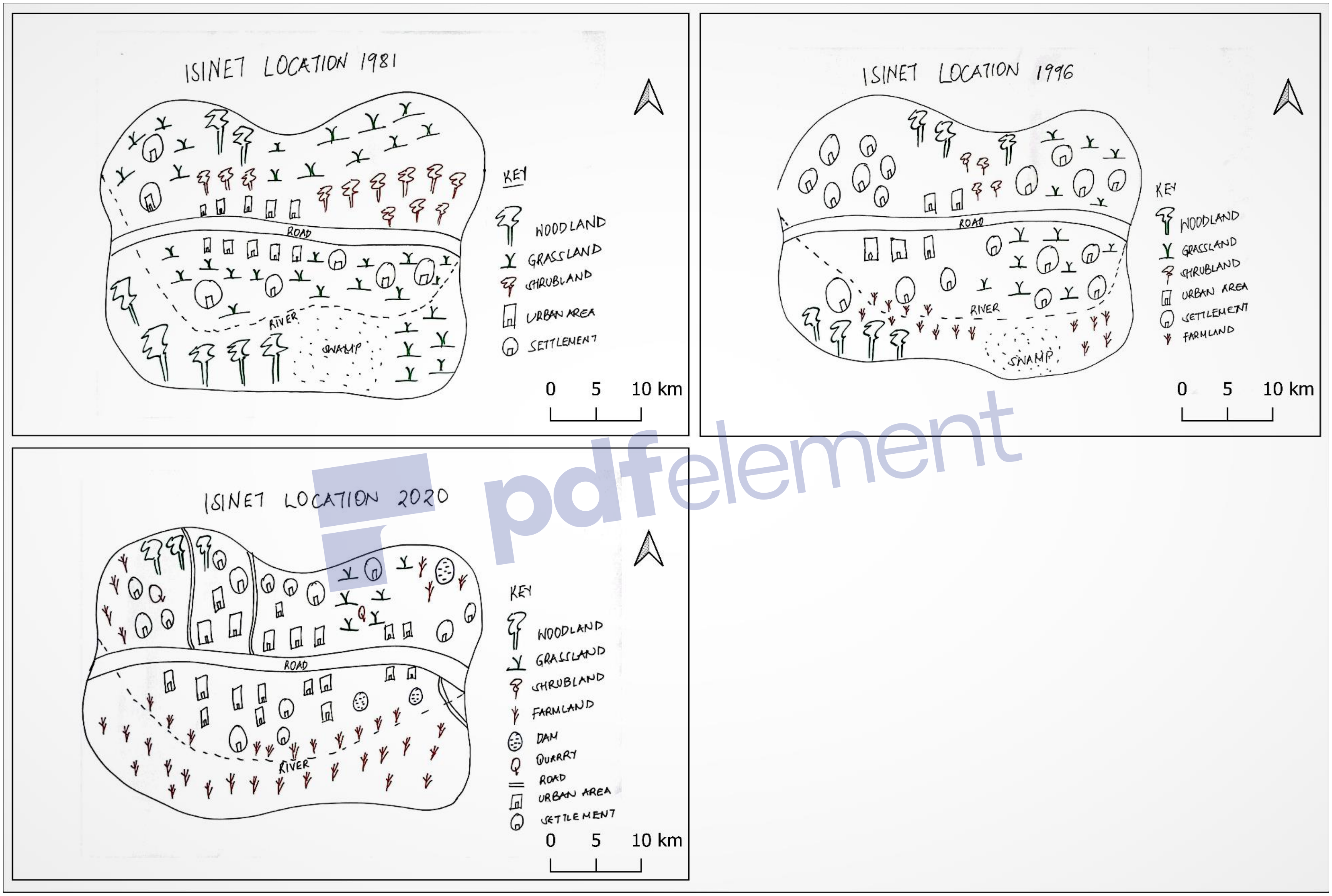

Figure 4. 10: Isinet location resource maps for 1981, 1996 and 2020

In 1996, they identified the same resources similar to 1981. However, it was indicated that some of the shrubland areas were cleared and transformed to grasslands. This was attributed to increased settlements that resulted in an increased demand for fenced bomas. Grasslands were also converted into settlement areas due to an increased population. In the 2020 period, the resources had shrunk due to the following reasons identified by the community; change in the location of the road, high influx of human populations into the area, construction of dams by the national government with community development funds (CDF), exponential increase in agriculture for subsistence and commercial purposes. This is summarized in table 4.18.

Table 4. 18:Percentage land use changes as reported by Isinet community members.

Land cover type	1981-1996	1996-2020
Urban area	20	92
Water sources	-25	-45
Farmlands	35	86
Woodland	-45	-98
Shrubland	-60	-100
Grassland	-60	-75

4.3.7.2 Resource change maps for Imbirikani Location between 1981 and 2020

Members of the Imbirikani location indicated changes in resources such as woodland, shrubland, farmland and grassland. The resource changes represented for 1981, 1996 and 2020 are shown in figure 4.13 and table 4.19 below.

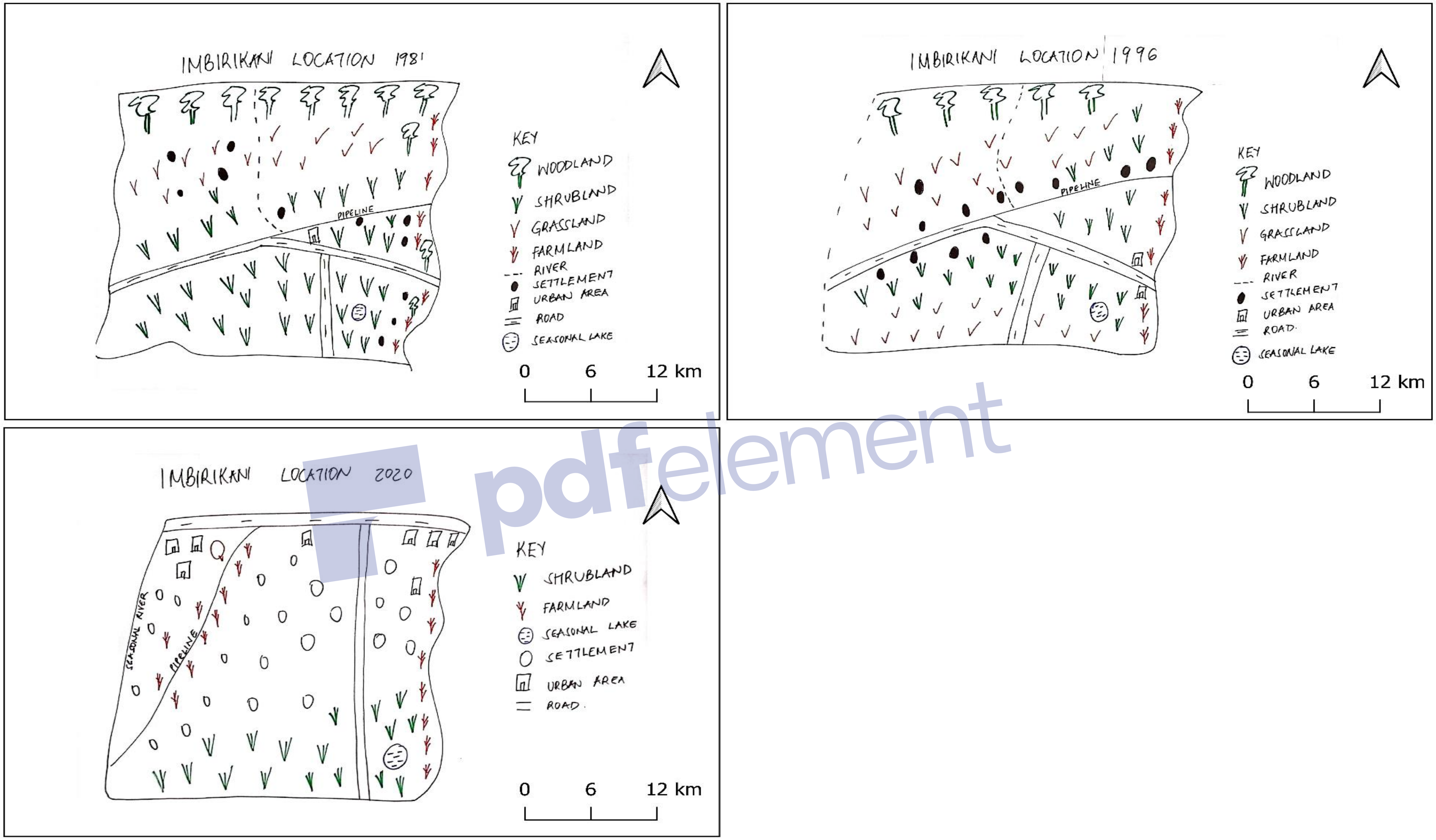

Figure 4. 11: Imbirikani Location resource maps for 1981, 1996 and 2020

Table 4. 19: Percentage land use and cover changes reported by local community of Imbirikani location between 1981 and 2020.

Land cover type	1981-1996	1996-2020
Urban area	75	43
Water sources	-15	-40
Farmlands	80	86
Woodland	-52	-90
Shrubland	-25	-65
Grassland	-50	-90

In Imbirikani Location there were no HEC incidents in 1981 according to the participants. HEC increased by 15% from 1981 to 1996 and by 95% by 2020. Resources that continued to decline in general were water resources, woodlands, shrubland and grasslands. The community reported a complete reduction in grassland and woodland cover by 2020 due to increased settlements, deforestation, increased livestock population and increased elephant population.

4.3.7.3 Resource change maps for Oltiasika Location between 1981 and 2020

In Oltiasika Location where the predominant land use is pastoralism with little rainfed/ irrigated agriculture and mining, the community described vegetation in 1981 as natural; “the way God created it”. In 2020, there were increased artificial water points such as boreholes and dams but reduced natural water sources. Emerging land use types included quarrying which began in 2015 with the establishment of a cement plant. This motivated the mushrooming of a town around this cement factory due to increased development and access to job opportunities. Urbanization is also evidenced by a tarmacked highway and the presence of several murram roads. Social amenities also increased. For example, a communal crush has been erected and 4 more schools have been constructed. Figure 4.14 and table 4.20 below shows land use changes within Oltiasika.

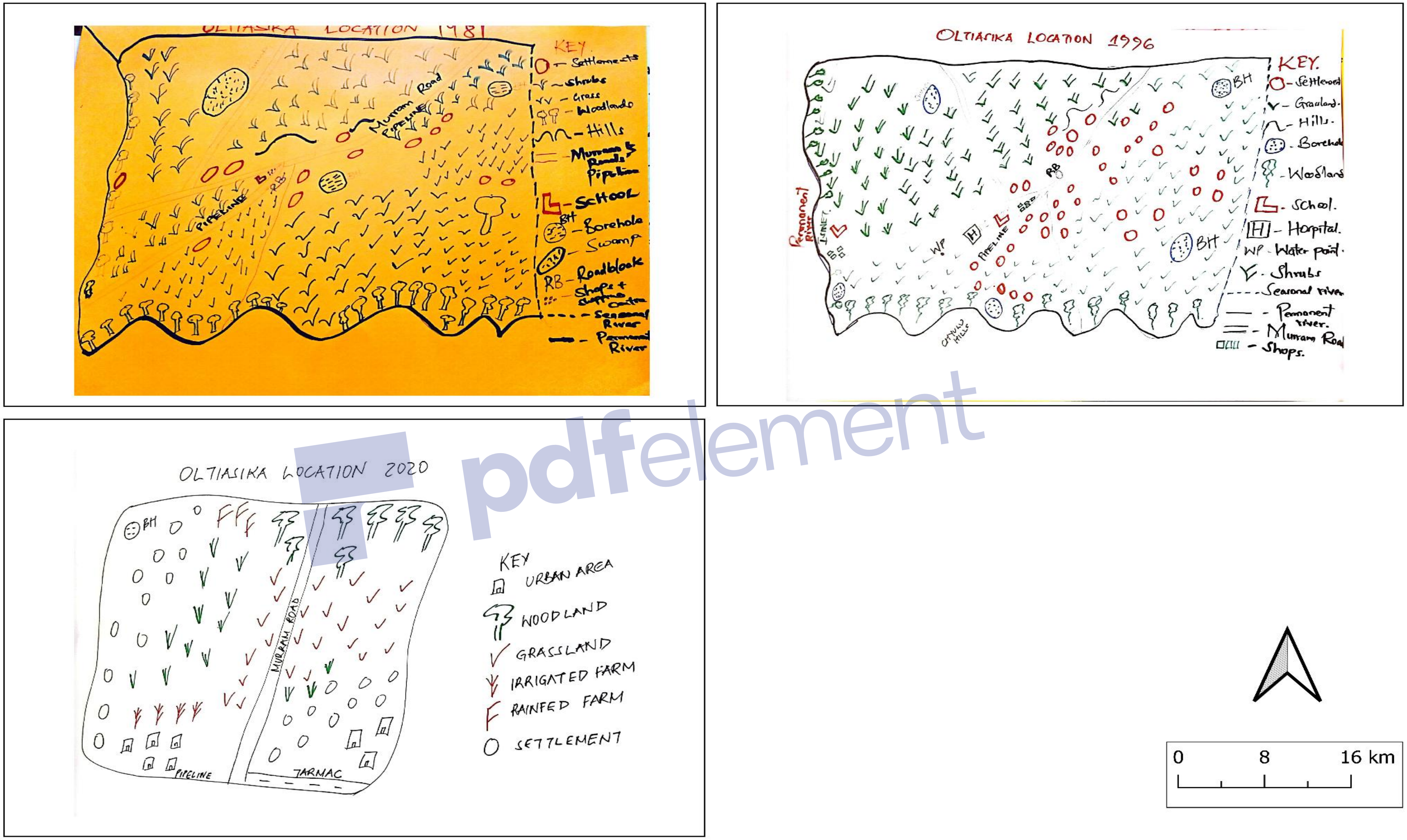

Figure 4. 12: Oltiasika location resource maps for 1981, 1996 and 2020

Table 4. 20: Percentage change in land use and cover from 1981 to 2020 by Oltiasika community.

Land cover type	1981-1996	1996-2020
Urban area	45	70
Water sources	-20	-30
Farmlands	55	60
Woodland	-30	-60
Shrubland	-35	-80
Grassland	-60	-90

4.3.7.4. Resource change maps for Imbirikani Group Ranch between 1981 and 2020

Between 1981 and 2020, the community in Imbirikani Group Ranch reported a 90% decline in grassland, 90% increase in settlements and urban areas, reduced water sources by 50% and 80% increase in agricultural land as depicted in figure 4.15 and table 4.21. Negative effects associated with these land use changes listed by the community in Imbirikani Group Ranch included water (rainfall) shortage, declined soil fertility, reduced feed resources for livestock, cultural dilution due to urbanization, increased use of agrochemicals jeopardizing people's health especially eye health, water pollution occasioned by open defecation and open air washing near the rivers, reduced fish population and other aquatic species such as hippos, loss of breeding/calving grounds for elephants and hippos, increased HEC incidences and augmented levels of malaria cases. Positive effects mentioned were increased food production, improved income from rental houses, enhanced access to education, better access to healthcare, spiritual empowerment due to establishment of more churches and improved management of malaria cases as a result of better health services.

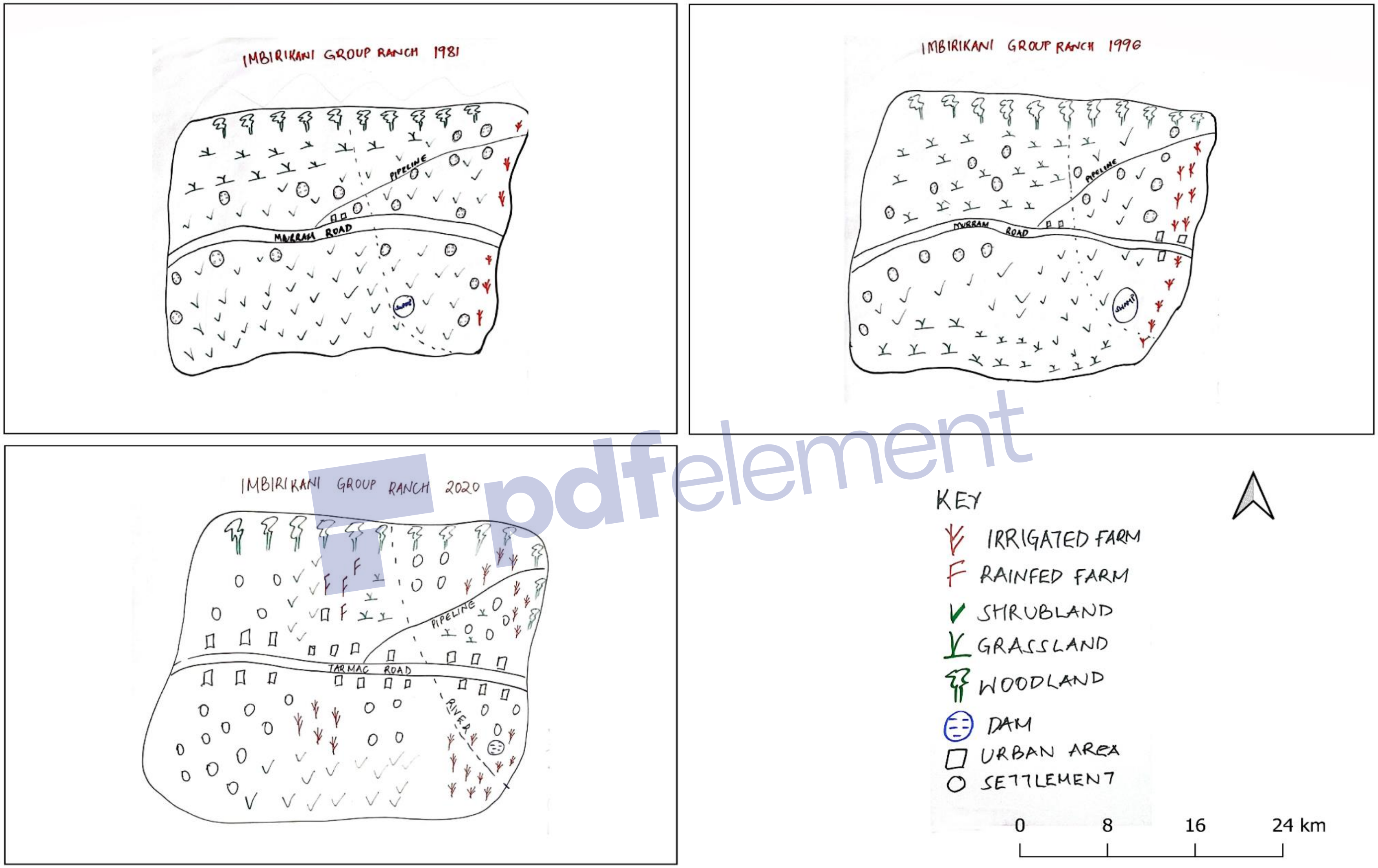

Figure 4. 13: Imbirikani Group Ranch resource maps for 1981, 1996 and 2020

Table 4. 21: Percentage changes in land use and land cover in Imbirikani Group Ranch

Land cover type	1981-1996	1996-2020
Urban area	50	90
Water sources	-30	-50
Farmlands	60	80
Woodland	-50	-60
Shrubland	-45	-80
Grassland	-50	-90

The FGD participants ranked problematic animals in descending order as; 1. Elephant, 2. Lion, 3. Monkey, 4. Hyena, 6. Buffalo. Crop raiding was perceived as the greatest damage caused by elephants. Among the crops preferred by elephants, maize was ranked the highest followed by water melons, onions, cabbage, bananas and tomatoes respectively. Destruction of property followed crop raiding with most destroyed structures being houses, granaries, boreholes and water canals. Habitat degradation, especially of woodlands by elephants in search of food, was ranked third. Additionally, killing of livestock during the rainy season was mentioned because of elephants' interactions with livestock as well as competition for food resources. Finally, elephants were said to cause road accidents according to the participants. Human death as a result of elephant attacks was mentioned as the least type of damage.

4.3.8 Changes in elephant populations as perceived by the community.

In 1981, the community cited a stable population of elephants. In 1996, the population was reported to have declined by 46% and in 2020 the number had increased by 82%, a change attributed to increased conservation efforts and protection of elephants. The trends reported by the participants were associated with increased human population and the resultant demand for land for settlement, rising demand for agricultural land, increased urbanization, land fragmentation and degradation of habitats. According to the community, HEC incidences had increased by 86% since 1981.

4.3.9 Management strategies of human elephant conflict by community, Kenya Wildlife Service and conservation agencies

The community uses different strategies to prevent entry of elephants into their farms and to mitigate against HEC in Imbirikani Group Ranch. These strategies include: the use of fire (using sticks, gunny bags and alcohol) to scare away individual elephants, use of thunder flashes given to them by KWS and BigLife officers, use of slings, employing guards to keep watch in the farms as well as using dogs as an alert mechanism. Moreover, the community reported that in case an elephant kills a human being, they "use spears on the elephant before KWS officials arrive". This action denotes the level of bitterness communities have on death due to elephant attacks and that they are not ready to tolerate interactions with deadly elephants.

The community nevertheless felt disenfranchised that KWS seems to protect and value elephants over people. They complained about lack of compensation for elephant damages and poor response by KWS during such raids. They felt that elephants should somehow be restrained in the protected areas to keep them off their farms. Even so, it was stated that KWS provided thunder flash tools to members of the community to ward off raiding wildlife which was deemed quite helpful. Compared to other authorities, BigLife Foundation was reported to respond faster to community emergency calls of wild animal attacks.

4.3.10 Recommendations for conflict mitigation by the community

The following recommendations were made by community members as means of mitigating human elephant conflict:

1. KWS should improve availability of elephant forage in the park.
2. Electric fencing especially for farms around Kimana Sanctuary should be put up. Security should also be improved by erecting electric fences around schools because elephants move from the sanctuary in the morning.
3. BigLife should increase game rangers from the community. They should train the community to increase participation in conflict management to redeem human-elephant

relations. They should employ rangers from Imbirikani and not from outside as they understand the area better and would be able to respond to conflict calls more promptly.

4. KWS should also recruit game scouts from the community as well as increase their presence on the ground.
5. KWS should relocate people from wildlife corridors.
6. KWS should adequately compensate victims of HEC.
7. NGOs should lease reserves or sanctuaries for wildlife and increase corporate social responsibility project activities.
8. KWS, County and national government as well as NGOs should increase water points to reduce competition from wild animals.

CHAPTER FIVE: DISCUSSION

This section highlights the findings and interprets the observed patterns in the study. Relationships and trends in human- elephant conflict will be described based on the geospatial analysis and household survey findings. The chapter is divided into three sections corresponding to the three objectives of the study.

5.1 Land use and land cover changes and their implications for human-elephant conflict in Imbirikani group ranch

The analysis of land use/cover changes revealed substantial changes in Imbirikani Group Ranch over the 32-year study period. Based on this analysis, it is clear that agricultural expansion, population growth (and the resultant needs for land resources) and development are major driving forces of land use and land cover change. Land use change maps suggest that agriculture began slightly before 1999. By 2019, there had been an exponential growth in farmlands for subsistence and commercial purposes. Most of the agricultural expansion has occurred in the oases of the area which were previously important elephant dispersal areas. Isinet location, for example, is an important migration area owing to its proximity to Kimana Sanctuary which borders Imbirikani to the south. Nevertheless, Isinet has suffered the greatest conversion to urban development and irrigated farmlands.

The years 1999/2000 and 2013/2014 experienced droughts. This explains the increased bareland in 1999 as well as reduced grassland cover. Similarly, 2013 displayed an increased bareland relative to 2019 in addition to declined grassland cover. Between 1999 and 2013, Kenya is reported to have had ten drought events (Kenya Drought Operations Plan, 2013). In this plan, Kajiado County was indicated as a high-risk zone of drought impacts based on a five-year average. While unpredictable and more pronounced climate variability due to climate change was reported to exacerbate droughts, population growth and pressure on land were mentioned as key driving factors for devastated rangeland resources. This coupled with less land and fewer drought refuge areas is hastening the collapse of a once productive and sustainable pastoral economy and wildlife ecosystem as was also noted by Kariuki *et al.,* (2018). Nyangena *et al.*, (2020) posited that after drought occurrence, vegetation takes up to two months to recuperate and regain vigour in the Chyulu-Amboseli ecosystem. However, with the increased pressure on rangeland resources, a two-month lag period is not the reality, undermining the rangelands' ability to support human, livestock and wildlife populations.

Land cover changes have significant consequences on elephant habitats, their feeding resources, their distribution as well as movements due to obstruction of migratory corridors (Mohammad *et al.*, 2021). The African savanna elephant has been listed on the IUCN Red List as endangered due to poaching and conversion of their habitats, largely to agriculture and other land uses (IUCN, 2021). Correspondingly, the geospatial analysis and ground observations showed the loss of wetlands and rangelands to agriculture and the resultant alteration of natural habitats and movement routes. Although the Amboseli Ecosystem Management Plan (2008- 2018) proposed adoption of ecosystem zonation, the land use practices are not in tandem with this scheme. Agriculture has encroached into zones designated as pastoral development and conservancy areas within Imbirikani as revealed by the preceding analysis. This implies a gap in the implementation of the land use plan. Without formal protection and land use planning, key resource areas for wildlife remain greatly under threat of unsustainable use and unplanned expansion of urban areas, settlements, and agriculture. Poor zoning and planning have fortified uncoordinated and incompatible land use practices in Imbirikani. Like in the adjacent Kimana Wetland Ecosystem of Kimana Group Ranch, the decline of woodlands, grasslands and wetland which form critical habitats, indicates that wildlife conservation is not an important livelihood for the local community as also noted by Kitina and Odiara (2014).

The analysis suggests a shift from wooded savanna with open and closed shrublands to open grasslands and patches of bareland. Biophysical factors may again explain this shift. An increasing elephant population with shrinking habitats has shown to increase browsing pressure on shrubs which may hinder their regeneration (Fletcher *et al.*, 2014). However, as observed in this study area and by other researchers (Liu *et al.* 2019), the greatest and most significant driver of a reduced wooded vegetation is human pressure due to a burgeoning human population and the resulting high demand for natural resources to sustain livelihoods. Such anthropogenic activities include wood extraction for charcoal production, fuelwood and construction as well as paving way for agriculture and development. Additionally, water has been progressively made more available through boreholes and the Olooltureishi Pipeline within Imbirikani. This allows for cultivation even in areas where water was absent during the dry season. This often drastically shrinks areas available to support wildlife populations in Imbirikani as also observed by Okello (2016) while studying the larger Amboseli ecosystem.

Besides expansion in cultivation and settlements, displacement of wildlife is also evident through land subdivision. Unplanned land subdivision has led to habitat fragmentation and the isolation of protected areas which threatens wildlife areas. Increasing human population within Imbirikani is evidenced by increased demand for settlements and thus subdivision of land. These observations corroborate recent observation by the African Conservation Centre (ACC, 2020). The implications of these are encroachment into wildlife movement routes. Additionally, high livestock densities have also driven degradation of habitats. They compete directly for the same water, forage and space resources with wildlife. That notwithstanding, Okello (2016) reported that the presence of cattle was not particularly damaging to any specific wildlife species despite grazing competition. The study proved that pastoralism was a compatible land use practice in wildlife habitats due to traditional resource use strategies by pastoral communities. On the other hand, Okello hypothesized that the shift from pastoralism to agricultural and agro-pastoral lifestyles had resulted in depletion of wildlife resources in the periphery areas of Serengeti National Park, Tanzania resulting in increased HWC incidences.

HEC resulting from land use changes has been observed in several other areas. For example, examining the relationship between land use change and HEC, a study in North Bengal showed that conversion of forest reserves to agriculture and settlements triggered habitat loss and damage to human property such as shelter, trees, crops and even social death (Naha *et al.*, 2019). A similar study in Fashiakali Reserve, Bangladesh, showed a worsening relationship between humans and wildlife, a situation attributed to encroachment of human settlements into elephant natural habitats (Mohammed, 2021). Similar observation were observed in Taveta subcounty of

Taita Taveta county whereby, land use changes characterized by expansion of agriculture lead to increased human wildlife conflicts (Mbau, 2013). These studies make it expressly clear that expansion of agricultural land and settlements in landscapes adjacent to protected areas heighten the probability of HWC including HEC. Increased human activity around protected areas threatens their ecological integrity as earlier noted also by Bailey *et al*.(2015), and sometimes leaving conservation areas as ecological islands further straining their ability to offer the required ecosystem services

The results of these studies agree with several similar studies. Schüßler *et al*. (2018) found that woodlands and bushlands decreased by 16.3% while agriculture expanded by 12.2% fragmenting important wildlife habitats and narrowing the migration corridors over a 43- year period from 1975 to 2017, in the Amboseli Ecosystem. In the same study, the researchers observed that although woodlands and bushlands declined significantly, open grasslands expanded in Amboseli National Park and its immediate surroundings. This exemplifies the tendency of data from Imbirikani where grasslands were observed to expand between 2013 and 2019. Okello (2012) observed that settlements and farming were concentrated along the main roads and water sources which would cause habitat fragmentation and possibly block migration paths in the Amboseli Ecosystem. This study revealed that human activities were clustered around strategic development points. In Imbirikani, the case is no different, with such activities notably being polarized around the Emali-Loitoktok Highway, Olooltureishi Pipleline and the Simba Cement factory. Undeniably, this has interfered with the dispersal behaviour of wildlife species, more so the elephant.

Aduma *et al.,* (2018) predicted future changes in Amboseli elephant population (under Representative Concentration Pathways) to increase significantly. This occurrence could affect the sustainability of the elephant population due to limited park space and thus most elephants will move into the group ranch areas outside the park. The study therefore predicted the potential for increased HEC scenarios in the coming years. One of the recommendations from the study was the formation of conservancies where wildlife conservation is the main landuse. In

Imbirikani Group Ranch, Oldonyo Wuas Conservancy has been established to serve this purpose but is yet to be registered (Amboseli Ecosystem Trust, 2020).

5.2 Nature and extent of human elephant conflicts in Imbirikani Group Ranch

This study, like a number of previous study findings, expressly confirms that agricultural activities are a major driver for HEC in Imbirikani Group Ranch. This situation can be attributed to a swelling human population and the associated demand for space food resources and income and livelihood opportunities. Most agriculture practiced in the area is irrigated which implies competition for water with pastoralism and wildlife. Furthermore, an increasingly sedentary lifestyle among the Maasai community has motivated the transition from pastoralism to agro-pastoralism resulting in further pressure on critical resources.

Shifting to irrigated agriculture from pastoralism and conservation is not a new phenomenon in the Amboseli Ecosystem or in Imbirikani. However, agriculture is rapidly taking the commercial route as demand for food increases and accessibility to markets through roads has significantly improved. Nevertheless, agriculture is still an incompatible land use to the ecology of Imbirikani as it has led to the conversion of wetlands into farmlands straining the few water resources available. Buchholtz *et al.*, (2019) hypothesized that distribution of water in space and time influenced how elephants used a mosaic landscape in Botswana. The spatial tracking of water brings them into closer contact with humans as these are the same water resources used for farming. Besides being a catalyst for HEC, agricultural practices have had detrimental effects on water quality through agro-chemical contamination from pesticides and herbicides used in crop production. This threatens the health of its users, wildlife included. Wildlife, therefore, have been completely exterminated from some of their habitats in Imbirikani in favour of irrigated agriculture.

Though spatial factors of HEC are land use practices and anthropogenic drivers, seasonality of these events is influenced by the agriculture calendar. Seasonal patterns of crop raids coincide with the dry season as indicated by the respondents. Farmers in Imbirikani normally plant maize between November to March which coincides with the two wet seasons (October to December and March to May). They then plant tomatoes during the period May to October which coincides with the longest dry season in Kenya. This explains why major losses were experienced by tomato and maize farmers. In addition, the analysis shows crop raiding behaviours also corresponded with the harvesting period. Elephants have been observed to prefer maize in several other areas which presents a challenge because it is a staple food throughout the country. In a similar study in Lower Sagalla, Weinnman (2018), found that elephants preferred farms with maize over those with ginger, garlic, lemongrass and onion suggesting that planting less palatable crops can be a potentially effective way to manage elephant crop raiding behaviour. The researcher also suggested sunflower and moringa as non-palatable options which are also economically viable. A number of studies have also explored chillies as a deterrent for crop-raiding (Chelliah *et al.,* 2011; Chang'a *et al.*,2016).

These findings are consistent with Chen *et al.,* (2016) and Naha *et al.* (2020) who documented crop raiding activities to be in peak relative to the harvesting patterns of key agricultural crops in Africa and Asia. Elephants respond quickly to forage and water availability changes, migrating in response to either large and small rainfall events (Bohrer *et al.,* 2014; Adama *et al.,* 2018) which they are hypothesized to detect through rain-system generated infrasound (Scheke *et al.,* 2015). Branco *et al.* (2019) also found that crop raiding formed part of elephants' optimal foraging strategy. Peak raiding season was observed as crops approached harvest when they are most palatable and highly nutritious. In Gorongosa National Park in Mozambique where the study took place, as well as many other parts of Africa, the best quality forage in farmlands is available at simultaneous times with low forage quality in the park when the forage is near its nadir. This behaviour where elephants spatially and temporarily track peak forage biomass also termed as "surfing the green wave" was the norm in Imbirikani Group Ranch.

The community identified nighttime as the most popular time for HEC incidents. These findings are corroborated by Okello *et al.,* (2016) who postulated that elephants will normally retire to safer places, with minimal human presence, during the day such as the Amboseli National Park. In the night, the pachyderms would freely move into human dominated landscapes when human activities were suppressed. Then, they would have the liberty to forage, even in people's farms. Elephants spend long periods grazing and continuously so, as they are non-ruminants. They therefore move into dispersal areas in the evening and retreat to the park in the morning to escape conflicts. This is a risk avoidance strategy adopted by the elephants in relation to human- elephant conflict. This is a challenge which conservationists need to address sufficiently.

Members of Imbirikani reported an upward trend in HEC since 1981. In a similar study carried out by Ekisa and Okello (2016) in Kimana Group Ranch, Kuku Group Ranch and in the slopes of Mt. Kilimanjaro, most of the research participants in all the three areas reported an increasing trend in the amount of HWC. Only very few respondents reported no conflicts or no change in conflicts. The majority, both agro-pastoralists and agriculturalists, reported 76 to 100 percent of property damage during their last HWC encounter.

Respondents observed that raiding is carried out by the same group of elephants. This suggests habitual raiding behaviour by culprit elephants. It was also reported that females raid during the lactating period as well as groups of male elephants. Pokharel et al. (2018) noted that males would undertake crop raiding more compared to their female counterparts. This is because crop raiding is a significantly high-risk foraging behavior which can lead to retaliatory killing by residents, mostly demonstrated by males in a bid to quickly get easy nutrition. Naha *et al.* (2020) found that crop raiding incidents in North Bengal involved mixed groups as well as lone bulls. The average herd size of 23 elephants from Naha *et al.* (2020) however, was different from that of this study which was found to be 10.

While this study focused on a general awareness of the community on the existence of climate change and its impacts, there were gaps in adaptation practices through climate smart agriculture. There is a general consensus through different models that rainfall will increasingly become erratic, and drought and flood events will be more frequent (Shaffer *et al.*, 2019). The timing, location and amount of rain will become less reliable (Boult, 2018). HEC will inadvertently transform as the distribution of key water and food resources is altered in the face of climate change. This implies that HEC hotspots like Imbirikani will likely face increased HEC as resource availability is expected to decline and as habitats increasingly become fragmented and transformed through land use change assuming status quo. Currently, it was noted that the community practicing irrigated agriculture did not see the need to conserve water since it is readily available in the wetter areas of Imbirikani (Isinet and Namelok). However, as rainfall declines, the community will be pushed to shift to more sustainable practices which they are not well equipped for now.

5.3 Community perceptions and attitudes towards human-elephant coexistence

The analysis suggests a good understanding of spatio-temporal resource changes by the local community. The local community was equally able to show the implications of the noted resource changes for HEC. These results are corroborated by previous studies. For example, Kimiti *et al.* (2016) documented a decline in grasslands and woodlands and an increase in cultivation, settlements and urban areas as reported by the community in the Amboseli Ecosystem. This knowledge and understanding can be a leverage point for conservation authorities to involve local communities in land use planning as well as in the development and implementation of conflict mitigation strategies.

Majority of the respondents displayed support for elephant conservation and expressed that it was important to protect elephants as long as they did not threaten their livelihoods. Abdullah *et al.,* (2019) documented similar results in a study carried out in Indonesia. The research found that the majority (64%) of the sampled population, though in support of elephant conservation, were not for conservation where crop-raiding wildlife, especially elephants threatened their interests and livelihoods. In general, those who had experienced crop depredation were likely not to support elephant conservation.

The results in Imbirikani Group Ranch showed that attitudes and perceptions towards elephant conservation varied with socioeconomic variables. The relationship between land use type or the type of livelihood a household engaged in and support for elephant conservation was not significant. This was also the case for age. These findings agree with those of Okello *et al.,* (2016) whose study suggested opinions on elephant conservation to be independent of the land use practiced as well as the age of the respondents. On the contrary, Abdullah *et al.*, (2019) found a statistically significant difference between respondents' type of livelihood and their opinion towards the conservation of elephants. The study found a significant relationship between attitudes and education level in addition to the location of the respondents and their gender. This is also in accord with the results of this study and indicates the importance of enhancing education and awareness in Imbirikani Group Ranch for meaningful support for elephant conservation in the area. Okello *et al.* (2016) also found that males tended to have positive attitudes toward elephant conservation relative to the females. Similarly, lower levels of education corresponded with negative attitudes in comparison to higher education levels. Additionally, Abdullah *et al.* (2019) also established a significant correlation between the education level of participants and their attitudes towards protection of elephants.

The demographic summaries showed a high number of people lacking education in the community. This should be of concern because for any community based natural resource management intervention, level of education is an important attribute of the community. In the same way, educational empowerment is a key foundation for elephant conservation as well as human-elephant coexistence. Low education levels may hinder community involvement in strategies and policies formulated to manage wildlife dispersal areas. Education would be instrumental in helping increase appreciation of wildlife and increase their tolerance towards the so-called problematic animals, particularly elephants. Murray and Agyare (2018) showed that education creates a wider awareness and reception to new ideas. The research also presented that education not only provided opportunities that freed people from direct dependence on natural resources but also made individuals more open to support conservation measures that restricted usage of resources.

The trends in HEC as well as elephant population were reported to be on an upward trajectory. This is substantiated by Okello *et al.*, (2016). 88% of the respondents of the study conveyed an increase in elephant population while 71% reported increasing HEC events. While it is true elephant numbers have been on the rise, the perceived increase by the community may result from increased encounters due to overlap of human-dominated landscapes and elephant habitats.

Increased human population and agricultural expansion are increasingly pushing people to the fringes of protected areas as well as attracting elephants into farmlands for readily available and highly nutritious food. According to the documented reports made by the community to BigLife and KWS, HEC incidences have been declining. However, this barely represents HEC severity on the ground as over half of HEC incidences, particularly crop raiding, go unreported (LIFE, 2018). This may be attributed to slow response of authorities as well as the reluctance to make reports for compensation claims, which is never forthcoming except for human casualty cases. Even then, the amount of compensation is quite dismal compared to the losses incurred hence the community does not see the need to report.

The community recommended fencing, community conservation initiatives, compensation, increased game rangers and translocation of problematic animals to mitigate against HEC. The presence of community rangers in Imbirikani through Big Life Foundation units, seems to be working in preventing crop raiding or other elephant damages. Big Life Foundation and KWS also provide olfactory and visual deterrents such as firecrackers which are used by community members to ward off elephants from farms and near homesteads. Big Life Foundation has also installed electric fences along wildlife corridors preventing farm invasions as elephants move from ANP to Kimana Sanctuary and onto Tsavo ecosystem. Although the fence has been effectively managing HEC for farms along this corridor, there are still concerns on the sustainability of fencing with the limitations to elephant mobility and the potential habitat fragmentation (Boult, 2018). Additionally, with the intelligence of elephants, it is likely they might in future re-route and circumvent these barriers (LIFE, 2019). This needs to be thought through in order to develop mitigation strategies in advance.

People's attitudes towards wildlife management authorities were negative overall. This can be explained partly by the negative experiences with elephants and the notion that the said authorities did not respond as expected to protect people's well-being, safety and livelihoods. Some respondents relayed their sentiments that if authorities would adequately manage crop depredation, then they would not need to depend on school bursaries for their children's education. Wildlife management authorities may not be able to compensate for all cases of HEC, more so crop damage due to financial limitations. They might also not be able to respond to all cases of HEC especially in remote areas due to understaffing and financial challenges. However, in order to leverage community support for conservation goals, wildlife authorities need to better communicate with local communities effectively as established by Mbau (2013) as well as Thondlana and Cundill (2017). Mutanga *et al.*, (2016) found that dissatisfaction from communities with regard to wildlife authorities stemmed from limited access to protected areas, absence of preferential jobs and development opportunities for the community, inadequate consultation with local communities and expansion of reserve into community land. The above studies illustrated that without factoring in community needs and concern, conservation goals may be difficult to achieve. Weinnman (2018) also found HEC had negatively impacted perceptions towards elephant conservation of the community as well as their relationship with KWS in Sagalla where the community members believed KWS and the government allowed elephants to destroy their livelihoods with no consequence hence prioritizing elephants over local communities. The community in Sagalla felt that elephants belong to KWS and the government should therefore compensate them for any damages caused by elephants. Such kind of sediments can partially be managed through effective engagement of local community in conservation matters.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study made the following conclusions:

1. GIS and remote sensing are widely recognized as indispensable tools for land use planning. This study demonstrates that supervised classification of multi-temporal satellite data is an effective tool for quantifying land use and for detecting changes in an area over a given period of time.
2. Imbirikani Group Ranch has undergone distinct land cover changes within the last 32-year timescale. Observed changes in the study area varied from one land use/cover category to another with some maintaining constant change over the four analysis periods.
3. While Imbirikani still displays viability in landscape connectivity for wildlife, this situation seems dire with increasing human populations and the consequent ubiquitous anthropogenic activities threatening key wildlife resources. Land use and cover changes bear a wide range of implications at all spatial and temporal scales.
4. Although a general trend of declining wood and shrublands, and increasing bareland was observed, cultivation has been expanding particularly in the wetter parts of the area, narrowing migration corridors while blocking dispersal routes.
5. The study established that land use changes and human attitudes and perceptions towards elephant conservation were important factors in HEC frequency and severity. HEC incidences have increased due to incompatibility of land use practices. This is despite Imbirikani being an important elephant dispersal area which is crucial if elephant populations in Amboseli are to thrive. The significant growth in human populations has further exacerbated the situation with increased uncoordinated land use.
6. It is important to understand the multidimensional nature of human- elephant interactions. This offers a broad understanding of the drivers of observed interactions, which is crucial to inform better decision making in elephant conservation and preservation of local community livelihoods.

7. Understanding the different components and dimensions of human-elephant interactions is a prerequisite for developing appropriate solutions that promote human-elephant coexistence and tolerance. This is because HEC is complex and therefore, requires multi-faceted approaches that are applicable locally. This study shows that local communities have extensive knowledge on resource changes and human-elephant coexistence. This knowledge should be recognized and used to improve wildlife management and inform conservation actions in Imbirikani.
8. Effective involvement of local communities in conservation is important. Wildlife Conservation benefits from collaborative efforts as observed with the outcome of collaboration between KWS, Big Life foundation and the Group Ranch Committee in Imbirikani Group Ranch. Such collaborations are essential for creating synergies for resource and skills mobilization to achieve the intended conservation goals. Collaboration will promote deeper dialogue and action in terms of spatial planning, financing, roles which are crucial for conflict mitigation in Imbirikani.
9. It is important to implement land use plans where available. In Imbirikani, Kajiado Land use plan and the Amboseli Ecosystem Plans are available for implementation. This can play a key role in mitigating Human wildlife conflicts while protecting community livelihoods.
10. Education and awareness are an important tool for managing human wildlife conflicts. When people are knowledgeable, they are likely to participate in wildlife conservation initiatives and are likely to design and implement alternative sources of income other than those that are nature based.
11. HEC will likely transform as the distribution of key water and food resources is altered in the face of climate change. This implies that HEC hotspots like Imbirikani will likely face worse incidences. The community will be forced to make a shift to sustainable practices such as climate smart agriculture, to adapt to these changes. The study shows they are not adequately equipped for sustainable agricultural practices.

6.2 Recommendations

This study advocates that land use and cover patterns and their spatial as well as temporal distribution are the fundamental basis for successful land use planning strategies required for the sustainable development of conservation ecosystems. The need for land use planning and implementation of management plans could not be more vital now as the group ranch is in the process of subdivision. Sustainable conservation calls for land use planning that is targeted to specific wildlife areas and dispersal pathways as well as migration corridors that offer connectivity among them. An ecosystem-based approach is necessary. Systems thinking within such ecosystems puts into account all viable land use options within wildlife areas and integrates in a manner that ensures ecosystem integrity through informed decision making.

There is an overriding need for collaborative implementation planning for effective development and execution of conservation connectivity strategies within Imbirikani Group Ranch and the Amboseli ecosystem at large. This should include wildlife managers, land use planners, land administrators, economists, ecologists, group ranch officials, agricultural and livestock officers, government entities and any other relevant stakeholders. Collaborative implementation of the AEMP (2020-2030) among conservation NGOs, KWS, community leaders, county and national governments is paramount for successful community-based conservation. The structures for implementation of AEMP within Imbirikani need to be continually monitored to curb any further unplanned land use. Chances are very high that Imbirikani Group Ranch will inevitably be subdivided. It is therefore, critically urgent, that the proposed integrated spatial planning and land use zoning be executed for improved conflict mitigation.

Similarly, regular monitoring of ecosystem health is key to ensuring effective ecological monitoring by revealing areas that require urgent restoration. In addition, monitoring of human, livestock as well as wildlife populations is instrumental in providing scientific foundation for interventions and management actions. Integrated use of these metrics should therefore be incorporated into management decisions. The exponential growth of human population in Imbirikani, and Amboseli Ecosystem in general, has not featured prominently in management plans even though this is crucial for spatial planning. This needs to be taken into consideration for there to be balance between wildlife conservation and economic development.

For long-term management of HEC and amplification of harmonious coexistence, focus should be directed towards management efforts on site-specific plans and their implementation at the landscape level to address pertinent anthropogenic drivers and their variation. For Imbirikani, this will involve implementation of its land use plan. This will be fundamental in incorporating the sociocultural component of HEC. This component has not always featured in previous management models in conflict prone landscapes.

To develop and implement an effective and comprehensive HEC mitigation plan, conflict patterns should be examined while establishing their links to anthropogenic activities. Land use planning is able to provide a long-term mitigation and prevention approach for HEC management. Therefore, HEC incidences relative to land use practices should be regularly studied. If the functionality and quality of elephant habitats is not restored, the extent of HEC events will keep increasing. Appropriate mitigation strategies are therefore necessary. There is need for restoration of natural foraging areas within protected areas as well as regulation of agricultural expansion within dispersal areas that lie in the fringes of protected areas,

Elephant repellent crops should be grown in HEC hotspot areas in Imbirikani and Isinet locations. Such crops include chillies, sunflower, moringa, ginger, garlic, onions and lemongrass depending on the ecological and socioeconomic factors. Not only do they act as deterrents, but they also provide income for households. Non-palatable crops could be used in buffer areas or on the edges of farms. Alternative livelihoods should be sought as a means for diversification such as bee keeping. Beehives have been proven to be effective in repelling elephants from farms. Beehives will also help reduce the amount of time spent guarding farms thus reducing the opportunity costs as well as providing an extra source of income from the sale of honey and other bee products. For the community to engage in such activities, they will require support from government and NGOs through capacity building and financial assistance. Other alternative livelihoods may include poultry farming and beadwork. In addition, it is important that community members engaged in farming should receive training in climate smart agriculture technologies which will increase resilience in the face of changing climatic conditions.

Communities should be empowered with understanding elephant behaviour, elephant ecology, reproduction, elephants' role as ecosystem engineers and why they need protection. With time this is likely to result in changes in attitudes toward elephants and reduce HEC as observed in this study. Women, who showed the most negative attitudes in the study, should be involved in awareness programs and in decision making.

Though KWS and other stakeholders have channeled some of the wildlife benefits to the group ranch committee, there is need for a more transparent, effective and equitable benefit-sharing programme. The design of this scheme should involve the community who do not feel they benefit much from the returns from wildlife. Additionally, the benefit sharing scheme should lay down structures for monitoring funds managed by the group ranch committee to ensure transparency and accountability in their disbursement. Direct benefits to members of the group ranch should also be considered to improve tolerance at the household level and as economic incentives to promote elephant conservation. Partnerships with the private sector can be sought for potential solutions such as microinsurance. Insurance schemes are a potential area that requires further research and could prove efficient and sustainable in mitigating the risk of HEC especially for crop farmers.

Involvement of local communities in planning and management is crucial for any conservation initiative to be successful since they bear the costs of wildlife conservation. This approach will foster positive attitudes toward wildlife and wildlife management agencies as well as fortify cooperation for elephant conservation activities and tolerance to the impacts of conservation. Communities should also be empowered to understand compatible land use options and be trained to undertake such ventures. This may involve encouraging the creation of community sanctuaries where they can benefit from ecotourism. In essence, mechanisms to incentivize conservation to discourage agriculture in wildlife habitats should be explored broadly and intensively. However, it is also important to ensure that the local community is well- equipped to manage community conservancies. It is also imperative that conservancies are not isolated but that they are ecologically connected to promote viability of elephant populations.

KWS and conservation agencies should consider deploying more personnel, particularly in the problematic animal control (PAC) units to reduce response time when elephant invasion reports are made. Slow response time was reported to increase chances of retaliating against elephants.

In addition adequate implementation of relevant national and local policies is vitally required at the grassroots level. For example, implementation of the Wildlife Act 2013 to compensate residents especially of human injury and deaths would increase tolerance of people who have suffered loss from crop depredation. Nevertheless, such deaths should be prevented from happening at all costs.

6.3 Areas of further research

Further research in a number of areas is necessary including:

1. The effectiveness of national wildlife policy in implementing community-based conservation,
2. The regulatory systems of implementation of the AEMP,
3. Projections on the impacts of climate change on HEC
4. Feasibility of market-based mechanisms to cushion agro-pastoralists from the risk of crop-raiding such as insurance schemes.
5. Studies on the medicinal value of elephant dung in Imbirikani Group Ranch

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APPENDICES

Appendix I: Household questionnaire

Questionnaire for Assessment of human-elephant conflicts

This questionnaire is designed and administered with the aim of assessing human-elephant conflicts in Imbirikani Group Ranch. The study will evaluate the relationship between land use changes to human-elephant conflicts over the last 40 years as well as the perceptions of the community towards human-elephant coexistence. Any information given will be treated confidentially and will not be used for any other purpose – April 2020.

1. Demographics Data

1.1 Household head name……………………………………1.2 Sex: 1.Male (   ) 2. Female (   )

1.3 Age of household head 1. 35yrs and below (   ) 2. >35-55yrs(   ) 3. >55-70yrs (   ) 4. >71yrs (   )

1.4 Education: 0 None (   ) 1. Primary (   ) 2. Secondary (   ) 3.Tertiary (   )

1.5 Household size/Composition

Adults	Children		No of school going children	others
	Boys	Girls		

1.6 What is the distance of your house from the highway?..................km

1.7 GPS coordinates S:……………………………. E:……………………………

1.8 Ward: …………………………………………….

1.9 Location:…………………………………………

1.10Sub-location:…………………………………….

1.11 Village:…………………………………………….

2. Land use Practices

2.1 Acreage of farm 1. 0-5 Acres ( ) 2. 6-10 Acres ( ) 3. 11-20 Acres ( ) 4. 21-50 Acres ( ) 5. >50 acres( )

2.2 How many years have you lived on the farm? 1. One year and below ( ) 2. >1-10 years ( ) 3. >10-20years ( ) 4. Over 20years ( )

2.3 Main source of livelihood: 1. Livestock ( ) 2.Crop cultivation ( ) 3. Business ( ) 4. Formal employment ( ) 5. Others ………………………………………… Alternative sources? ………………………………………………………………………………………………… …………………………………………………………………………………………………

2.4 Have you subdivided your land? 1. Yes ( ) 2. No ( )

If yes, what are the sizes of the subdivisions? 1. Below 2 acres ( ) 2. >2-5 acres ( ) 3. >5-10 acres ( ) 4. >10-20 acres ( ) 5. Over 20 acres ( )

2.5 What are the land use practices/land cover types on the subdivisions? 1. Crop production ( ) 2. Livestock production ( ) 3.Crop and livestock production ( ) 4.Forestry ( ) 5.Grassland ( ) 6. Other –specify ………………………………………………………….

2.6 In your opinion, which land use practice is most beneficial? 1. Crop production ( ) 2. Livestock production ( ) 3.Crop and livestock production ( ) 4.Forestry ( ) 5.Grassland ( ) 6. Other –specify ……………………………………………………….
Give reasons…………………………………………………………………………………
……………………………………………………………………………………………….

2.7 How do you graze your animals? 1. Freely on your farm ( ) 2. In the forest ( ) 3. Communal land ( ) 4. Zero grazing ( ) 5. Not applicable ( ) 6.Other (specify) ………………………………

2.8 Have you observed any changes in land use and cover over the past 40years? 1. Yes ( ) 2. No ( ) Explain your answer ………………………………………………………………..
………………………………………………………………………………………………...

2.9 How would you describe the changes in the following land cover types. Indicate the change in percentage

Land cover type	**Increasing (%)**	**Decreasing (%)**
Bareland		
Grassland		
Dams, swamps, water bodies		
Irrigated farmlands		
Rain fed farmlands		
Indigenous forest		
Plantation forest		
Settlements		

3. Human Wildlife Conflict

3.1 Which wild animals invade your farm? List all that apply

1. ………………………………………………..
2. ………………………………………………..
3. ………………………………………………..
4. ………………………………………………..
5. ………………………………………………..
6. ………………………………………………..
7. ………………………………………………..

Rank them starting from the most problematic to the least problematic

1. ………………………………………………..
2. ………………………………………………..

3. ………………………………………………..
4. ………………………………………………..
5. ………………………………………………..
6. ………………………………………………..
7. ………………………………………………..

3.2 How would you describe your interactions with elephants? Use Likert scale 1. Very negative ( ) 2. Negative ( ) 3.Moderate ( ) 4.Positive ( ) 5. Very Positive ( )

Explain…………………………………………………………………………………………

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

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

3.3 Have you had any problem of elephants? 1. Yes ( ) 2. No ( )

If yes, what is the nature of the problem? Tick all the applicable 1. Crop damage ( ) 2.livestock depredation ( ) 3.Human death ( ) 4.Human injury ( ) 5. Shelter ( )

6. food store destruction ( ) 7. Water structures damage ( )

7. Disruption of school-going children ( )

8. Other specify ………………………………………………………………………………..

…………………………………………………………………………………………………

3.3.1 When did you start encountering these conflicts?

Type of conflict	This year	2-5 years ago	6 – 9 years	Over ten years ago	Not applicable
Crop damage					
livestock depredation					
Human death					
Human injury					
Shelter destruction					

Food store destruction					
Water structures damage					
Disruption of school-going children					
Other					

3.4 How many such incidences have you experienced in the previous years?

Type of conflict	Once	Twice	Thrice	Four times	More than four times	Never
Crop damage						
livestock depredation						
Human death						
Human injury						
Shelter destruction						
Food store destruction						
Water structures damage						

Disruption of school-going children						
Other						

3.5 Elephants usually come during the wet season? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.5.1 Elephants usually come during the dry season? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.6 What is the group size of the elephants involved? …………………

3.6.1 What is the herd composition of the elephants involved? Adult Male …………………… Adult Female …………………… Subadult …………………… Juveniles …………………..

3.6.2 Female elephants usually come during the gestation period? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.6.3 Female elephants usually come during the lactating period? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.6.4 Female elephants usually come during the mating season? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.6.5 Male elephants usually come during the mating season? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.7 What time do they come to your farm? 1. Day ( ) 2. Night ( )

3.8 The raids are always from the same group? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.9.1 Elephants usually come during the early stage of crop growth 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.9.2 Elephants usually come during the mid-stage of crop growth 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.9.3 Elephants usually come during mature stage of crop growth 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

3.10 Can you quantify the crop damage after a raid? 1. 100% ( ) 2. 80% ( ) 3. 50% ( ) 4. 30% ( ) 0% ( )

4. Farm attributes

4.1 What crops do you grow on your farm? Tick all applicable 1. Maize ( ) 2.Beans ( ) 3.Tomatoes ( ) 4.Onions ( ) 5.Cabbage ( ) 6.Pastures ( ) 7. Water melons ( )8. Other-specify

…………………………………………………………………………………………………..

4.2 Which crops are preferably destroyed by elephants Tick all applicable 1. Maize ( ) 2.Beans ( ) 3.Tomatoes ( ) 4.Onions ( ) 5.Cabbage ( ) 6.Pastures ( ) 7. Water melons ( ) 8.Other-specify……………………………………………………………………………………

Rank the crops starting with the most preferred to the least

1. …………………………………………………..
2. …………………………………………………..
3. …………………………………………………..
4. …………………………………………………..
5. …………………………………………………..
6. …………………………………………………..
7. …………………………………………………..

4.3 Please fill in the following table

Crop type	**No of acres planted**	**No of acres destroyed**	**Quantity destroyed (2019)**	**Unit price(Ksh) (2019)**	**Estimated total price (Ksh)**
1.Maize					
2. Beans					

3. Tomatoes					
4. Onions					
5. Cabbage					
6. Pastures					
7. Others-specify					

4.4 What are the estimated costs in Ksh for the following incidents on your land, if applicable?

1. Below 10,000 ( ) 2. 10,001-20,000 ( ) 3. 20,000- 30,000 ( ) 4. 30,000-40,000 ( )

5. 40,000- 50,000 6. Above 50,000 ( ) 7.not applicable ( )

a) Food store damage……………………….
b) Human injuries………………………….
c) Water structures damage……………….
d) livestock depredation……………………….
e) Others-specify…………………………….

4.5 Do you report these incidences? 1. Yes ( ) 2. No ( )

If yes, to whom? 1. KWS Warden ( ) 2. Big Life Rangers ( )

3.Ministry of Agriculture ( ) 4.Police( ) 5.Area Chief( )

6. Other- specify……………………………………………………………………………….

4.6 How would you describe their rate of response

1. 1 week ( ) 2. 2weeks-1 month ( ) 3. 2months-4months ( ) 4. 5months- 1year ( )

5. Over 1 year ( ) 6. Never ( )

4.7 What action was taken? ....

....

4.8 Have your ever received compensation for your crops, property damage or livestock/human attacks? 1. Yes ( ) 2. No ( )

If yes, how much? ………………………..Ksh and after how long…………………..weeks

4.9 What would you describe the human-elephant conflicts in the following periods 1. Very high (more than 80%) 2. high (50-80%) 3. Moderate (50%) 4. low(20-50%) 5. Very low (less than 20%)

a) 1981- 1981 ……………..

b) 1988- 2007 ……………..

c) 2008- 2013 ……………...

d) 2014- 2019 ……………..

What do you think is the reason for the trend above? …………………………………………………………………………………………………… ………………………………………………………………

5. Practices and technologies dealing with food security, adaptation, and mitigation and on climate-information services

5.1 Are you aware about climate change? 1. Yes ( ) 2. No ( )

5.2 Climate change effects visible: 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

If in agreement, in which way

b) livestock/crop production system 1. Yes ( ) 2. No ( )

5.3 Do you practice any of the following strategies (for crops and livestock) or other enterprises on your land to mitigate against climate change? If yes, please describe briefly

	1. Yes 2. No	Briefly describe
a) Farming systems		
b) rainwater harvesting		

c) climate informed crop farming		
d) herd size management		
e) agroforestry		
f) minimum tillage		
g) integrated nutrient (such as manure) management		
h) adapted varieties		
i) adapted livestock breeds		
j) forage development		
k) seed banks		
l) water conservation (such as mulching)		

5.4 Do you think climate change has influenced the frequency and severity of elephant raids around your household? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

Explain………………………………………………………………………………………

……………………………………………………………………………………………

6. Community perceptions on human-elephant coexistence

6.1 How do you feel regarding free-roaming wildlife in ImbirikaniGroup Ranch?

1. Very bad ( ) 2. Bad ( ) 3.Indifferent ( ) 4. Good ( ) 5. Very good ( )

6.2 Rate your support for elephant conservation

1. Not important at all ( ) 2. Barely important ( ) 3. Indifferent ( ) 4.Important ( ) 5. Very important ( )

Give reasons for your answer……………………………………………………………

…………………………………………………………………………………………..

…………………………………………………………………………………………..

6.3 Elephants should be protected? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

6.4 People who poach should be punished? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

6.5 National parks are of value? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

6.6 Conservation is a waste of land? 1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

6.7 What people and their livestock/crops need are more important than saving elephants?

1. Strongly agree ( ) 2. Agree ( ) 3.Neutral ( ) 4.Disagree ( ) 5.Strongly disagree ( )

6.8 Are there any benefits (direct and indirect) you gain from elephant conservation?

1. Yes ( ) 2. No ( )

If yes, describe the benefits

1. Cash ( ) 2. Projects done with cash from wildlife conservation ( )

3.School bursary ( ) 4. Educational( ) 5. Medicinal ( ) 6. Ecological ( )

6. Aesthetic ( ) 5. Others –specify ………………………………………………………

…………………………………………………………………………………………………..

6.9 What strategies are you using to manage human-elephant conflict

a) for crops on your farm

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

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

b) to protect your livestock

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

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

c) as a community?

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

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

6.10 What would you want done by wildlife authorities so that you can reap maximum benefit from your farm? Tick all applicable 1. Community conservation ( ) 2. Fencing of forest/Conservation area ( ) 3.Translocation ( ) 4. Fencing and community conservation ( ) 5. Fencing and compensation ( ) 8. Other- specify…………………………

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

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

Would you like to share any extra comments, observations or suggestions you may have on human-elephant conflict in your area?

Thank you for your time

5 point Likert Scale for measuring attitudes

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

Appendix II: Focus group discussion guide

Question guide for focus group discussion for men, women and youth to assess the relationship between land use and land cover changes on human elephant interactions in Southern Kenya.

Objectives

I. Map land use and land cover changes in Imbirikani Group Ranch

II. Evaluate the nature and extent of human-elephant conflict within ImbirikaniGroup Ranch.

III. Assess the community perceptions towards human-elephant conflict.

1. Changes in land use systems for the last 40years (sketch resource map for 1981, 2013 and 2020)

a) Irrigated agriculture
b) Rainfed agriculture

c) Conservation
d) Settlements
e) Urban centers
f) Infrastructural development

2. Land tenure changes

i. Communal

ii. Group ranch system

iii. Clan ownership

iv. Private ownership

3. Changes in habitat types

a) Forest
b) Savanna grassland
c) Bareland
d) Swamps
e) Semi-desert
f) Desert

4. Discuss the wild animals that come around your house and rank them starting with the most problematic to the least problematic.

5. Discuss changes in elephant populations in previous years.

6. Discuss trends in human elephant conflict in previous years.

7. Discuss and rank the most affected crops by HEC.

8. Discuss mitigation strategies by the Government (County and Central), conservation agencies and the community as well as how the community perceives them.