IMPACTS OF CLIMATIC VARIABILITY ON WILDLIFE AND LIVESTOCK COMPOSITION AND PRODUCTIVITY INDEX IN MAASAI MARA NAROK COUNTY, KENYA

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DECLARATIONS

DECLARATION BY CANDIDATE

This thesis is my original research work and has not been presented for the award of any Diploma or degree in any university

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DEDICATIONS

This thesis is dedicated to my late father Geoffrey, mother Zipporah and my children Cliffton, Solomon and Vanessa for their moral support during my study.

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ABBREVIATIONS AND ACRONYMS

AASC	American Association of State Climatologists
APE	Animal Population Emulator
ASAL’s	Arid and Semi-Arid Lands
BOI	Breakdown of Offtakes and Intake
CBD	Convention on Biological Diversity
DIC	Demographic Program Input Constants
DMI	Dry matter intake
DRSRS	Directorate of Resource Surveys and Remote Sensing
FAO	Food and Agriculture Organization of the United Nations
FEE	Feed Energy Efficiency
FOC	Find Optimal Culling Practice
GDP	Gross Domestic Product
GHGs	Green House Gases
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
KWFT	Kenya Wildlife Fund Trustees
KWS	Kenya Wildlife Services
LWP	Livestock Water Productivity
MARIS	Mara Rangeland information System
MEAs	Multilateral Environmental Agreements
MDG’S	Millennium Development Goals
PRY	Prying livestock productivity

PIC	Produce Related Input Constants
RNE	Regional Office for the Near East
SAM	Stationary- State Animal Demographic Model
TOV	Total Output Value
UNCCD	United Nations Convention on Combating Desertification
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

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ABSTRACT

Climatic variability is the spatial and temporal differences or fluctuations in climatic factors that include, total annual precipitation, timing of precipitation events, the amount of rain that falls during a single precipitation event and its duration, total rainfall differences in areas that are geographically similar, temperature averages in a particular season and temperature extremes in a single season. Mara-Serengeti region is a rangeland supporting the most diverse migration of grazing animals. The study looked into impacts of climatic variability on wildlife and livestock species composition and productivity index in the Maasai Mara National Reserve and ten adjacent conservancies. The specific objectives were 1) To examine rainfall and temperature trends on wildlife and livestock numbers in Maasai Mara National Reserve and conservancies, Narok County from 1975 to 2016. 2) To establish the selected livestock and wildlife productivity index using the Prying livestock productivity model.3) To establish the selected livestock and wildlife composition in the study area using the Prying livestock productivity model. Stratified random sampling was applied to determine the sample size of 382 respondents from ten conservancies and 185 respondents from the hospitality sector and government. Questionnaires were distributed randomly within the manyattas. Interviews were conducted on key informants. Prying livestock productivity a species independent bio-economic model was used to assess productivity and composition of the animals which was compared with variations in climatic trends. Landsat images of 1976, 1985, 1995, 2000, 2003, 2013 and 2016 were acquired, analysed and classified for change detection of land cover. Statistical Package of Social Sciences and excel sheets are used for analysis of data. T-tests were used to find out significance difference at a confidence level of 95%. The null hypothesis where wildlife and livestock productivity vary significantly indicated that the FEE of livestock and wildlife grazers and browsers are not significantly different with a P-value of 0.024 and 0.028 respectively. Comparisons in composition of livestock and wildlife yielded a P-value of 0.013, therefore they were not statistically significant. The data was presented in line and bar graphs and tables. Landsat images indicated decreasing grasslands and increasing shrublands, more so from 1976 to 2016 when grasslands decreased from 88% to 75% while shrublands increased from 6% to 18%. In dry years wildlife numbers decreased from1976 and notably 1995 and 2000 when there were droughts and also 2013 and 2016, a contributing factor being the upward trend in temperatures and reduced rainfall, that was also erratic. The results show that Elephants had the lowest productivity with a Feed Energy Efficiency of 0.02 and warthog had the highest, of 0.10, yet Elephants consume large amounts of dry matter. Mixed feeders had the highest productivity with a mean of 0.062, browsers 0.056 and grazers 0.053 Feed Energy Efficiencies. Goats and sheep (Shoats) numbers increased as the wildlife decreased attributed to high percentages of breeding females and controlled management practices in livestock. The study recommends that, drought resistant forage should be encouraged to provide good nutritional feed to livestock and wild animals' to cope with climate variability, to increase the wildlife and livestock numbers. Number of water points is introduced depending on the total area to cope with dry seasons/droughts. Animal populations and their composition need to be maintained depending on the carrying capacity of the land, to avoid overstocking.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Climate is the average state of the atmosphere for a given time scale (hour, day, month, season, year, decade and so forth) for a specified geographical region. Climate change is defined as the change in climate attributed to either directly or indirectly to human activity which, in addition to natural climate variability, observed over comparable time periods (Houghton, 2002). Climatic variability is a symptom of climate change. It is the spatial and temporal differences or fluctuations in climatic factors that include, total annual precipitation, timing of precipitation events, the amount of rain that falls during a single precipitation event and its duration (quality of precipitation events), total rainfall differences in areas that are geographically similar, temperature averages in a particular season and temperature extremes in a single season (Jost, 2002).

Changes in temperature influences on the rate of precipitation and evapotranspiration that determine the climate of an area. These climatic elements control the temporal and spatial distribution of flora and fauna in rangeland ecosystems. Maximum and minimum temperatures, rainfall amounts and seasonality are some climatic factors that limit plant growth and distribution (WWF, 2001). A growing concern is that wildlife habitat conditions would be altered by climatic changes and animal composition and dominance in rangelands will change (Watson *et al.*, 1998). (Owen –Smith and Mills 2006) mention that dynamics of animal population are directly influenced by prevailing resources, human population density and environmental conditions.

According to (F.A.O, 2016), climate variability affect livestock keepers and production. With rainfall variability, animals suffer shortages in drinking, servicing water and diseases where vectors, pathogens and parasites increase, new diseases arise and transmission and distribution of diseases change. With feed crops and forages, yields and forage quality decrease, pasture composition changes especially in communities and species, production systems change, an example being going from mixed crop-livestock system to rangelands.

Generally, there is domestic biodiversity loss. Just like rainfall variability, temperature rises, forages, yields and forage quality decrease, pasture composition changes. When temperatures increase, heat stress will cause decreased feed intake and livestock yields, increases in mortality and altered metabolism and conception rates decrease. Increased temperature levels also reduce the resistance of animals, increase disease vectors, pathogens, parasites and new diseases occur. Both rainfall variability and temperature rises affect the labor force and capital by, decreased productivity, conflict for resources, migration and altered human health and resource allocation to livestock. Increased atmospheric Carbon dioxide causes pastures composition changes and partial stomata closure (FAO, 2016).

(Van de Steeg & Tibbo, 2012), further affirm that higher increased water stress through increased potential evapotranspiration may result from high temperatures. This result to net primary production above ground being reduced, livestock carrying capacity decreasing and overgrazing occurs and eventually the livestock face serious nutrient shortages in these dry environments. Impaired water cycles, soil erosion, release of carbon from organic matter, vegetation degradation and reduction in biodiversity occur due to Pasture degradation.

In developing countries growth in markets for livestock is greatest with rainforests normally storing at least 200 tons of carbon per hectare. The tonnage of carbon stored per hectare reduces to 8 when forest is replaced by moderately degraded grassland where each hectare of grazing land supports no more than one head of cattle on average and whose carbon content is a fraction of a ton. After forest and other vegetation are cut, burned, or chewed over 200 tons of carbon per hectare may be released within a short time and another 200 tons per hectare may be released from the soil beneath, not forgetting yet more Green House Gases from livestock respiration and excretions (Goodland & Anhang, 2009).

The total arid and semi-arid areas of the world covers 44.7 million $km^{2,}$ out of which arid areas form 27.3 million km^2 and semi-arid areas form 17.4 million km^2(Shahriary & Javadi, 2002).These semi-arid areas are characterised by rangelands with sparse vegetation, low productivity, high wind velocity, experiences high temperatures and high rate of evaporation, erratic precipitation, high light intensity, high soil alkalinity/salinity, sandy/roamy soils, poor water holding capacity with low moisture content, severe soil erosion, low atmospheric humidity, low agricultural potential due to rainfed agriculture, risk of crop failure, poor water quality, inadequate surface and saline underground water (Manohar *et al.*, 2017). According to (Western & Nightingale, 2005), a fifth of the earth's surface is rangeland, which is home to large migratory wildlife populations, traditional subsistence herders as well as commercial ranchers.

According to (Jost, 2002), 66% area of Africa is under fragile ecosystem or agricultural drylands, most vulnerable to degradation due to climatic variability, overgrazing and migration of animals and human population together with domestic cattle. Rangelands are fragile ecosystems that are used for livestock and wildlife grazing with 4% of the world's range areas allocated to ranches, conservancies, National Parks and other equivalent reserves. The rangelands of East Africa are heterogeneous as a result of spatial gradients of climate, soils, landscapes and disturbances (Galvin *et al.*, 2004). These areas are relatively unproductive.

These rangelands support about 80% of the nutrition of Africa's livestock population of about 184 million cattle, 17 million camels and 3.72 million sheep and goats. A vibrant tourist industry has been seen in these rangelands contributing to the National Gross Product in many countries. Human interference in rangelands has led to serious reduction in diversity and distribution of species (UNEP & WMO, 2006). This has not left out the Maasai Mara which has a wildlife dispersal area occupied by pastrolists, with increasing land subdivisions, fencing and farming.

The rangelands in Kenya cover 85 percent of the country. They consist of a variety of vegetation types that are suitable habitats for wildlife and livestock (Kinyamario *et al.*, 2003). Semi-arid areas are characterized by dry, warm to hot extensions of land with low and erratic rainfall, soils poor in nutrients that are thin and prone to salinization. The vegetation cover is limited or discontinuous. These areas are prone to increased frequency of drought, or prolonged periods of dry spell, one of the major climatic variabilities and water is a limiting factor (Watson *et al.*, 1998 & Kinyamario *et al.*, 2003). In Kenya, wildlife resource is unique and economically valuable having a significant role in a complex ecological system. The wildlife maintains checks and balances, ecosystems stability, genetic resources in addition to natural beauty that attracts tourists (Lado, 1992).

The Mara –Serengeti ecosystem supports the most diverse migration of grazing animals on the earth. During the critical points in the dry season, the Mara, which is only a quarter of the ecosystem, is crucial to survival of the entire system as it is the source of forage for the wildlife migrating through the Serengeti National Reserve. Only 25 percent of the wildlife in the Mara area is protected in the reserve. The area outside the game reserve has pressure from human population growth and expansion of wheat farming and tourist facilities in wildebeest calving grounds (Reid *et al.*, 2003). The land outside the reserve is being privatised and families are splitting it in anticipation of allocation of land parcels and as this happens, it is estimated that 40% of wildlife will be lost. (Reid *et al.*, 2003).

(Norton-Griffiths, 1994), supports this by asserting that increasing share of income in rangelands South and North of Serengeti National Reserve is from tourism, agriculture and livestock management yet the rangelands are being converted to agricultural land at the expense of wildlife conservation. (Said *et al.*, 2003), noted that Narok, Laikipia and Kajiado counties are facing loss of rangelands to agriculture.

African Conservation Foundation's, conservation report in indicates a 60% decline in wildlife populations both inside and outside the Mara Reserve since the mid 1970's. Despite 20 years of conservation efforts in the Maasai Mara region, more than half of big mammals have disappeared in the last 20 years and others may disappear in the next 20 years if nothing is done. Important in these efforts are unified efforts of the stakeholders.

Kenya Wildlife Fund Trustees (KWFT) and United Nations Environmental Programme (UNEP, 1998), summarizes problems in Maasai Mara National Reserve and Amboseli Park as human life damage, livestock and crop damage, property damage, diseases, wildlife cropping and hunting ban despite the overpopulation of some wildlife, ranch land unavailable due to cultivation and much land under parks, park boundaries disputes, grazing and watering livestock in park, lack of planning between stakeholders, traditional values of locals being eroded, overexploitation of locals by tour operators and drivers, tourism revenue flowing out, lack of education, subdivision of group ranches, misinterpretation of research goals by locals and lack of dissemination of research findings to the locals.

In a study on declining wildlife populations in Kenya carried out by (Ogutu *et al.,* 2016), wildlife species populations of 18 of the most common species had declined to less than one third in the Kenyan rangelands from 1977 to 2013 some going to an extent of being rated either vulnerable or endangered. However, sheep, goats and camel numbers increased while cattle numbers decreased. This was attributed to increase of human populations in rangelands, human wildlife conflicts and climate change.

1.2 Problem statement and justification

Climate variability plays an important role in influencing animal species composition and productivity indexing. Therefore, this research was conducted in Maasai Mara area to study the relationship of climate variability on wildlife and livestock species composition and productivity indexing in the Maasai Mara region, Kenya.

Wildlife tourism is important to the economy of Narok including supporting the local livelihoods yet the numbers of wildlife in Kenya and in the East African rangelands in general are declining. The populations of wildlife in Maasai Mara have declined at an alarming rate as a result of the expansion in agricultural activities, encroachment and habitat loss from the 1980s (Lamprey & Reid, 2004). Other reasons for the decline in wildlife numbers include drought, floods, poaching, and anthropogenic reasons.

However current and future vulnerability will be different than in the past, even if climate were not to change since the society and the environment as well change (American Association of State Climatologists, 2001). (Ogutu & Norman, 2003), after carrying out similar studies in South Africa, say that in East Africa, studies on climate and population dynamics were scarce and suggested that climatic shifts could be causing population declines among large mammal species diversity elsewhere in Africa. (Verdin *et al.*, 2005), expressed an urgent need for increased African capacity for rainfall observation, forecasting, data management and modelling applications to manage climate change and variability in order to devise coping strategies.

African savannahs which are the most extensive ecosystem are the richest grasslands in the world with rich mammal diversity (United Nations Framework Convention on Climate Change, 2006), yet threatened by climate change. Narok County is semi-arid and is dependent on wildlife-based tourism. Just like other East African rangelands, Narok County has witnessed a decline in wildlife numbers over the years (Waithaka, 2004; Muthiani & Kristjanson, 2003; Trollope *et. Al.*,2003). The area, being a rangeland depends on the wild fauna, key to the wildlife-based tourism, a key contributor to the Kenyan economy.

A lot of work has been done on droughts, but scanty information exists on the effect of climatic variability productivity indexing and composition of animals. According to (Thornton *et al*., 2014), there are substantial limitations in impact models, at all scales including models of crops and livestock and on the effects of variability on the quantity and quality of crop and livestock production. They also emphasize extending the applicability of current crop and livestock models to the higher-temperature and projecting of more variable climates as increasingly likely under higher greenhouse gas emission scenarios.

Different scenarios of climate– animal, interaction ecosystem models have largely been covered in the Maasai Mara ecosystem. According to (Galvin *et al.*, 2004), there is likelihood that the nature of climate variability pattern that pastoralists are used to coping with has changed. In the past, pastoralists were able to track climate variability due to centuries of exposure to intra and inter annual droughts. There is need to understand inter-linkages between climate variability and biodiversity changes in rangelands ecosystems. This study therefore intends to examine impacts of climatic variability on wildlife and livestock composition and their productivity in Maasai Mara, Narok County.

1.3 Research questions

The study was guided by the following questions: -

(i) How do climatic factors influence wildlife and livestock numbers in Maasai Mara? (Kenya Meterological Department and DRSRS)

(ii) What are the productivity indices of the livestock and wildlife species studied within the study area? (Wildlife and livestock inherent parameters from measurements and information from respondents)

(iii) What is the composition of the livestock and wildlife species studied within the study area? (Wildlife and livestock inherent parameters from measurements and information from respondents)

1.4 Research Hypotheses

H_1: Climatic variations have not impacted on livestock and wildlife in the Maasai Mara region, Narok County from 1975 to 2016.

H_2: Wildlife and livestock productivity indexes vary significantly.

H_3: Wildlife and livestock composition vary significantly.

1.5 Objectives of the study

The Broad objective of this study is to determine impacts of climatic variability on wildlife and livestock composition and productivity index in the Maasai Mara, Narok County, Kenya.

The specific objectives of the study are:

1. To examine rainfall and temperatures trends on wildlife and livestock numbers in Maasai Mara National Reserve and conservancies Narok County from 1975 to 2016.
2. To establish the selected livestock and wildlife productivity index using the Prying livestock productivity model (PRY).
3. To establish the selected livestock and wildlife composition in the study area using the Prying livestock productivity model.

1.6 Significance of the study

Kenyan drylands are characterised by changes in climate that affect livestock productivity. Reduced livestock productivity leads to enhanced poverty levels. According to (Galvin *et al.*, 2001), rainfall seasonality in arid and semi-arid areas, affects forage availability, livestock production and ultimately the livelihoods of the pastoralists.

Wildlife in the Maasai Mara attracts a lot of tourism generating millions of dollars annually contributing social, economic and environmental sustainability as per the (Agenda 21 of Rio, 1992 & Waithaka, (2004). This study will contribute to improved understanding of synergies between land use and climatic variability, which is important in implementation of some Multilateral Environmental Agreements (MEAs). These include United Nations Convention on Biological Diversity (CBD), the United

Nations Convention on Combating Desertification (UNCCD) and United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC came into force in 1994 with an aim of stabilizing greenhouse gases concentrations in the atmosphere at a level which would prevent dangerous anthropogenic interference with climate system (Hulme, 1996). This is in turn expected to contribute to improved management of livestock and wildlife enterprise in Narok thereby contributing to poverty alleviation in the study area as they are some of the income earners in the region.

The study findings drew the inter-linkages to enable the affected communities improve land use practices in their specific location as influenced by climatic variability. This assisted in community-based climate change mitigation practices. The research findings also benefited the government agencies, County government and Non-Governmental Organizations operating in Narok. The findings could be replicated in other similar ASAL areas by influencing policy through the incorporation of climatic information in land use planning and management as well as management of livestock and wildlife. Sustainable community coping strategies with climatic variabilities in rangeland ecosystem of Kenya could be designed.

The animal species composition and productivity data, for the area will be important in agriculture in general, especially in livestock management, water supply, as well as the wildlife management in the study area and other areas with similar conditions.

1.7 Scope of the study

1.7.1 Scope

The study was based in the Maasai Mara area, Narok District in South Western Kenya. The National Reserve covers 1510 km^2 with an adjacent 3000 km^2 dispersal area owned by the local Maasai. The Maasai Mara ecosystem has one of the richest wildlife assemblages in the world with 237 herbivores per Kilometre Square that are supported and promote tourism in East Africa. The study focused on herbivores and livestock. Two important parameters of climate, rainfall and temperature were considered up to 2016.

1.8 Conceptual framework

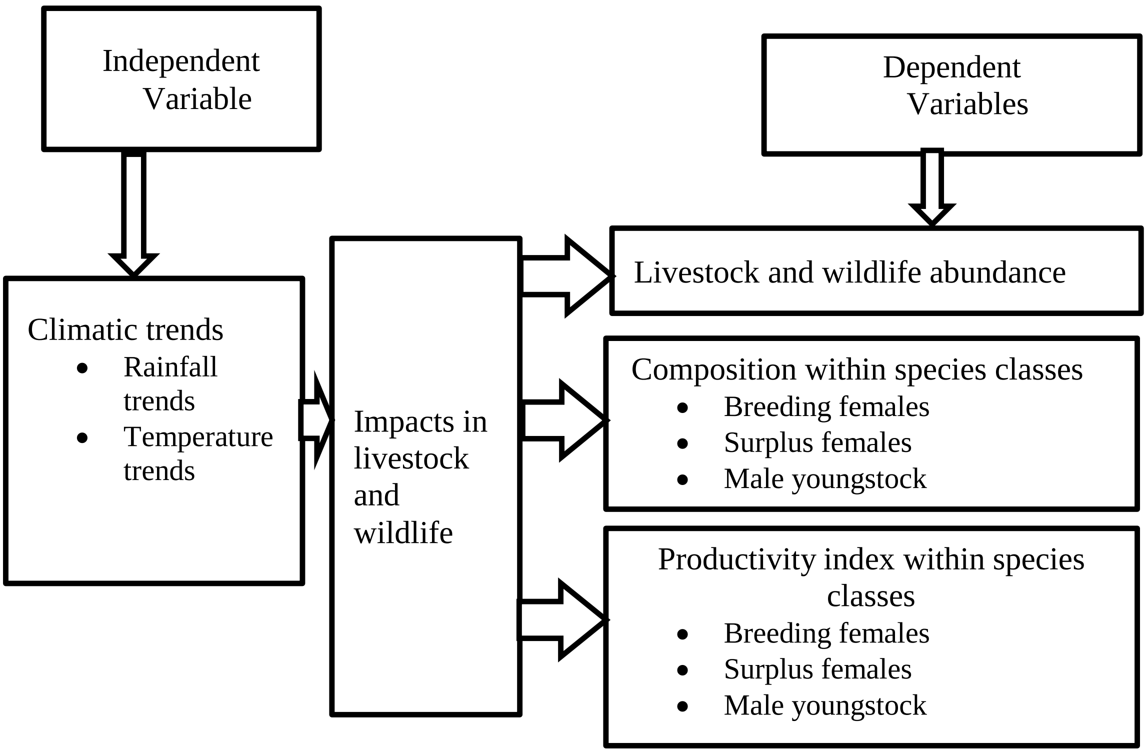

Figure 1.1 Conceptual framework

e portion of income in the rangelands. Increase in their numbers improves income levels but can at the same time increase land pressure. The inherent and produce related traits of animals are distinct within the different animals and will largely affect their productivity and composition.

Rainfall decreases, irregularities and temperature increases have contributed to decreasing animal numbers, in addition to other factors like human encroachment. PRY modelling with imputed specific animals demographic and produce related imputs distinguishes the composition and productivities within the various classes within species. These climatic parameters trends combined with the PRY model outcomes (composition and productivity in breeding females, surplus females and male youngstock) gives a picture of the future of the animals in the ecosystem.

Increases of animal numbers with high productivity and composition creates a scenario of high potential in sustainability of the species but at the same time a need for caution due to pressure on natural resources in the ecosystem. A reverse of this where composition and productivity within species is low with unfavourable climatic conditions depicts an imbalance or decline in number of livestock and wildlife calling for improved management systems to control the drop in numbers and need to improve breeding in the ecosystem.

Productivity and composition classification according to breeding female, surplus female and male youngstock determined the animals that are likely to have numbers controlled and the ones that need to be retained for a proper balance and protect the integrity of the ecosystem.

1.9 Definition of operational terms

The operational terms used in the study are explained below.

Adaptation	These are adjustments in natural or human systems in response to actual or expected climatic stimuli effects or their effects which moderate farm or exploit beneficial opportunities (IPCC,2007).
Biodiversity	This are the changes *and variability of the living organisms on Earth. 'These sources include, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.'* (Convention on Biological Diversity, 1992).
Carbon sinks	These are portions of the ecosystem with the ability to absorb certain quantities of carbon dioxide, including forests and oceans.
Climate	Refers to the mean condition of the atmosphere including wind, humidity, temperature, precipitation, pressure and their variations over a long span of time in a given locality (Ogola *et al*., 1997).
Climate variability	This is variations in the mean state and other characteristics of climate "on all spatial and temporal scales beyond that of individual weather events." Climate variability may occur at random time does not appear to be caused systematically.

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Climate change	Climate change refers to long-term changes between the averaging periods either in the mean values of climatic variables or in their variability (Ribot *et a.*, 1996). The United Nations Framework Convention on Climatic change's definition is *a change of climate, which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural variability observed over comparable time periods (*Ogola *et al.*, 1997).
Climate stabilization	The policy of reducing fossil-fuel use to a level that would not increase the potential for global climate change.
CO_2 equivalent (CO2e)	Measure of total greenhouse gas emissions/concentrations, converting all non- CO_2 gases to their CO_2 equivalent in warming impact.
Drylands	Refer to all types of arid areas that are characterized by evaporation exceeding precipitation. They are created when climatic, topographic or oceanic factors bar moisture bearing weather systems reaching that zone. They include hyper-arid, arid, semi- arid and dry- sub humid characterized by wide temperature.
Global warming	Rising global mean temperature resulting from enhanced Green House Gases effect as a result of GHG concentration increase in the atmosphere.
Livestock Water Productivity	The ratio of the net beneficial animal products and services, produced in an agricultural production system to the amount of water depleted as a cost of producing them (Oweis & Peden, 2008).

Mitigation	Anthropogenic intervention to enhance the sinks or reduce the sources of GHGs to reduce magnitude of long term impacts of climate change.
Prying Livestock Productivity (PRY)	is a herd and flock dynamics model, which is a microcomputer Package that uses fitness characteristics traits, yield levels, unit produce values, energy for and culling practice to assess productivity referred to as productivity indexing.
Rangelands	Land carrying natural vegetation which provide suitable habitats for herds of wild or domestic ungulates or both. Consist of grasslands, savannahs and woodlands.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

The chapter reviews literature on climatic variability causes and consequences on biodiversity, livelihoods and economies that depend on that biodiversity. Climate variability and components including, temperature and rainfall and their role in variability are explained. The chapter also looked into the impacts of climatic variability on Wildlife and livestock productivity, adaptation and mitigation of Green House Gases in livestock systems.

2.1 Causes and consequences of climatic variability

Climatic variability may be caused by increased carbon dioxide levels in the atmosphere. Further, (Hoffman & O'Connor 1999; Schneider *et al.*, 2002) asserts that, atmospheric concentration of CO_2 and other gases are increased by human activities due to the burning of fossil fuels which intensifies the greenhouse effect on the earth. Large volumes of greenhouse gases are released to the atmosphere and causes climate variability due to human activities within industrial era.

Carbon dioxide, nitrous oxide and methane have increased mainly as a result of human induced activities. Methane and nitrous oxide emissions from agriculture and industry increased burning of fossil fuels such as coal, oil and natural gas manmade chemical substances such as chlorofluorocarbons (CFCs) all contribute to the greenhouse effect (Pethika & Ostriker, 2015; Harris *et al.*, 2017; Schneider *et al.*, 2002).

(Bast, 2010) further explains that, anthropogenic/man-made (AGW) global warming is the theory of climate change that most people are familiar with. The theory holds that, predominantly the cause of the global warming that occurred during the past 50 years is man-made greenhouse gases, primarily carbon dioxide. Chemical and biological processes bring about negative feedbacks entirely or almost entirely offset whatever positive feedbacks might be caused by rising Carbon dioxide.

Physical properties of the surface of the earth and processes of energy transfer within the atmosphere always influence on climatic variability. Impacts of climatic variations are mainly global warming, sea-level rise, changes in rates of evaporation and in rainfall patterns which causes water scarcity and drought especially in the arid and semi-arid regions, but in in high rainfall causes deterioration of water quality, flooding, soil erosion, destruction of biota, change in plant species composition will be experienced (Ogola, 1997).

(UNFCCC 2006), asserted that floods are recurrent in some African countries, occurring even in dry areas. This results to erosion of fertile soil, burying water canals and increased evaporation, respiratory problems and degraded infrastructure. Reduced water availability is expected due to increase in temperature, reduction in precipitation and changes in sea level. Agricultural production declines and causes food shortages to increasing human population.

Lack of financial, institutional and technological capacity makes Africa vulnerable to climate change. (Frank, 2003) noted that, varied precipitation results in periods of drought stress that reduces green biomass and photosynthesis activity in plants.

Livestock affected by drought show decrease in weight, animal production and decrease in water resources for drinking and improper grazing distribution in the rangelands that lowers the productivity of animals (Shahriary & Javadi, 2002). Productivity of animals is decreased directly through higher temperatures and indirectly, as a result of changes in fodder quality and feed availability. Management of various National Parks have been hit by fluctuations in livestock numbers. Reasons for such declines to the parks management could be attributed to; change of the habitat, land use conflicts, land degradation, climate variability, decline in pasture quality and quantity (Gamba-Ssemebajjiwe, 2004).

In a study conducted in Kalahari on large herbivores that included ostrich and livestock, monthly and accumulated rainfall figures and distance to water pans were compared to group sizes. Favourable conditions account for the concentration of herbivores due to abundance and good food quality, salt/mineral licks and availability of water at the pans. In some areas animal numbers and group size correlated with rainfall (Bergstom & Christina, 1999).

(Omenda, 1997) mentioned that, positive impact of climatic variability include, elevated Co_2 levels that may modify physiological behaviour in plants, photosynthesis rates may increase as Co_2 is an important substrate, increased growth rates, increased productivity and efficiency in water use. These depend on location, water and nutrient statues, development stage, plant species and variety. Climate variability however has negative outcomes like changes in atmospheric chemistry, feedbacks of ecosystems, competition for limited soil based resources, higher temperature influence on respiratory systems and photosynthesis.

According to (Pethika & Ostriker, 2015; Harris *et al.*, 2017; Schneider *et al.*,2002), Carbon dioxide is a greenhouse gas that's important to the Earth's energy balance. Energy arrives at Earth, essentially all of it in the form of sunlight. The Earth then loses energy to the cold vacuum of space. Earth's temperature will be said to remain constant when there's a balance between the incoming sunlight and the energy lost to space. Sulfate aerosols are formed by gases emitted from Coal-fired power plants burning high-sulfur coal. They reflect incoming solar radiation and these results in a cooling trend. Volcanic eruptions and the evaporation of seawater form Natural aerosols produce a cooling effect.

(Harris *et al.*, 2017), adds that Greenhouse Gases continue to affect the entire planet's climate long after they are emitted as they persist in the atmosphere for decades or even centuries. Stabilizing or "freezing" emissions will not solve the problem since Carbon dioxide and other greenhouse gases continuously accumulate in the atmosphere. To prevent these ever-increasing atmospheric accumulations major reductions in emissions, need to be effected. Carbon dioxide atmospheric concentration passed the milestone of 400 ppm in the year 2015. With the inclusion of other greenhouse gases, a Carbon dioxide equivalent **(**Co_2**e),** a concentration of 430 ppm or more is reached yet this has not been experienced in over 800,000 years.

(Ogola, 1997) reported that, ecosystem processes can be affected directly by greenhouse gases. Variations in climate have shown an upward trend in temperature. An example of the effect of the greenhouse gases is the global average temperature rise by 0.6^{O} C during the 20th century with a projected 1.4^{O} C rise in the 21st century. This leaves most ecosystems vulnerable to this projected rate and magnitude of climate change (Chiran, 2003).

Rises in global average surface temperatures of 1.0 to 2.5 degrees Celsius are estimated by the year 2100 and precipitation will rise by 10 to 15 percent since a warmer atmosphere holds more water. All these are results of increases in atmospheric concentrations of greenhouse gases thus doubling of carbon dioxide. Perennial plants make the best use of soil and climate in the long dry season. They protect themselves through a range of morphological and physiological mechanisms and protect plants growing under their shelter by biological and microclimate improvement of the environment. The main perennial plants in arid lands are palms, woody and succulent species. Annual plants are vulnerable to fluctuations in climate (Salem & Palmberg, 1980; Wickens *et al.*, 1984).

Biodiversity losses affect intricate web of forest life and are likely to interfere with the food chain. Increased greenhouse gases concentration and accompanying change in climate in the coming 50 to 100 years is likely to result in natural communities' disruption and extensive of population and species in a large scale (Omenda,1997). Examination of these and also documentation is little accomplished for the vast communal lands of Kenya. Reduction of natural vegetation zones as a result of variability in climate is a good indicator of how significant climate change may be in environmentally related aspects-wildlife habitat, tourism and agriculture among others. Effects are being felt widely with recurrent droughts, poverty, floods, overdependence on rain-fed agriculture, inequitable land distribution and settlements affecting disadvantaged populations (Hulme *et al.*, 1995).

Climate change in addition to other non-climate factors may affect distribution and prevalence of infectious disease vectors, which might lead to increased mortality and morbidity from diseases like malaria and cholera (Downing & Patwardhan, 2006). Ecosystems in Africa, according to historical evidence are faced with adverse impact from existing climate variability the nature of which will almost certainly be altered by long term climate changes. An example is that climate variability is the major driver of major change in rangelands (Brown & Havstad, 2004).

Loss and fragmentation of rangeland ecosystems according to (Reid *et al.,* 2004), has led to the following: - Reduction in abundance and richness of species, loss in genetic variation, breeding failure, changes in the fitness of species and population, changes in biophysical environment. African continent wide changes in the distributions of species and ecosystems, changes in gene frequencies within population are all effects of ecosystem fragmentation.

Climate variability effects ecosystems, with some areas becoming drier, others humid impacting on farming conditions. The Intergovernmental Panel on Climate Change's third assessment report indicated that climate change may bring about changes in food security and water resources especially in length of growing seasons, precipitation and carbon uptake, availability of water, desertification, changes in flood risks, incidences of extreme weather events, human diseases, plant pests distribution and prevalence. Overall reduction in agricultural productivity and yields including rangeland and livestock production may occur due to increased temperature and reduced precipitation as a result of climate change (IPCC, 2001).

According to (Pethika & Ostriker, 2015), the shifting of climate patterns between El Niño and La Niña events are the biggest cause of droughts and floods around the world. In many tropical and subtropical areas El Niño events favor drought on land. Wet conditions in many places are due to La Niña events as has happened in recent years.

Variability of natural climate in Africa in terms of temperature and rainfall is large. Severe drought or prolonged desiccations over one or more decades in different parts of the continent are manifestations of climate variability (Watson *et al.*, 1998). Droughts in rangelands are common, characterized by low precipitation in relation to long-term averages and precipitation of less than 75% of the average amount. Climate variability can trigger desertification. Biodiversity has been affected with some medium and small sized mammals becoming extinct (Pickup, 1998).

According to (Wodon *et al.*, 2014), economic activities are affected when agricultural crop production, livestock, or water availability decrease due to climate and subsequent environmental degradation all leading to migrations to urban areas or where there are improved services, opportunities like employment, well-established community networks that help reduce uncertainty and risk, and available housing. The most vulnerable individuals or organizations are those that use climate information to make decisions and their interests are affected by climate anomalies referred to as users of climate information as those involved in health, water resources, agriculture, food security, energy and transport. The table 2.1 analyses the sectors, climate related risks and the consequent impacts (WHO, 2005).

Table 2.1: Specific sectors, climate related risks and consequent impacts

Sectors	Climate related risks	Impacts
Agriculture	Flood, heavy rainfall, hailstorm	Effects on early seedlings, damage to crops and submergence, inefficiency of applied fertilizers; damage to food and shelter for livestock; worm infestation
	Drought	Early establishment in high lands, low plant stand, damage to crops; outbreak of diseases such as black quarter, anthrax in cattle, increased risk of wildfires
	High/low temperature	Yield reduction; diseases such as foot-and-mouth disease, peste des petits ruminants in cattle, heatstroke and production loss, cold stress and production loss
Tourism	High/low temperature	Travellers may be subject to sudden changes in temperature and the body requires time to adjust
	Radiation	Harmful to skin and eyes
	Wind	Adds to the discomfort of people, especially when laden with moisture
	High humidity and temperature	May lead to dehydration and even fatality
Water resources	Heavy rainfall	Increased river discharge, inundation, dam management
	Dry spell	Poor water quality, reduced water resources, effect on reservoir management and freshwater distribution in urban areas

(Source: WMO, 2005)

(Mary, 2011), summarizes the principles of climate justice, a human centered approach achieved by linking human rights and development to safeguard rights of the most vulnerable, equitable and fair sharing of benefits and burdens of climate change. The principles include, respecting and protecting Human Rights around internationally agreed values around where common actions can be negotiated and then acted upon with due respect of a person's dignity. Also Supporting the Right to Development, where combined mitigation and adaptation efforts include the poor especially by scaling up and transferring green technologies and supporting low carbon climate resilient strategies. Another principle is to Share Benefits and Burdens of climate change equitably and fairly. The responsivities and capabilities in reducing greenhouse gases need to be accepted with those emitting most acting first. Those accumulating wealth and benefiting from the emissions through industrialization, having an ethical obligation in sharing benefits with those affected by the emissions, have them embrace and access low carbon developments and have opportunities to adapt to the impacts of climate change especially in the developing countries.

Decisions on Climate Change are Participatory, Transparent and Accountable is another principle that highlights hearing and acting upon the voices of the persons most vulnerable to climate change. Also for the growth of a culture of climate justice, they need to have an opportunity to participate in decisions that should be accountable, fair, open and corruption-free especially in policy developments and policy implementation.

Highlighting Gender Equality and Equity Harness the Transformative as a principle that looks at different genders being affected by climate change differently with the women greatest affected yet they are very important agents of change in their communities and bear the bigger burden in poverty situations. Therefore, their voices should be on the forefront in climate justice. Power of Education for climate stewardship is a principle that calls for environmental education at all education levels and informally including web-based channels for all to be aware and conscious of climate change. Using Effective Partnerships to Secure Climate Justice is a principle that integrates solutions to climate change within states and across boundaries. This includes involving partnerships of those most and least affected by climate change with pooling of resources and skill sharing world over. The principle of partnership points in the direction of solutions to climate change integrated both within states and across state boundaries (Mary, 2011).

(Chevron Human energy, 2014) on their part considers some four principles as guideposts for climate change policies development. Global engagement and action is required in reducing greenhouse gas emissions. Balancing and measuring policies ensuring long-term economic, meeting of all environmental and energy security needs, equitable costs allocation, gradual and predictable way and actions consider both Green House Gases mitigation and climate change adaptation. To enable long term significant and cost-effective mitigations to climate change there is need for continued research, innovation and application of technology. Lastly, global consumers receive transparent and open communication on the costs, risks, trade-offs and uncertainties associated with Green House Gases reduction and climate change adaptation efforts and policies.

According to (Mwanga, 2015), human growth, economy, ecosystems, water resources, food, health, coastal zones and industrial activities are affected by climate variability and has become the most considerable challenge of the times in Kenya.

2.2 Temperature

An increase of Earth’s average surface air temperature by about 0.8 °C equivalent to 1.4 °F since 1900 is evidence of Climate warming taking place since the mid-1970s (Pethica & Ostriker, 2015). Global temperature assessments show that since instrumental global average surface temperatures first became available in 1850, except the year 2008, the warmest decade was the one between 2001–2010 with a combined Global sea and land surfaces mean temperature estimates of 0.47°C ± 0.1°C above the 1961–1990 average of 14.0°C. The warmest year was 2010 and was closely followed by year 2000 (WMO, 2012).

On animals live-weight, activity like walking long distances and environmental temperature (too cold or too hot) influence the nutrient requirements for maintenance of animals (Infonet Biosystems, 2016). In Kenya and Ghana, correlations have been identified between high ambient temperatures and mortality in human. An example is Malaria spreading to highlands where it was not present in Kenya, Rwanda, Burundi and Ethiopia due to population movement from lowlands to highlands (Olivia *et al*., 2015).

2.3 Precipitation/ Rainfall

Since the decade of 1971–1980, the decade of 2001 to 2010 was the first to record above-global-average land surface precipitation with only 2001, 2002 and 2009 years less-than-global average precipitation while 2003 recorded a near-average value. The year 2010 after 1956 and 2000, recorded the wettest year globally for all time and in the decade 2001 to 2010. On average 2002 was the driest year of the decade 2001 to 2010. In 2003, most parts of Asia and West Africa received Wetter-than-normal conditions but below-normal precipitation. Wetter-than-normal conditions dominated 2004. The year 2005 was dry especially in East and Central Africa and the Greater Horn of Africa region. In 2005 above-normal precipitation records were experienced in Northern Africa. In 2006, a wetter-than-normal trend was experienced in most parts of Africa. Above-average precipitation was recorded in north-western and southern Africa in 2009. In 2010 most areas globally including Sahel in Africa received above normal precipitation (WMO, 2012).

Changes expected in East Africa include floods, increased number of dry days, sea level rise, projected around 30% increase in ground water recharge, infrastructure and health impacts (UNFCCC, 2006). Another scenario is that heavy rains likely in East Africa with infiltration limits may also lower ground water recharge. In East Africa rainfall seasonality affects availability of forage and livestock production (Galvin *et al.*, 2004).

The El-Niño flooding in 1997-1998 and consequent La-Nina drought in 1998-2000 in Kenya led to 10-16% annual damage of Gross Domestic Product. Hydro power production also decreased by 41%, agricultural losses and elevated industrial production costs as a result of drought. Reduced agricultural yields due to rainfall extremes have led to reduced Gross Domestic Product. Agricultural output has fallen by 2.66% with every 1-degree increase in temperature. Agricultural production heavily dependent on precipitation may decrease (UNFCCC, 2006).

According to (Ericksen *et al*., 2012), its projected that some 1.8 million extra cattle in Kenya could be lost by 2030 as a result of increased drought frequency, with a value of the lost animals and production foregone amounting to US$ 630 million. A study by (Ogutu *et al.*, 2016) on wildlife populations and livestock numbers in the rangelands of Kenya from 1977-1980 and 2011-2016 showed increases in livestock numbers and decreased wildlife numbers in Narok.

2.4 Livestock and climatic variability

Forty five per cent of the global surface area is occupied by Livestock systems with a value of at least $1.4 trillion. At least 800 million poor smallholders in the developing world are directly supported by Livestock industries and value chains and employ at least 1.3 billion people globally. Livestock provide an important nourishment source with a contribution of 33% of protein and 17% of calories consumed globally. Sixty percent of the global poor depend on livestock for some part of their livelihoods. About 90% of the global 1.3 billion poor are found in Asia and sub-Saharan Africa (Thornton *et al*., 2014b). Sub-Saharan Africa and South Asia are the regions identified as the most vulnerable to climate change, and are where farmers and rural communities rely the most on livestock for food, income and livelihoods, and therefore expected contribute immensely to nutrition and food security (FAO, 2016).

A major cause of global warming is livestock and livestock systems. This means that climate change and variability will have major impacts on poor livestock keepers, the services and on the ecosystem goods on which they depend. Methane, Carbon dioxide and Nitrous oxide are the main greenhouse gases from livestock systems. Methane from animals contributes 25%, nitrous oxide from manure and slurry 31% while carbon dioxide from land use and its changes contributes 32%. A total of 18% global anthropogenic greenhouse-gas (GHG) emissions are contributed by Livestock. However, the amounts of Green House Gases emissions from livestock are believed to be modest compared to other activities and considering the huge number of livelihoods supported and increased resilience of vulnerable poor people through diversification of risk and increasing assets (Thornton *et al*., 2014b).

(FAO, 2016) summarizes sources of emissions in livestock value chains as 9.7% from manure management further broken to (5.2% Manure Management Nitrous oxide, 4.3% Manure Management methane), 4.7 % energy consumption (2.9% Post farmgate Carbon dioxide, 1.5% Direct energy use Carbon dioxide, 0.3% Indirect energy use, Carbon dioxide) , 46.7% feed, (16.4% Applied & deposited manure, Nitrous oxide, 13% Feed, Carbon dioxide, 7.7% Fertilizer & crop residues, Nitrous oxide, 0.4% Feed Rice, Methane, 6% Soybean, Carbon dioxide, 3.2% Pasture expansion, Carbon dioxide) 39.1% due to enteric fermentation. Methane gas is produced when ruminants digest in a process called enteric fermentation. Methane (CH_4) is an important Green House Gases because, it traps 84 times more heat than Carbon Dioxide (CO_2), has an atmospheric life span of 12 years hence a short lived pollutant, it is responsible for half of the observed rise in ozone levels and accounts for 1/3 of climate forcing. Natural sources of anthropogenic Methane account for 40% while 60% is from human activity (Enteric fermentation 30%, manure 4%, Rice 10%, fossil fuels 25%, landfills 12%, biomass burning 3%, waste water 9%, others 7%), (FAO, 2016).Green House Gases have also been produced in Ruminant production systems when they use fossil fuels and electrical power (Mara *et al*., 2008).

2.5 Adaptation and mitigation of Green House Gases in livestock systems

According to (Tibbo *et al*., 2008), supplementation is also a strategy for animals reared mostly for market, since marginal rangelands only produces a third of the livestock feed requirements. Drought resistant fodder can be grown to supplement or be used to make nutritious low-cost feed blocks which are made from cheap, easily available agro-industrial by-products and contain multiple nutrients. (Van de Steeg & Tibbo 2012), highlight that rain fed farming can become more sustainable with better technologies and better ways of managing farm inputs. There is need for Research into farming methods to obtain information on increasing carbon dioxide levels arising from the primary productivity changes of species, their distribution and the rangelands carrying capacity.

(Goodland & Anhang, 2009), emphasize that the best strategy to reverse climate change is to have better alternatives to replace livestock products that can reverse ongoing water and world food crises in addition to reducing Green House Gases in the atmosphere. The approach will record more rapid results than replacing fossil fuels with renewable energy when it comes to Green House Gases emissions and their atmospheric concentrations. A total of 51 percent of annual worldwide Green House Gases emission are attributed to livestock and their byproducts amounting to at least 32,564 million tons of Carbon dioxide equivalent per year.

(Goodland & Anhang, 2009), further deals with livestock breathe as an anthropogenic cause of Green House Gases accumulation and compares of Carbon dioxide exhaled by livestock to an auto tail pipe. Presently livestock in tens of billions are exhaling more Carbon dioxide than in preindustrial days. As forests are cleared the earth's photosynthetic capacity has declined yet we continue overwhelming the carbon absorption by adding carbon to the air by burning fossil fuels.

In Adaptation to spatial and temporal variations in precipitation, mobility remains the most important for pastoralists and even more important with climate change yet this but has been affected by encroachment, privatization of communal grazing lands and settling for human services and food aid access, making pastoralists more vulnerable to climate change as a result of less mobility (Thornton *et al.,* 2014b). Animals will also have to cope with less watering and walk long distances for watering, move to areas with unfamiliar diseases, parasites and disease due to overcrowding, overgrazing neighborhoods all due to climate variability. Average distances trekked have tripled in the drought years. To reduce emissions from livestock farming and increase carbon sequestration in agro-pastoral systems, policies that foster the adoption of a wide range of technologies and management practices that are available can be adopted to reduce the sector's contribution to climate change.

Enhancing rangeland productivity is a strategy being employed by pastoral communities in an environment where resource base is declining an example being Southern Ethiopia Borana rangelands. This is where traditional range enclosures are used for seasonal grazing by calves and sick/weak animals addressing pasture unavailability in dry seasons for milking animals around sedentary homesteads (Thornton *et al.*, 2014b; Van de Steeg and Tibbo., 2012; Van de Steeg *et al*., 2009).

Green House Gases emissions from livestock systems can be reduced through technologies, policies and incentives in several ways; Healthier people will be realized in the developed world and reduction of pressures on land and natural resources in developing countries with reduction in demand for livestock products. In semi-arid lands a major limitation to livestock production is Livestock feed security. Amounts of methane produced per unit of animal product will be reduced with better quality fodder for ruminants, an example being improved fodder technologies like improved pasture species, legumes, fodder banks and supplementation with crop by-products. Compared to emissions from grass-fed animals, those fed on legume forages have been observed to emit less Methane. Reduction in methane emissions as a proportion of energy intake is seen with a higher proportion of concentrate in the diet. Reducing emissions have been observed with improving pasture quality, especially in less developed regions, because of improvements in animal productivity and a reduction in the proportion of energy lost as methane. Cereal silages including maize, when fed to ruminants may give reduced methane emissions compared to grass silage since starch in the cereal silages gives higher propionate fermentation (Souzana *et al*., 2010).

Shifting of livestock species and use of more productive breeds by replacing low producing breeds with fewer high potential breeds by crossbreeding of changing breeds suiting a certain environment for higher productivity, while still maintaining or increasing the supply of livestock products will reduce total emissions. Another strategy is Introducing manure management regulatory frameworks to reduce nitrous oxide. Green House Gases emissions can be reduced by integrating crop-livestock system especially in the developing world where livestock are fed on crops and crop residues and the manure used as crop-livestock systems fuels like ethanol or diesel and nutrient source for crop production. Adopting grazing systems that enhance Carbon dioxide removal from the environment by increasing carbon reserves by increasing the photosynthetic uptake of carbon, or slowing the return of stored carbon to Carbon dioxide via respiration, fire or erosion. Up to four percent of global Green House Gases emissions could be offset through soil carbon sequestration by the world's permanent pastures (Thornton *et al*., 2014b; Mara *et al.*, 2008).

Adjusting the diet of animals to reduce metabolic heat production and cooling systems use are being used to alleviating the effects of high temperatures. To adapt to climate change, expanded use of weather information to rural pastoral communities will help them make better decisions in management of their enterprises. Weather-indexed Livestock insurance schemes will ensure that policy holders are paid in response to 'trigger events' such as or high local animal mortality rates or abnormal rainfall leading to poor crops. This has been done in Northern Kenya through International Livestock Research Institute and there are some insurance companies selling farming insurances. Some livestock farmers change the mix of livestock species by either changing herd composition or species mix to deal with drought, and better suited to particular environments, an example being changing cattle to goats that are more adapted to hotter weather. Productivity per animal for the resources available could be higher with this strategy (Thornton *et al*., 2014b).

In the Sahel, species substitution due to vegetation and climate changes is being carried out. An example is cattle and sheep that feed on herbaceous vegetation which has been overused, being replaced by dromedaries and goats respectively that browse on trees and shrubs thus well adapted to the climate. Camel rearing is now a common activity in countries like as Niger and Mauritania since they also browse. Enabling institutional environments for long term climate adaptation can be done by emphasizing need for supportive institutions and policies at local, national and international levels (Van de Steeg & Tibbo., 2012; Van de Steeg *et al*., 2009).

(Zaroug, 2011) affirms that for policy making and strategic planning, there is need to access reliable data and statistics at the national and sub-national levels, in addition to food insecurity, poverty monitoring and other socio-economic factors. However, there is incompleteness, incompatibility and inconsistency of Information which is a setback in appropriate enhanced food security and poverty reduction efficient decision making processes. According to (IFAD, 2009), the role of women is important since their tasks are daily while those of men are seasonal. The responsibilities of men include herding, marketing, purchasing animal feed, procuring veterinary services while women are often responsible for on-farm duties like feeding, milking, watering, collecting fodder, cleaning stables, traditional animal health care and milk processing. They indeed nurture livestock therefore cannot be ignored in adaptation and mitigation strategies and their needs. When women are empowered, community resilience to climate change will be built.

In Adaptation, a powerful tool for avoiding problems for herders, farmers and other decision makers who must commit resources before the yearly precipitation outcomes are known is the early warning drought forecasts. For preparedness and response prediction and forecasting of extreme events is a crucial. In risk areas preventive vaccination in high incidence seasons can be done, plans of planting, fertilizer application and seeding rate for economic value of season-specific forecasts (Hazell, 2011).

(FAO, 2016), summarizes adaptation methods in livestock production. In forages and feeds, solutions include irrigation, cropping calendar changes, purchasing feeds for the animals, heat and drought resistant breeds of forages and crops, increasing mobility for resources and agroforestry. When it comes to labor force and capital, livestock insurance policies are important, on and off farm diversification, reconversion in regional/ national zoning context, institutional changes that include trade, conflict resolution and income stabilization programs. In animals, adaptation can be achieved through water management for example digging of boreholes, disease control and animal health provide shade (trees) and indoor cooling systems, heat drought breeds and harsh environment resistant breeds, also species, breeds and or production system shifts an example being shifting to poultry or small ruminants. (Oweis & Peden 2008), stress that, better management of livestock water interactions increases Livestock water productivity (LWP), thus hope for sustainably improving livelihoods of the continent's poor and making more fresh water available for other human needs and ecosystem services.

2.6 Impacts of climatic variability on Wildlife and livestock productivity

(Sejian *et al*., 2016), noted that heat stress causes the most significant direct impact of climate variability on livestock production. Livestock growth and reproduction is affected, milk production levels reduced, adaptation and increase in disease occurrence are experienced, leading to severe economic loss. In growth, body weight, body condition scoring, average daily gain, feed conversion efficiency, feed intake and allometric measurements decrease. In milk production, the production/yields of milk declines, milk fat, lactose, non-solid fat, milk protein and the milk quality all decease with palmitic and stearic acids increasing.

In reproduction, climate variability and especially heat stress, will affect the estrus expression, fertilization, rate of conception, spermatogenesis by inhibiting spermatocytes proliferation in males. During pregnancy foetus growth can be lowered and foetal losses increase with heat stress. It also alters secretion of the hormones and enzymes regulating reproductive tract function may also be altered by heat stress. In disease occurrences, vector borne diseases are bound to arise with examples of bovine viral diarrhea, Trypanosomiasis, Rift Valley fever, Theileriosis and Rinderpest (Sejian *et al*., 2016).

The most significant climatic variables affecting livestock disease outbreaks are temperature and rainfall variations. In the tropical environments, animals reared are generally subjected to more than one stressor at a time. Animal production, reproduction and immune status are greatly affected by the multiple stressors. Climate variability can adversely affect productivity, species composition, and quality, with potential impacts not only on forage production but also on other ecological roles of grasslands (Sejian *et al*., 2016).

(Root & Schneider, 2002), add that Phenology, abundances, ranges, physiology, morphology, community composition, behavior and biotic interactions are also affected by climate change. The animals that are most likely to be affected by climate change are the ones limited to isolated habitat and whose populations are small and risk easily become extinct with climate change. Where the temperature change is largest, these changes are expected to be concentrated and less evident elsewhere (Root & Schneider, 2002).

Feed energy conversion in animals is also affected by climate variability. Low energy feeds are high in fibre, moisture and low in dry matter. An animal derives water and dry matter from a feedstuff. In an animals dry matter is broken down to organic (proteins, carbohydrates, vitamins, fat and lipids) and inorganic (micro and macro nutrients) as indicated in figure 2.1.

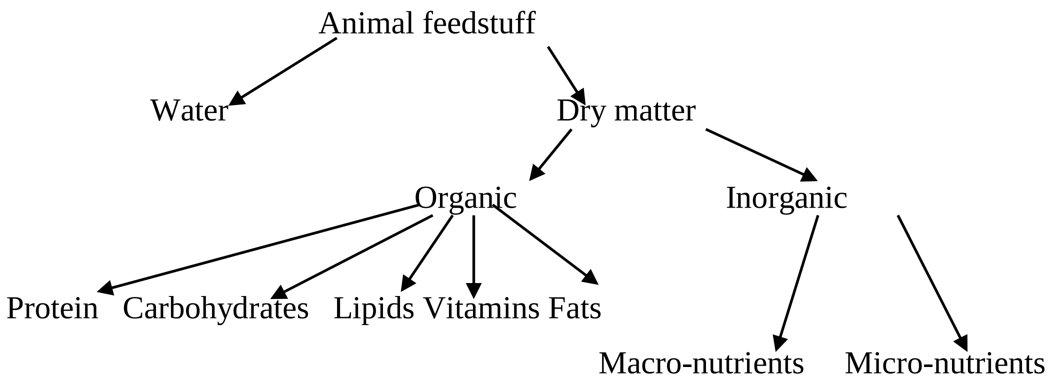


Figure 2.1: Breakdown of an animal feedstuff

When organic material in a feed is completely burnt, it produces gross energy. Some of the gross energy is lost through excretions to give the digestible energy (gross energy-feacal energy) which is the energy content of digested nutrients. Metabolic processes occur in the body further loosing energy through excreting gases like methane and urine by burning of digestible energy in feeds to give Metabolizable energy. The body loses heat by evaporation, conduction, convection or radiation leaving the net energy available for the production and maintenance of an animal, figure 2.2 (Infonet Biodivision, 2016).

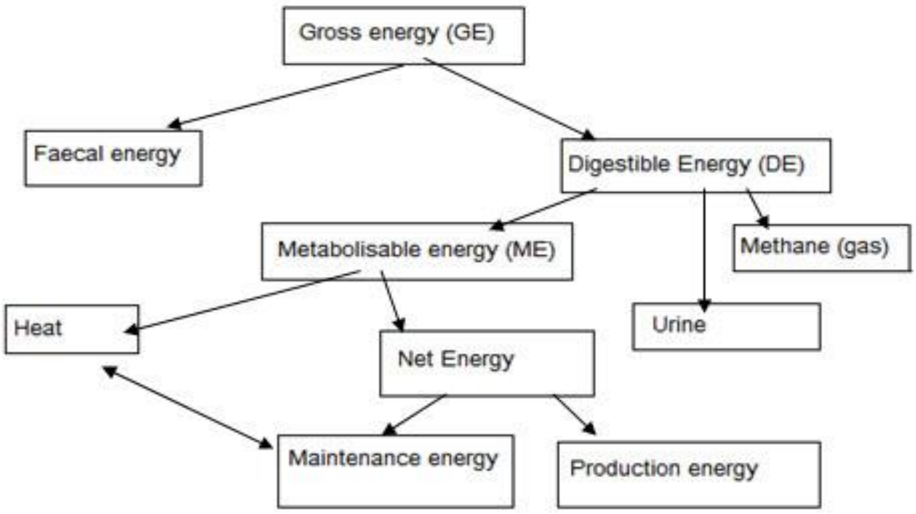


Figure 2.2: Breakdown of feed energy in an animal.
(Source: Infonet Biodivision, 2016)

Daily feed and water intake of an animal is determined by the stage of production like gestation or lactation, forage quality, growth stage, activity, health, environment and the weight of an animal. Animals consume more forage when it is of high quality since it is easily digestible (An example is the elephant that consumes up to 450kg of feed per day but only 40% of the feed is digested).

CHAPTER THREE: MATERIALS AND METHODS

3.0 Introduction

The chapter includes study area climate, topography, hydrology, Geology and soils; flora and fauna**,** data collection, sampling procedures and sample size and analysis of climatic variability, determination of animal counts and animal composition of the selected wildlife animals' and livestock animal populations and their productivity indexing assessments are explained.

3.1 Study area

The study was conducted in the Maasai Mara National Reserve that covers an area of 1510km^2 and a dispersal area 3000km^2 owned by the local community in Narok County in the southern-western Kenya. The Reserve is situated 168 kilometres south of the equator and borders Serengeti National Park to the south, between Sirea (Oloololo) escarpments to the West, Loita hills to the East and Loita plains to the North. The Reserve is approximately 280 kilometres west of the city of Nairobi and was established in 1961. Borders extend into Trans Mara and Narok Counties in the Rift Valley between latitudes 1^o 15' and 1^o 45' South and longitudes 34 ^{o} 45' and 35 ^{o} 25' East at altitude between 1400 and 2170 meters above sea level. The Reserve is managed by the two County governments with Trans Mara County controlling the West of Mara River and Narok County East of Mara River.

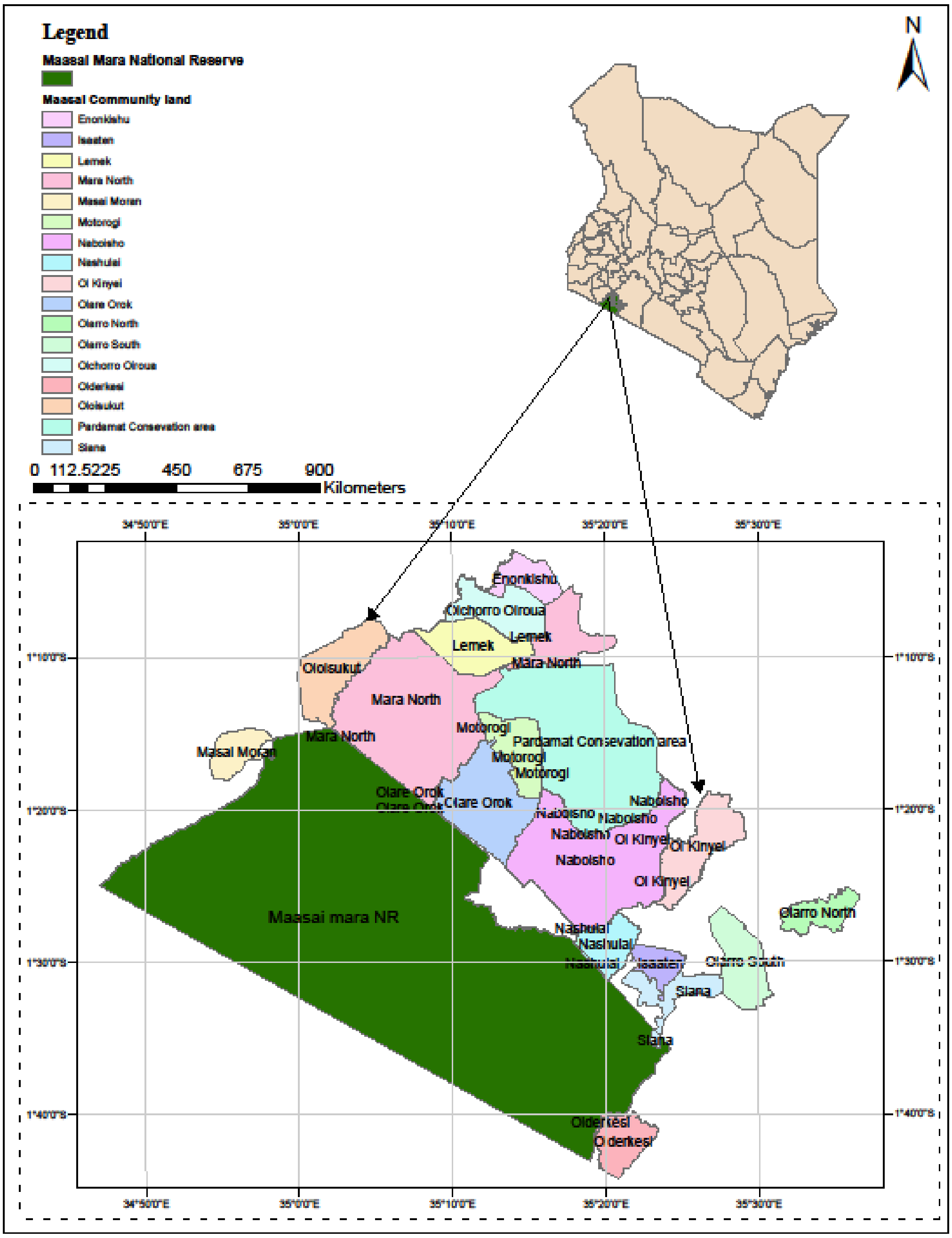


Figure: 3.1a Map of Kenya showing the location of the Maasai Mara National reserve and present day conservancies and environs, Narok, County.

Source: Kenya Wildlife Conservancies Association (2016).

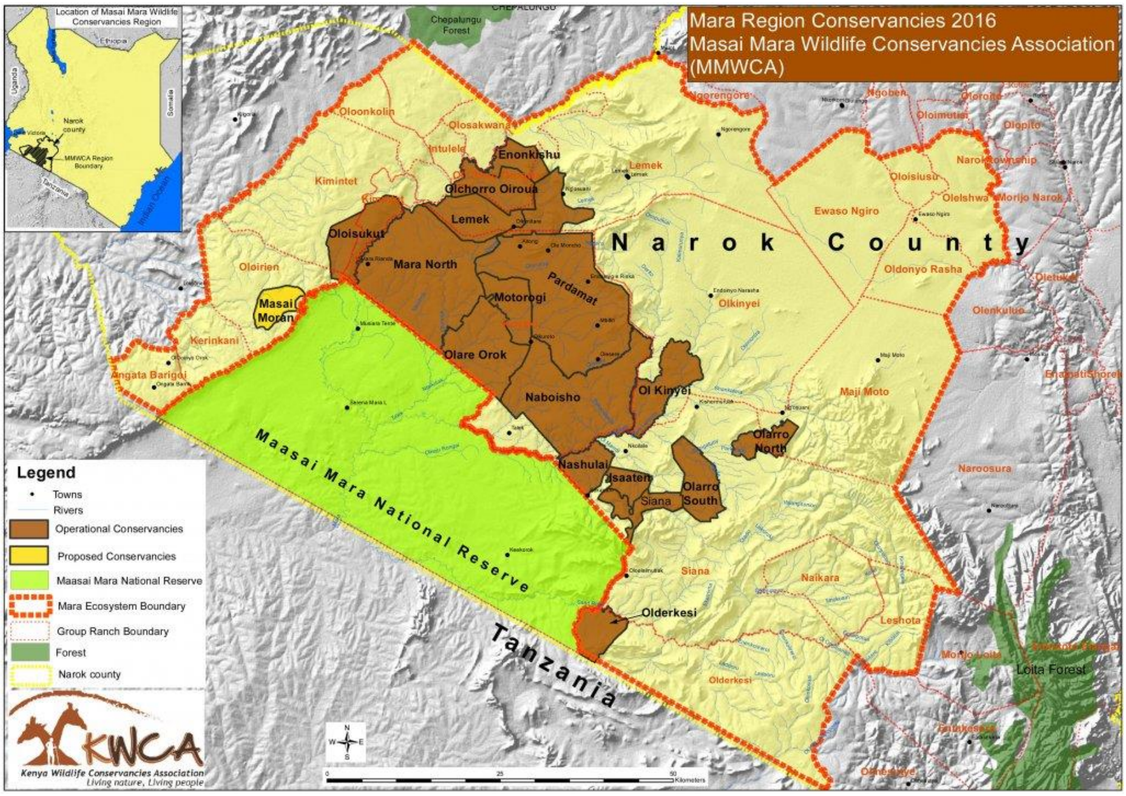


Figure: 3.1b Pictorial map of Kenya showing the location of the Maasai Mara National reserve and present day conservancies and environs, Narok, County. Source: Kenya Wildlife Conservancies Association (2016).

3.1.1 Climate

The minimum temperatures of the area range between 12^{o}c and 14^{o}c while the maximum lies between 26.5^{o}C and 31^{o}C. The gradient of rainfall increases from East to West across the Maasai Mara Game Reserve. Long rains are from March to May while the short rains are from November to December. The main dry period is experienced from mid-June to mid-October with a shorter dry season from January to February. The mean annual rainfall is 800 to 1200 mm per year. The Mara triangle and Siria escarpment receive the highest rainfall.

3.1.2 Topography

The Mara has three topographical units with the Ngama hills to the East and Siria escarpment on the Western boundary. The Mara River and the Siria escarpment are separated by the Mara triangle. The central plains are between Ngama hills below Sekenani gate and Mara River. The Eastern side of the game reserve is hilly. In the South of the Mara triangle, there are flat plains with rocky outcrops.

According to (Karanja, 2002) the major plains are characterised into the following:- Burrangat that is South of Talek River, Central plain north of East of the point where the Mara River flows into Tanzania, Eluai plain found on the middle of the Mara triangle, Paradise plain on the Mara River's upper curve, Meta plain Southeast of the Burrangat plain and the Posee plain, on the south of the Talek gate.

The Northwestern boundary is the Esoit Oloololo or Siria escarpments while the boundary to the South-Eastern side are the Ngama hills below Sekenani gate. Midway between Oloololo and Talek gates is the Rhino ridge that runs Northwest to South West.

3.1.3 Hydrology

Hydrological patterns are determined by the topography of the area. The River Mara originates from the Mau hills, runs through the park from North to South, and is served by many tributaries, many being temporary with exceptions of major tributaries like Talek and Sand Rivers and drains to the Lake Victoria.

3.1.4 Geology and Soils

The soils are mostly volcanic in nature mostly alkaline, ranging from black heavy clay to brown sandy loams. Most of the area has the upper soils dominated by lava dust and other pyroclastic material. Siana and Loita hills have quartzites from grits and sandstones. Quartzites, schists, gneisses, amphibolites, mylonites and pegmatites are on the Nguruman escarpments. Shallow, sandy and porous soils are found in Ngama hills and are dominated by shrub species Croton dichogamus.

3.1.5 Flora and Fauna

Riverine forests form the smallest vegetation type in the Mara region on the borders of River Mara and its tributaries. The dominant tree species are *Warburgea ugadensis* (African greenheart), *Euclea divinorum*, *Diospyros abyssinica*, *Olea Africana* (African olive), shrubs including *Grewia*, *Croton dichogamus*, *Teclea*. There are seven Acacia species such as A. *brevispica*, *A.hockii*, *A.senegal*, *A. seyel*, *A.gerrardii*, *A.drepanolobium* (whistling thorn*)*, *A.xanthophloea.* Animals on riverline forests are elephants *(Loxodonta Aficana)*, buffalo (*Syncerus caffer*), bushbuck (*Tragelaphus sylvaticus*), red duiker (*Sylvicapra grimmia*), olive baboon (*Papio Anubis*), vervet monkey (*Chlorocebus pygerythrus*) and other monkey types.

Bush lands are dominated by *Croton dichogamus*, a woody shrub and *Euclea dinovorum* (Stelfox *et al.*, 1986).The shrub *Croton dichogamus* leaves are silver when young but orange or red when mature. The fruits are liked by elephants, impalas, baboon but the plants preference by animals is low.

In the Mara, savannah Grasslands dominate the natural vegetation. The common grass that dorminates the area is (*Themeda triandra*), red oat grass that is very palatable and nutritious when young, with scattered Acacia and Balanites species, *Bothriochloa insculpta* (sweet pitted grass) and *Setaria phleoides*. *Hyparrhenia* species are also common in the Mara area. Sodom apple (*Solanum incanum*) shrub with purple and yellow flowers and small round yellow fruits are found in the Mara grasslands. Elephants, Thompson's gazelle and impalas feed on their fruits. Open grassland plains are characterised by *Themeda triandra*, *Pennisetum* species, *Aristida* species, and *Sporobolus* species. On termite moulds, *Rhus natalensis* and *Cordia ovalis* are common bushes. On old termite hills grows *Euphorbia species* and *Sanseveria* (wild sisal) and

Acacia. The herbivores and plants species studied were summarized in appendix 9 and appendix 10.

3.1.6 Social economic activities

The social-economic activities carried out are pastoralism that is compatible with wildlife and tourism trade. According to (MMWCA, 2019), in tourism the local community contributes 60%-70% of the staff working in camps, lodges and conservancies encompassing people with different levels of education for skilled and unskilled work. The community also benefits through displaying cultural dances, beadwork, curios, and tourists visiting cultural villages. Tourists' operators also purchase water, buy food from the local markets, hire vehicles, and casual labour. Tourism is working as a self-sustaining business model in some conservancies. Land owners enjoy direct payment from leases. Some crop farming is seen to the north of the area.

3.2 Data collection and analysis

Primary data were collected in the field in the Maasai Mara Game Reserve and the adjacent group ranches for livestock and wildlife. Interviews with the use of questionnaires and informal talks and observation method were also used. Relevant photographs were taken in the study area for visual explanation.

3.2.1 Sampling procedures and sample size

The population in this study is finite so the Fischer formula was used to get the sample size;

$$n_f = \frac{z^2 pq N}{e^2 (N-1) + z^2 pq}$$

Whereby:

n_f = Desired sample size in case of finite population

N = size of the population (55777)

z = the standard normal deviate at the required confidence level (1.96)

p = the proportion in the target population estimated to have the characteristics being measured (0.5)

q = 1- p (1- 0.5)

Determination of the sample size was done using an assumed confidence level of 95%. The target population proportion was assumed to be 50%. Response achieved was within -5 and + 5 of the state of population targeted. Desired accuracy level was at 0.05 while the z- statistic was 1.96.

$$n = \frac{1.96^2 * 0.5 * 0.5 * 55777}{0.05 * 0.05(55777-1) + 1.96^2 * 0.5 * 0.5} = 382$$

To gather information from the field, stratified random sampling was applied to determine the sample size for each strata/ conservancy as detailed in table 3.1 and was applied in ten conservancies namely, Mara North, Mara Naboisho, Motorogi, Olare Orok, Lemek, Olarro South, Mara Siana, Ol kinyei, Nashulai Maasai Conservancies and Pardamat Conservation Area adjacent to the Maasai Mara National Reserve (Table 3.1). (Kenya Wildlife Conservancies Association, 2016). Questionnaires were distributed randomly within the manyattas.

Table 3.1 Sampling size in conservancies

	Name of conservancy	Number of target/ accessible households	Sample size (*n*)	Frequency (%)
1.	Mara North Conservancy	8,040	55	14
2.	Mara Naboisho Conservancy	6,070	42	11
3.	Motorogi conservancy	3,058	21	6
4.	Olare Orok conservancy	2,190	15	5
5.	Pardamat Conservation Area	14,000	96	25
6.	Lemek Conservancy	5,730	39	10
7.	Olarro Conservancy	2,154	15	4
8.	Mara Siana Conservancy	10,271	70	18
9.	Ol kinyei conservancy	3,574	24	6
10.	Nashulai Maasai Conservancy	690	5	1
Totals		55777	382	100

Source: Kenya Wildlife Conservancies Association (2016).

Snowball method, where some people were selected through Intentional/ non-random purposeful sampling that involved purposive or deliberate selection of particular units of the population, for constituting a sample which represents the population was also used to get individuals knowledgeable and who provided most information on their areas of work relevant to the study and they named others. When a known characteristic of the universe is to be studied intensively, purposive sampling is considered desirable when the universe happens to be small (Leedy & Ormrod, 2005; Kothari, 2004). This method was used to select an additional 120 in the hospitality sector in some lodges targeting the tourists, hotel workers, balloon pilots, tourist guides and drivers through informal talks. Others selected were key informants, 25 Kenya Wildlife Service officials both at the headquarters and in the field, 10 Kenya meteorological Department officials dealing directly with Narok County, 8 Narok County government officials both at the head office and in the Game Reserve, 4 livestock officers at the Narok County and 2 at the National headquarters dealing with data, 3 local teachers, 3 DRSRS officers, 10 I.LR.I officers that worked in the Maasai Mara during the study.

Table 3.2 Sampling size in the hospitality sector and key informants

	Name of Sector	Sample size (*n*)	Frequency (%)
1.	Hospitality	120	65
2.	KWS	25	14
3.	KMD	10	5
4.	Narok County government	8	4
5.	I.LR.I	10	5
6.	Teachers	3	2
7.	DRSRS	3	2
8.	Livestock officers	6	3
	Totals	185	100

3.3 Analysis of climatic variability

Maximum and minimum temperature and rainfall records were collected and analysed for the period from 1975 to 2016, from the Kenya Meteorological Department. The secondary data over long term trends for this station were also collected. The rainfall figures from stations existing, within the Maasai Mara Park and the adjacent conservancies were triangulated mostly from figures from WWF, Kenya

Meteorological Department and individual private stations. Spatial characteristics and trends were assessed. Remote sensing data from landsat satellite were used for landcover analysis. Landcover was categorised into forestland, grassland, shrublands, croplands, waterbody and otherlands (bare land, rocky ground, roads, built areas). Landsat images analysed from 1976, 1985, 1995, 2000, 2003, 2013, 2016 were used to show land cover changes and were compared with the rainfall and temperature changes.

3.4 Animal counts

Determination was done using animal counts records from 1975 to 2016 from the Directorate of Resource Surveys and Remote Sensing (DRSRS). Comparative livestock counts figures from Narok district were obtained from the Ministry of livestock offices to establish comparative trends. The animal counts for both livestock and wildlife were classified into two categories, wet and dry season counts from 1975 to 2016.

3.5 Animal populations composition and their productivity indexing

3.5.1 Animal genotypes

Every animal species constitutes a genotype. Livestock included cattle, sheep and goats. Emphasis in wildlife concentrated on the herbivores that were classified into mixed feeders, grazers and browsers in the study area. Linkages in animal composition and productivity were drawn in, trends in livestock and wildlife numbers trends and climatic variability as well as Livestock and wildlife composition and productivity indexing were documented.

3.5.2 Wildlife and livestock population composition and productivity assessments

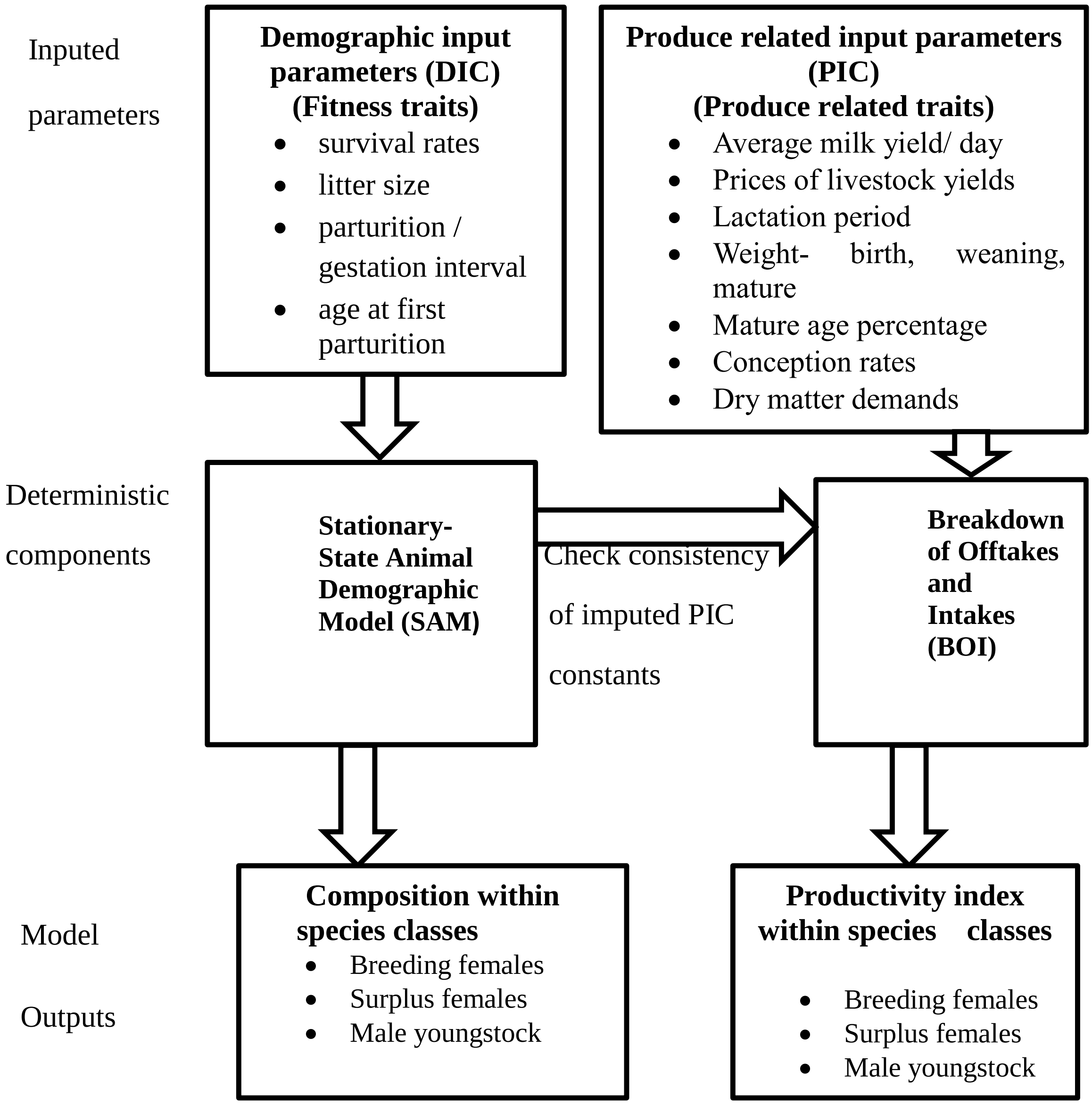


Figure 3.2 Illustration of Prying livestock productivity model components

Productivity assessment involved analysing interactions of births, mortalities and disposals using bio-economic and species independent model- Prying livestock productivity (PRY), (Baptist, 1988). PRY is a herd and flock dynamics model, which is a species and time independent microcomputer package that uses fitness characteristics/traits, yield levels, unit produce values, energy for and culling practice to assess productivity referred to as productivity indexing. It has been used in evaluating cropping strategies in wildlife ranching as reported by (Baptist, *et al.*, 1989). The model has two imputing devices including, the Demographic Program Input Constants (DIC) for inherent fitness traits and the Produce Related Input Constants (PIC) devices and four deterministic components of modelling including Animal Population Emulator (APE), Stationary- State Animal Demographic Model (SAM), Find Optimal Culling Practice (FOC) and Breakdown of Offtakes and Intake (BOI).

PRY can also be used in prediction of internal rate of return (profit) in harvesting wildlife populations, when served with the interest and inflation rates at pre-determined sex dependant recruitment rates.

To determine productivity and composition of wildlife and livestock, the two imputing devices Demographic Program Input Constants (DIC) and Produce Related Input Constants (PIC) and two deterministic components of modelling SAM, and Breakdown of Offtakes and Intake (BOI) were used in this study (Figure 3.2).

3.5.3 Wildlife and livestock demographic parameters

Demographic parameters fed to the Prying livestock productivity model for the wildlife and livestock were obtained from interviews, informal talks with the local community members and Kenya Wildlife Service staff, veterinarians, conservationists and farmers. Livestock data were obtained from interviews with the livestock farmers/ pastoralists.

When compared with secondary sources, the figures collected in the Maasai Mara were similar to those of some other areas with similar climatic conditions. For instance, the gestation of an Eland (*Tragelaphus oryx*), is in the range of 260-272 days (Chris & Pilde, 2000; Williamson & Payne, 1987; Walker, 1975; Estes, 1997). Age at first parturition for the Eland was 38 months and parturition interval of 11 months (Chris & Pilde, 2000).

(Thinkquest.org, 1998) refers to Grants Gazelle (*Nanger granti*), with a mention of the Maasai Mara ecosystem with male and female maturity weights of 65 kg and 45 kg respectively and age at first parturition at 18 months. The same figures are shared by (Walker,1975), who also has examples from Africa. Informal talks yielded the same results, with local residents, KWS staff, veterinarians, conservationists. (Chris & Pilde, 2000; Estes, 1997) had close figures of weight at maturity in the range of 700 kg and 686 kg for male Buffalo, 550 kg and 576 kg for female Buffalo, 340 to 345 days gestation period. The male elephant has an average weight 3000 kg and 5000 kg while the female is between 2150 kg and 3000 kg at maturity, with a gestation period of 660 days. Reference to the wildebeest (*Connochaetes taurinus)*, cited the Maasai Mara and the migration trends.

Gestation period of Topi (*Damaliscus lunatus*) was 240 days according to (Chris & Pilde, 2000; Walker, 1975; Estes, 1997). Age at first parturition was 18 months, (Walker, 1975; African Wildlife Foundation, 2006). Maturity weight of the warthog (*Phacochoerus aethiopicus*), males was 82.5 kg and 82 kg from (Chris & Pilde, 2000; Estes, 1997) respectively. (Chris & Pilde, 2000) mentioned average body weights at birth of the Zebra (*Equus burcheli*) in the Maasai Mara. The female Steenbok (*Raphicerus campestris*), maturity weight ranges from 11 kg to 11.3 kg (Chris & Pilde, 2000; Estes, 1997), gestation period of 170 days (Chris & Pilde, 2000), 171.5 days, (Estes, 1997). According to (Estes, 1997), age at first parturition was 8 months.
Oribi (*Ourebia ourebi*), in (Chris & Pilde 2000) had a mature body weight of 17kg in males and 15 kg in females. The ranges in gestation were 210 days, according to (Chris & Pilde, 2000; Estes, 1997) and 214 days in Walker (1975).

Klipspringer (*Oreotragus oreostragus*) had almost similar ranges in (Chris & Pilde, 2000; Estes 1997), with female birth weight of Klipspringer at 1 kg and 1.1 kg, male maturity weight at 10 kg and 10.6 kg, female maturity weight at 13 kg and 13.2 kg, gestation period of 210 and 214 days respectively. Average Weights of White Rhino mature males were 2150 kg and female 1500 kg. The White Rhino (*Ceratotherium simum*) had a gestation period of 480 days in the (Chris & Pilde, 2000; Estes, 1997). According to (Chris & Pilde, 2000; Estes, 1997) the Black Rhino (*Diceros bicornis*), had a gestation period range of 450 to 465 days.

3.6 Data analysis

Data was collected from primary sources through interviews, observation, informal talks and secondary sources, were analysed using SPSS and excel sheets. T-tests were used to test for significance difference. A confidence level of 95% was used to determine the sample size with a desired accuracy level of 0.05 while the z- statistic was 1.96. The target population proportion was assumed to be 50%. Comparisons were made on wildlife and livestock productivity indexes and also wildlife and livestock composition. The data was presented in line and bar graphs, percentages and tables.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents analysis of data and discusses the results of the study in terms of climatic factors influence on wildlife and livestock populations that include rainfall and temperature, productivity assessment (index) of livestock and wildlife in the Maasai Mara including grazers, browsers mixed feeders. The chapter also looks into selected animal composition within species in the Maasai Mara. Livestock and wild animals' composition, productivity indexing of selected populations of wildlife herbivores that are most preferred by tourists in the Maasai Mara and the relationship between climate and populations numbers trends were also summarized.

4.1 Respondent characteristics

The gender of the respondents was both men and women. The younger to middle age respondents were knowledgeable on the demographics of animals. The elderly had history of the area and responded to climate patterns. Ages of the respondents ranged between 20 and 60 years old.

Level of education was from those who had not gone to school but were very knowledgeable, primary level, secondary. The key informants had gone through higher education with most of them being professionals working in livestock, wildlife and hospitality sectors. Religion in the study area was predominantly Christian, with a few Muslims. The social economic activities were tourism and livestock keeping. Crop farming had also grown to the north of the conservancies.

The ethnic group in the area was Maasai and few inhabitants from other ethnic groups especially in the settlement areas like Sekenani. These included traders, County workers, National Reserve workers, hospitality sector workers and government workers.

4.2 Response rate

The response rate among the respondents from the conservancies was 80%. The high response rate was as a result of availability of respondents in the sampled manyattas. In the hospitality and key informants category, response rate was higher at 92% since they were more easily accessible in their work stations.

4.3 Climatic parameters and their impacts on wildlife and livestock populations from the years 1975 to 2016

4.3.1 Rainfall

According to the respondents in the conservancies adjacent to the Maasai Mara Game Reserve, in 1997 there were floods which are in line with the rainfall figures that had very wet months of April, May and November. Trends also show low rainfall figures in Narok in 1976, 1979, 1981, 1984 (lowest figures), 1992, 1993, 2000, 2005, 2008 and 2013 with irregularities in the distribution of rainfall within the year especially in 1979 and 1993.This concurs with the indications of dry years by the respondents, that lead to low productivity of the livestock, deaths and starvation. The trends agree with the classification of disasters by (Shauri, 2003), with droughts in 1983-1984, 1995-1996, 1999-2000, and El-Nino floods in 1997-1998. (Stuth *et al.,* 2003) stresses the fact that, one of the greatest perils to rangelands throughout the world is drought with temporal shifts in precipitation and temperatures and changing drought frequencies. These rainfall trends in Narok were presented in figure 4.1.

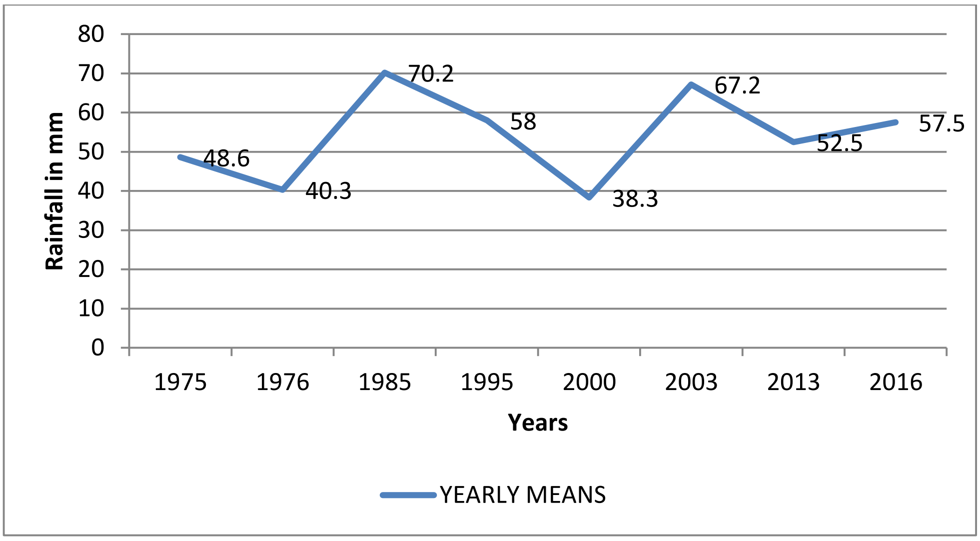


Figure 4.1: Average annual Rainfall distribution in Narok from 1975 to 2016

4.3.2 Temperature

Appendix 2 gives monthly and yearly temperature averages in Narok from 1975 to 2016. Generally, the temperatures show an upward trend meaning that higher temperatures are being experienced (figure 4.2a). In general, livestock producers will have a significant financial burden due to heat stress in reproductive efficiency, milk component and milk production, meat production and animal health (Sejian *et al*., 2016). Therefore, animal performance will be directly impacted by rises in temperature which are linked to decreasing production in both livestock and wildlife in the Maasai Mara.

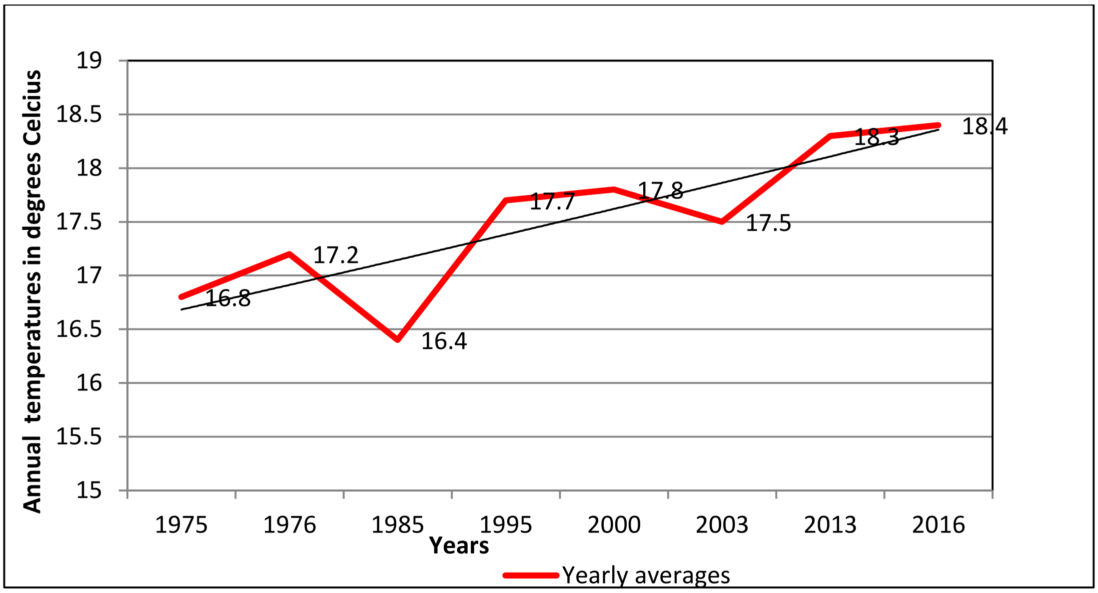


Figure 4.2a: Annual average temperature distribution in Narok from 1975 to 2016

Temperatures increased by 0.4°C between the years 1975 to 1976, 0.5°C from 1976 to 1995, 0.1°C from 1995 to 2000, 0.5°C from 2000 to 2013. The trend line indicates increasing temperatures over the study period from 16.4°C in 1975 to 18.4 degrees centigrade in 2016, a rise of 1.6 °C.

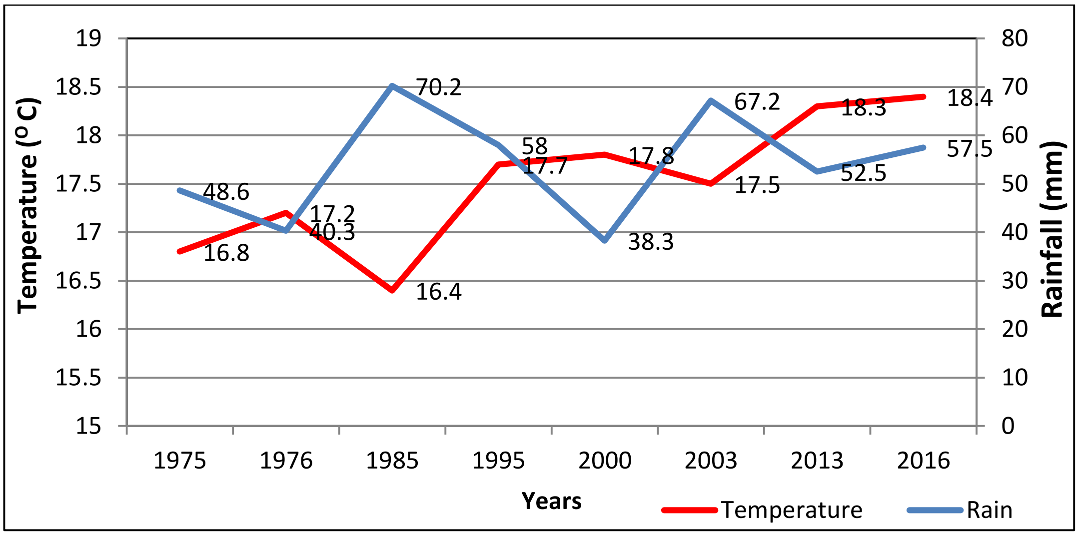


Figure 4.2b: Annual average temperature and rainfall distribution in Narok from 1975 to 2016

There was a general trend of animal decreasing in numbers. The dry years had low rainfall (figure 4.2b) with corresponding wet years having low temperatures figures. Examples are in 1975, 1985, 2003 when rainfall was high with low temperatures and 1976, 1995, 2000, 2013 with high temperatures and low rainfall. According to the rainfall figures, the dry years were characterised by low animal numbers (1984, 1986, 1993, 2000, and 2005) as highlighted in appendices 3, 4 and 5. Buffalo numbers wet counts reduced from 29559 in 1982, to less than half in 1984 and in the dry counts the figures decreased from 16428 in 1983 to a drastic 6833 in 1984. The Eland wet count figures decreased from 8410 in 1979 to 946 (-89%) in year 2000. In the same period other animal numbers that decreased were, Giraffe 7034 to 1732 (-75%), Topi 34023 to 5627 -(83.5%), Wildebeest 130079 to 85113 (-34.6), Zebra 76788 to 36910 (-52), Grants gazelle 25893 to 12559 (-51.5%), Impala 72379 to 30640 (-57.7%), Hartebeest 9429 to 1125 (-88.1),Thompson's gazelle 131583 to 30282 (-77%), Waterbuck 280 to 89 (-68.2%), Warthog 4740 to 1697 (-64.2%), and Ostrich 866 to 553 (-36.1%). The numbers of shoats in the same period rose from 127582 to 234436 (+84%), Elephant increased from 790 to 875 (10.8%) but cattle numbers decreased from 216680 to 116092 (-46.4%), Buffalo 33233 to 4680 (-86%) and donkeys 13711 to 3037 (-77.8%). The trend shows an increase in wildlife numbers in the wet years due to availability of forage leading to higher productivity. An example is the increases in dry counts from 1979 to 1980 except for animals like elephant, warthog, ostrich and donkeys that decreased. Notable increases were in most species in the wet years like 1989, 1990, 1992, 1994, 1997, 2002 when forage and water was available.

Figure 4.3 summarized wildlife and livestock trends in Narok up to 2016 where shoats numbers increased and wildlife numbers decreased. This can be explained by the changes in rainfall and temperatures in Figure 4.2b, where temperature increased and rainfall figures were erratic reducing forage due to water stress. (Bahrani & Bahrani, 2003), acknowledge that one limiting factor in crop and forage production in arid and semi -arid regions is drought stress.

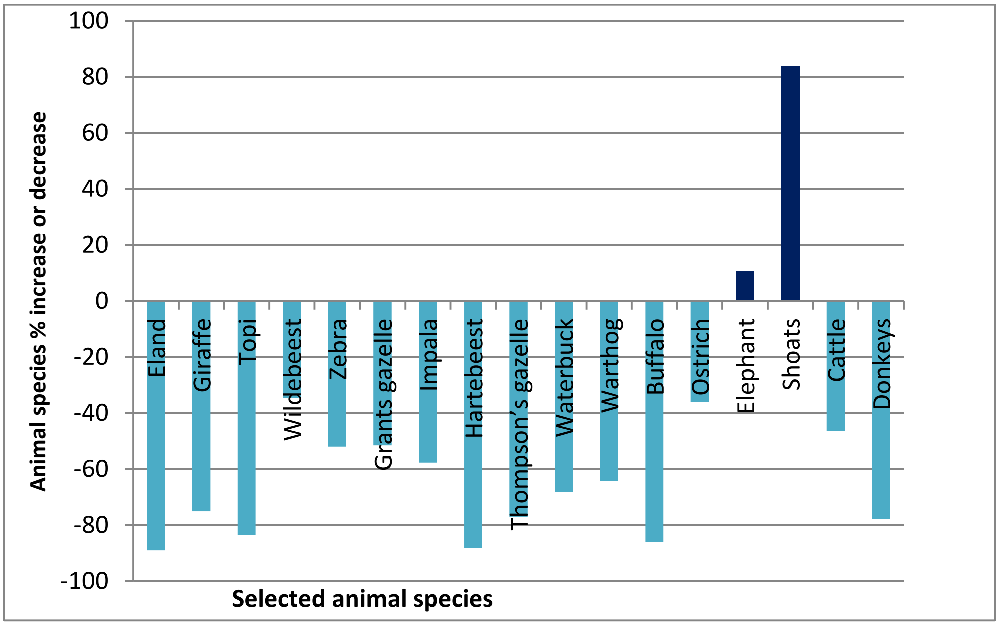


Figure 4.3: Selected wildlife and livestock species population trends between years 1979 and 2016 in Maasai Mara, Narok, Kenya

4.4 Land cover changes

Remote sensing data from landsat satellite maps showed that Land cover for 1976 and 1985 indicate high percentage of grassland 88% and 92 % low percentage shrubland (6 % and 5%). From 1976 to 2016 grasslands decreased from 88% to 75% .Shrublands increased from 6% to 18%. Land cover changed due to high yearly average temperatures increasing from 17.2°C in 1976 to 18.4 °C in 2016 (figure 4.2) and corresponding erratic and decreasing rainfall at 70.2 millimetres (mm) in 1985 to 57.5 mm in 2016 (figure 4.1). This combination reduces quality and quantity of forage, availability of water is also reduced, heat stress is experienced, animal diseases, wildlife movement (in search of pasture and water), reduced reproduction levels and competition for the resources. This in turn caused reduction in the numbers of wildlife and livestock (figure 4.3). Hotter and drier climates increased shrublands range and decreased grasslands. In years with higher rainfall, grasslands increased while shrublands decreased. In the dry/ drought years high percentages of shrublands are shown. These are presented in figures 4.4 to figure 4.10.

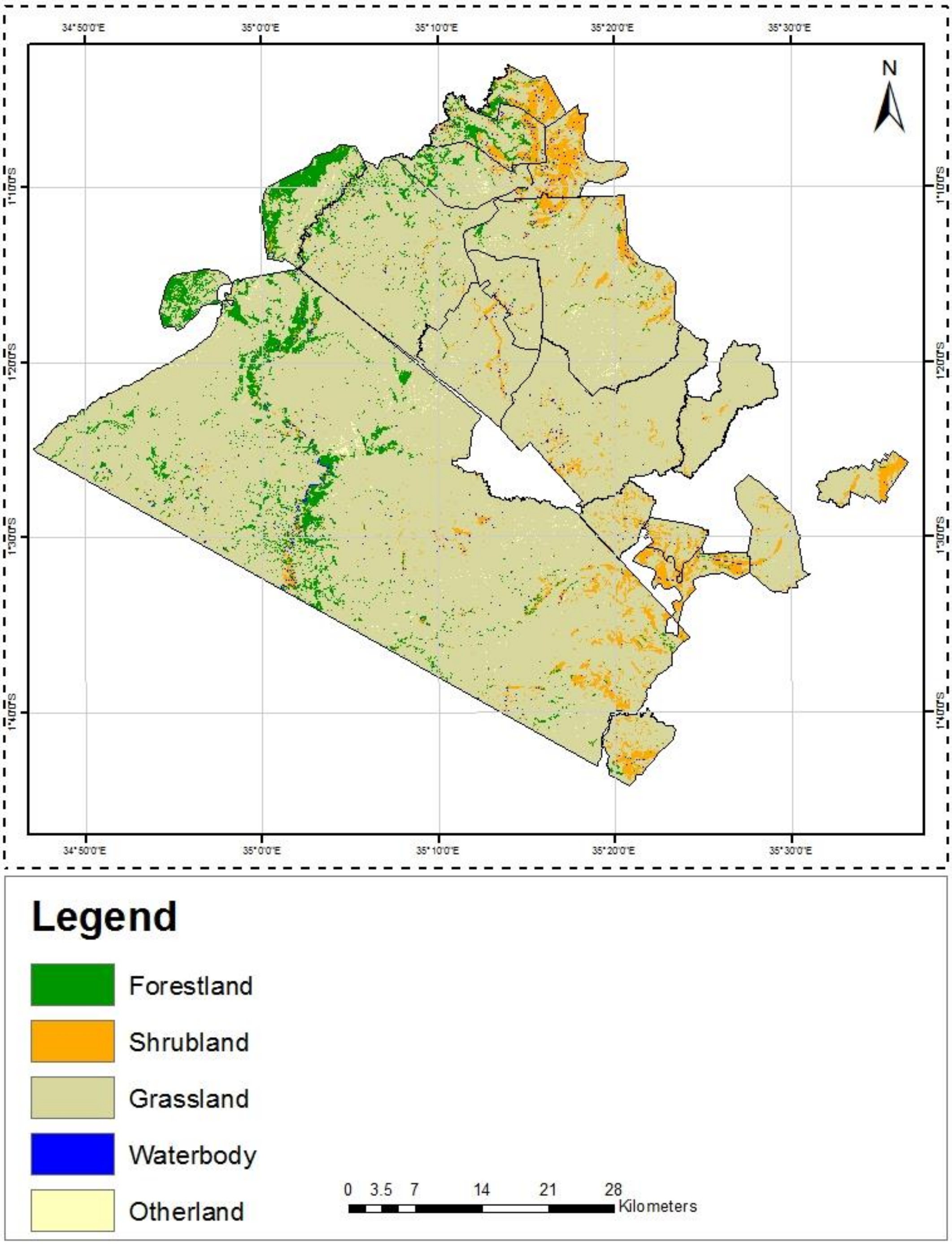


Figure 4.4: Land cover of Maasai Mara during the year 1976

Source: Landsat images classified by author (2019)

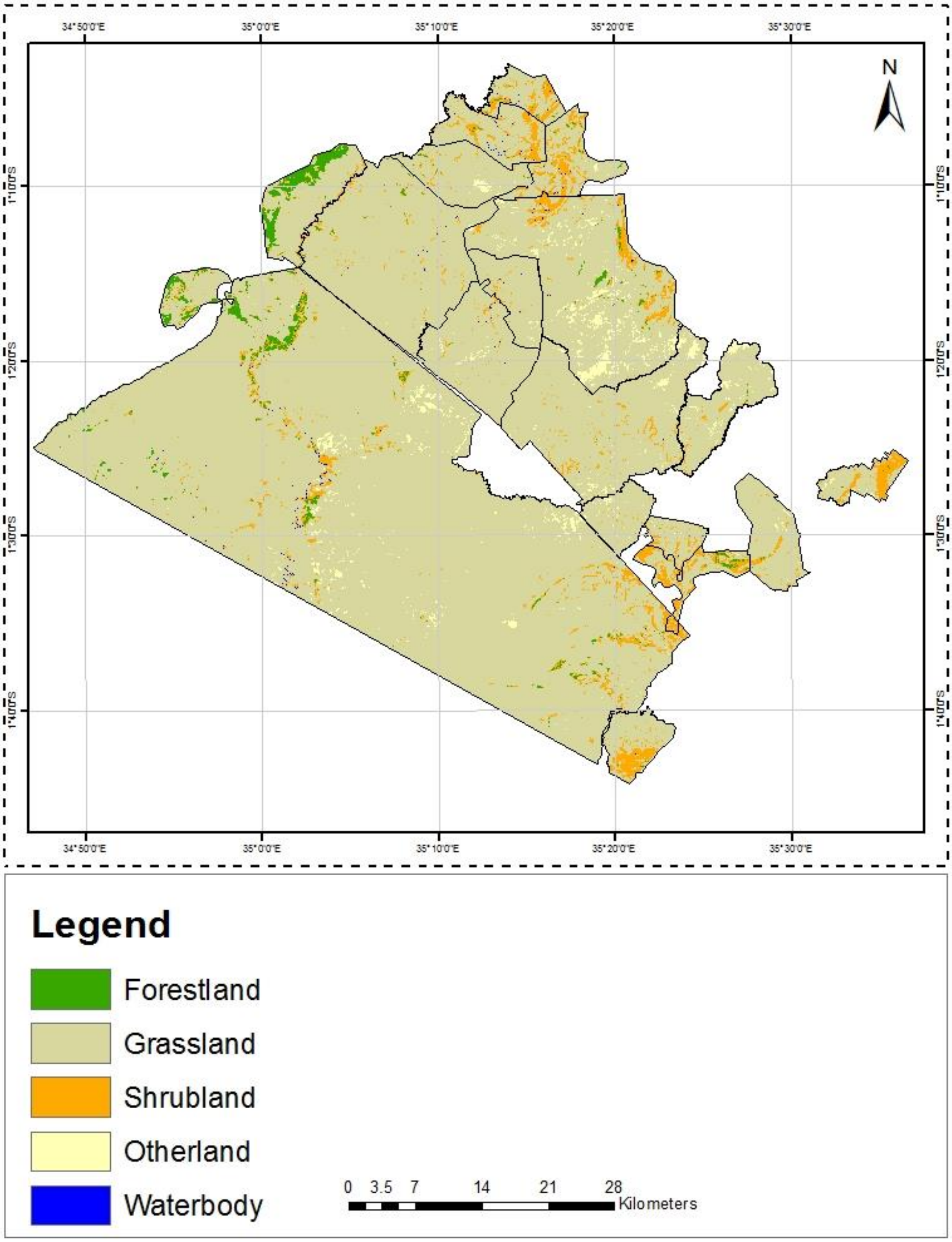


Figure 4.5: Land cover of Maasai Mara during the year 1985

Source: Landsat images classified by author (2019)

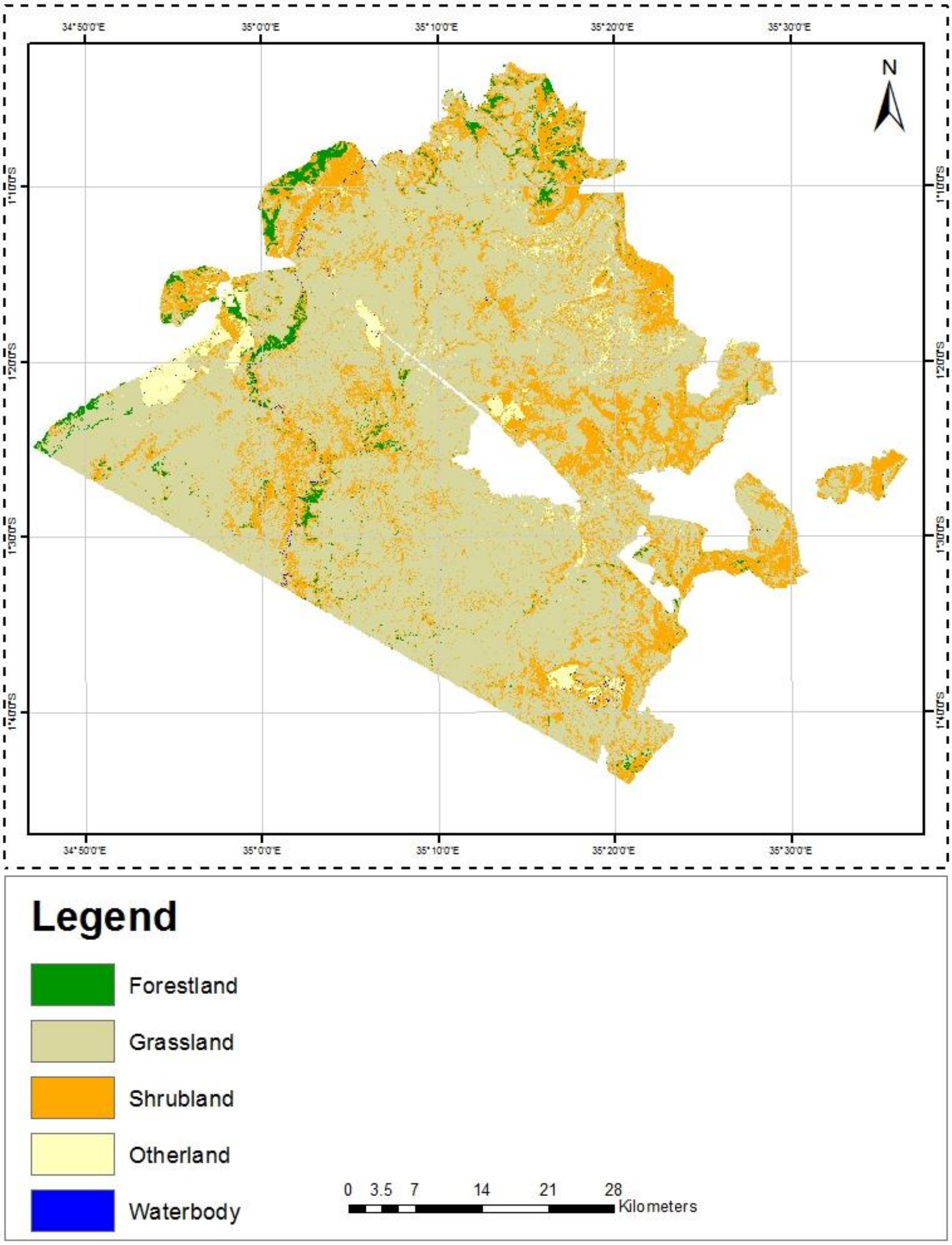


Figure 4.6: Land cover of Maasai Mara during the year 1995

Source: Landsat images classified by author (2019)

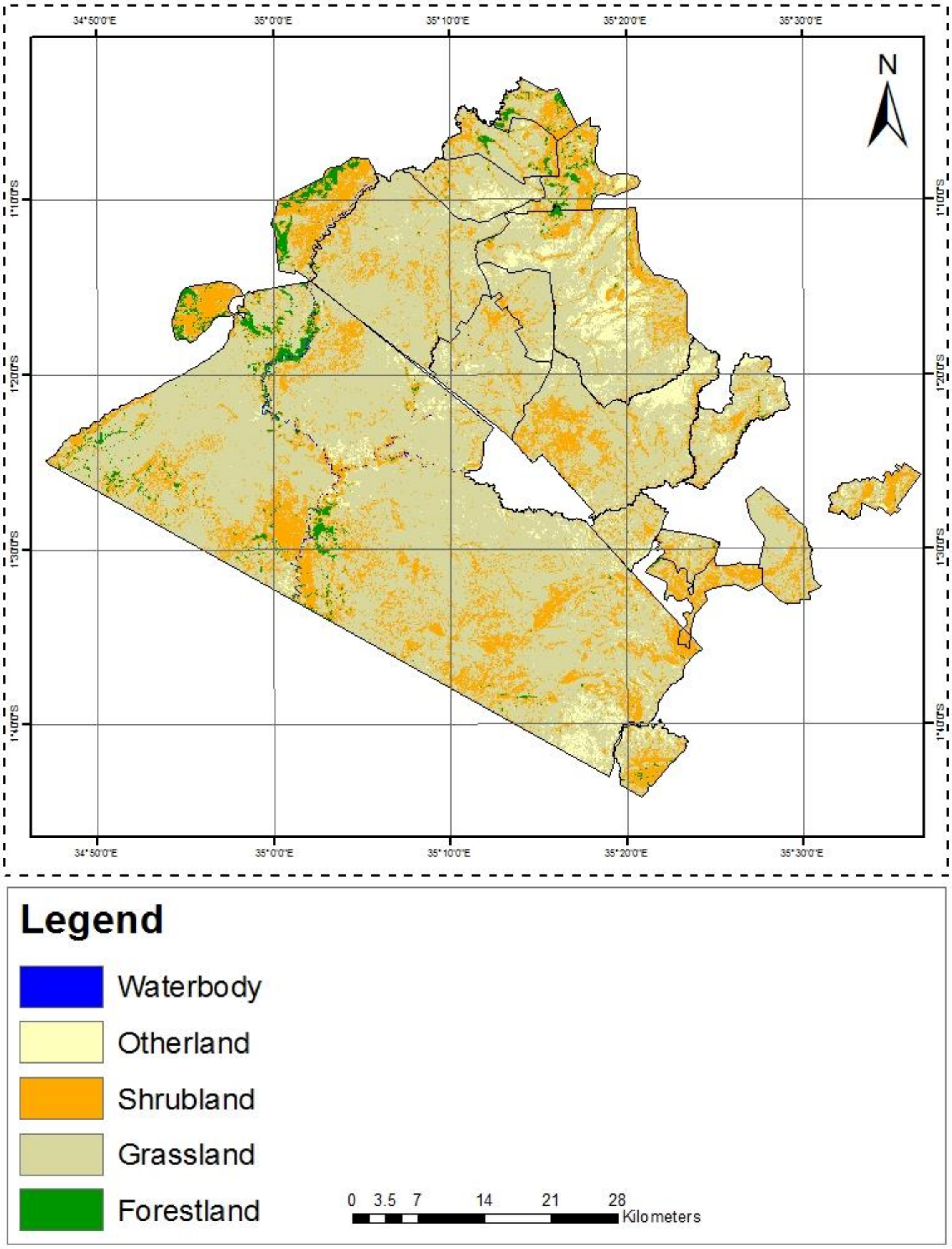


Figure 4.7: Land cover of Maasai Mara during the year 2000

Source: Landsat images classified by author (2019)

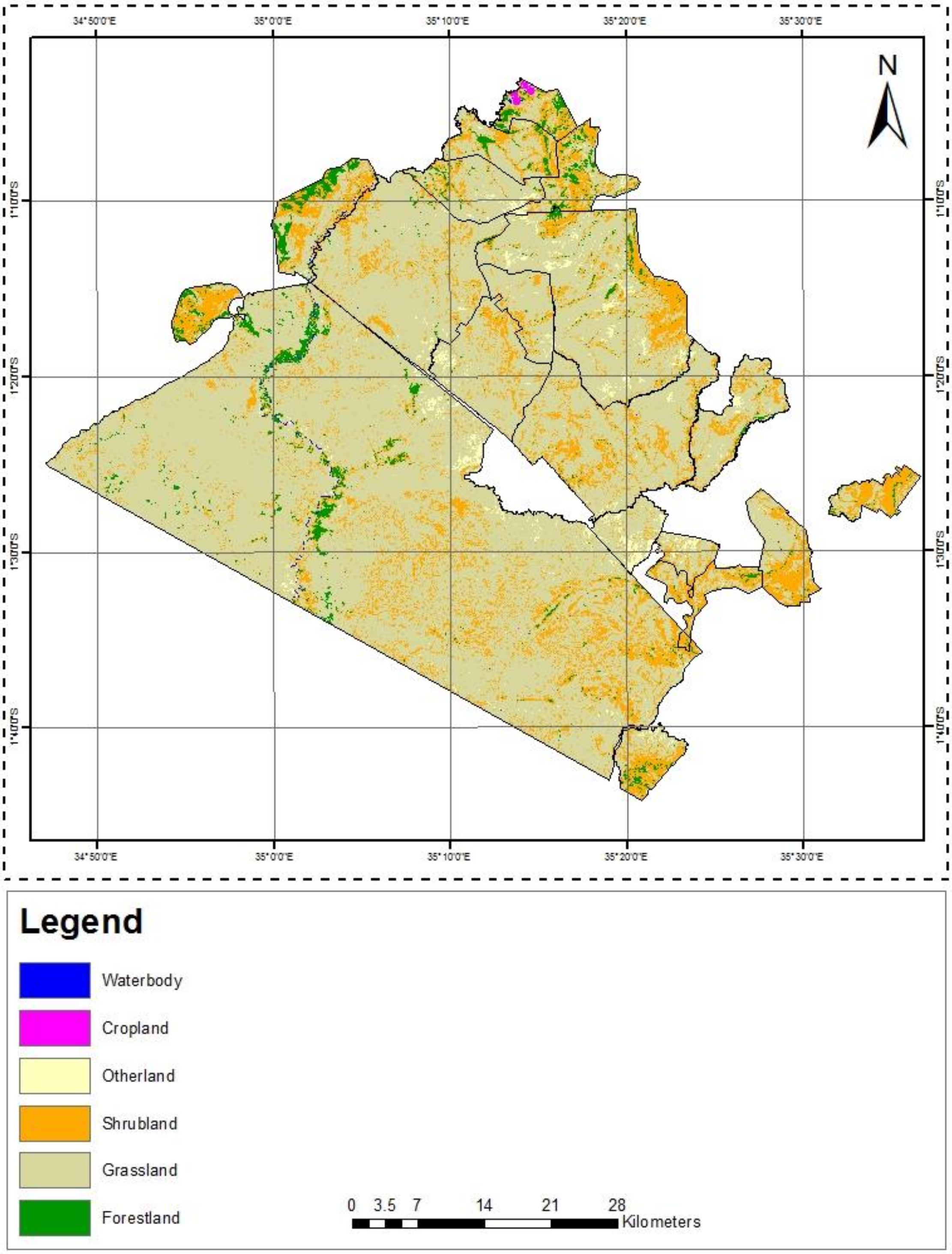


Figure 4.8: Land cover of Maasai Mara during the year 2003

Source: Landsat images classified by author (2019)

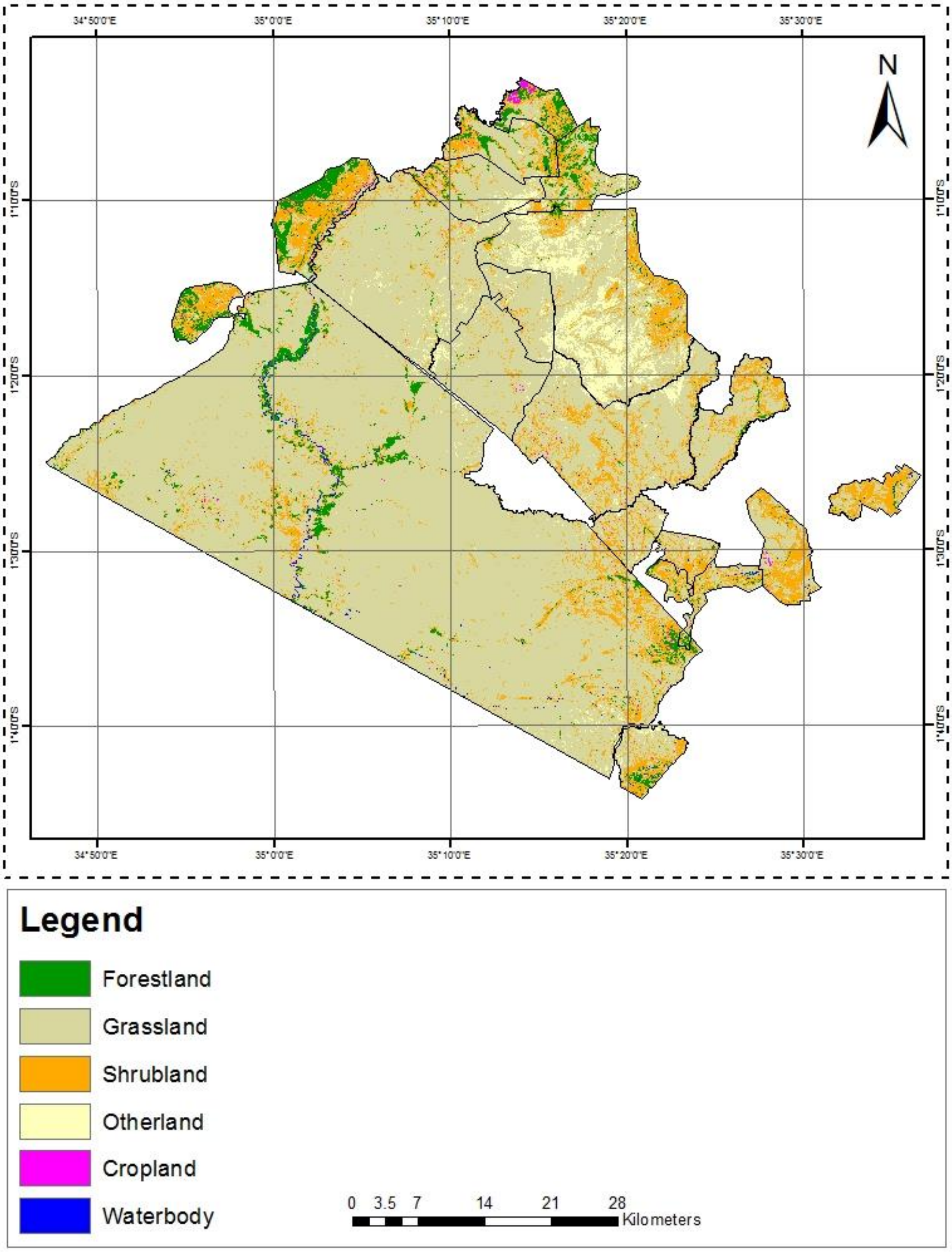


Figure 4.9: Land cover of Maasai Mara during the year 2013

Source: Landsat images classified by author (2019)

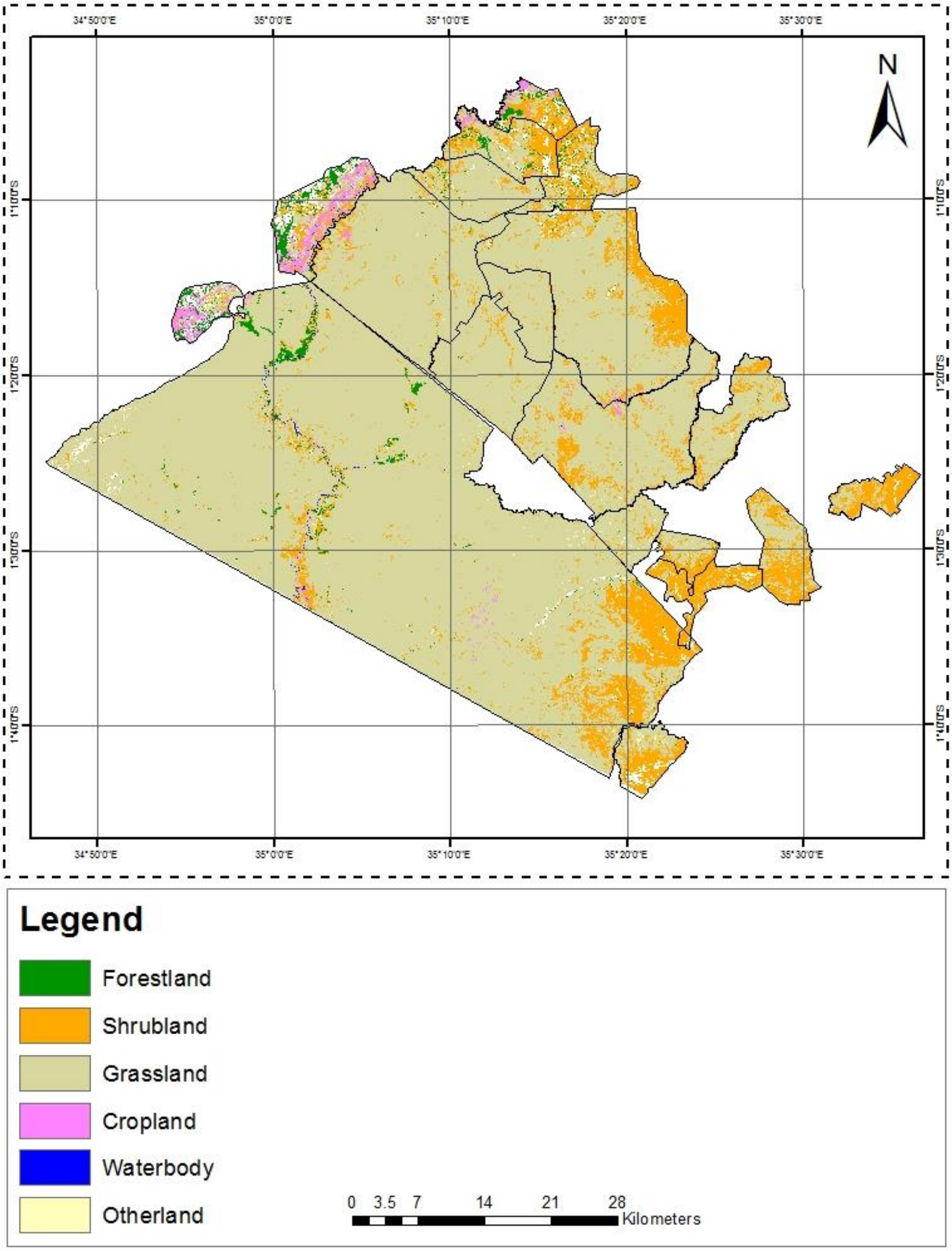


Figure 4.10: Land cover of Maasai Mara during the year 2016

Source: Landsat images by author (2019)

Table 4.1: Land cover changes in (hectares) from 1975 to 2016 in Maasai Mara the study area

LAND COVER TYPES	1976	1985	1995	2000	2003	2013	2016
	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares
FOREST LAND	16221.94	4450.8	5678.203	6478.203	9030.366	11802.11	15806.25
GRASSLAND	259324.6	271235	202919.3	209919.3	228585.1	231305.6	230168.2
SHRUBLAND	18031.28	14578.5	65111.31	63311.31	53195.68	40387.71	55395.36
OTHER LANDS	1102.965	5171.81	22434.84	16324.84	5208.606	11225.41	1557.45
CROPLANDS					235.2508	878.4554	1594.26
WATERBODY	1635.178	341.194	571.8735	681.8735	460.8014	1116.243	767.34
TOTALS	**296316**	**295777**	**296715**	**296715**	**296716**	**296715**	**305288.9**

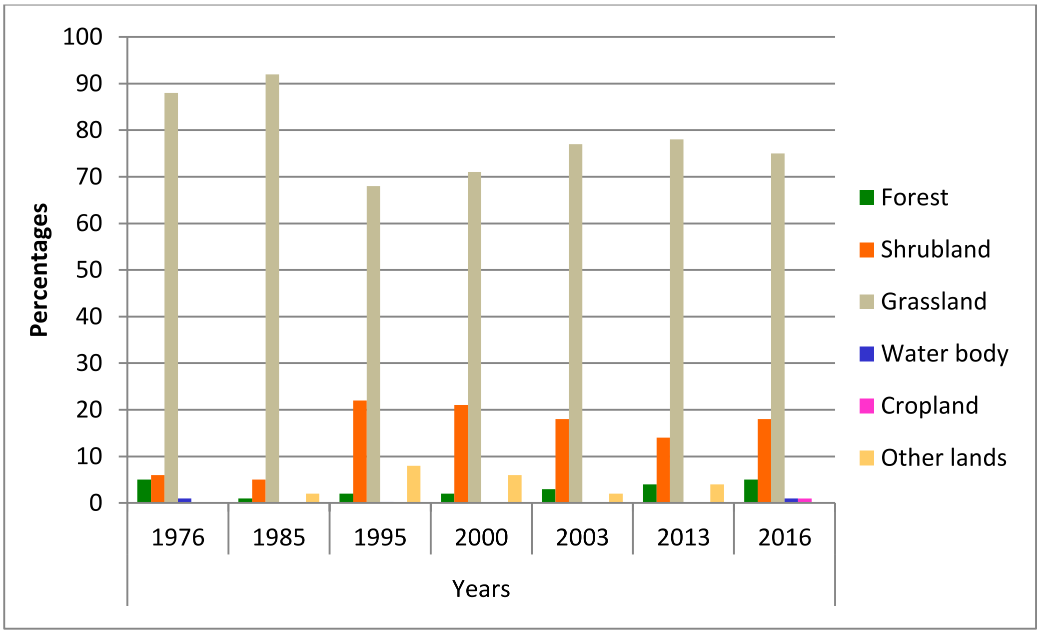
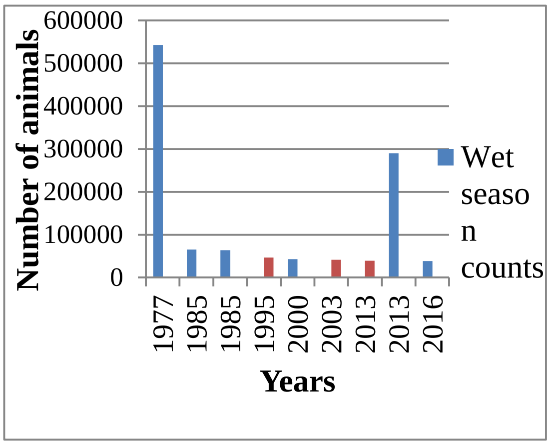
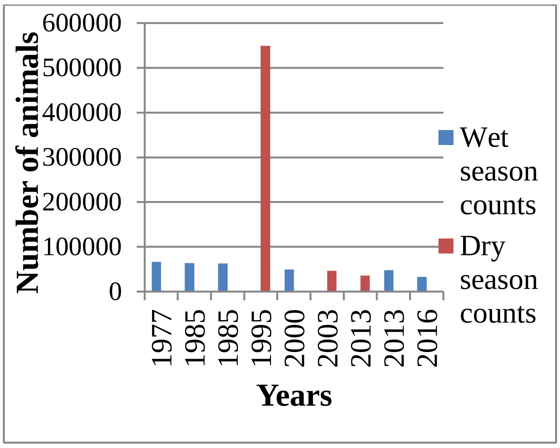


Figure 4.11: Land cover changes (%) from 1976 to 2016 in Maasai Mara the study area

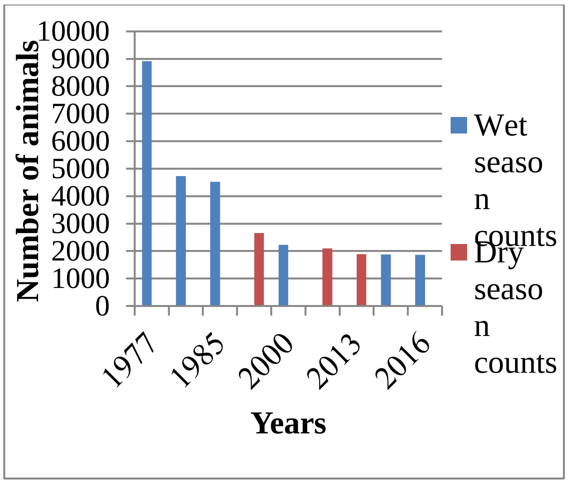
Figure 4.11 indicates decreasing grasslands and increasing shrublands, more so from 1976 to 2016 where grasslands decreased from 88% to 75% while shrublands increased from 6% to 18%. In years with higher rainfall, grasslands increased while shrublands decreased while shrublands increased in dry years and grasslands decreased. Shrublands may be formed out of ecological succession when better plants ecology is destroyed and are found in dry areas with low rainfall. In dry years, wildlife numbers decreased as seen in figure 4.11b and appendix 3 and 4, including 1976 and notably 1995 and 2000 when there were droughts, also 2013 and 2016.



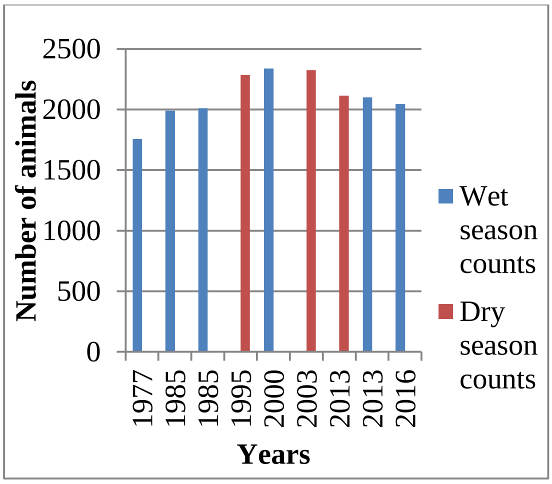
Wildebeest



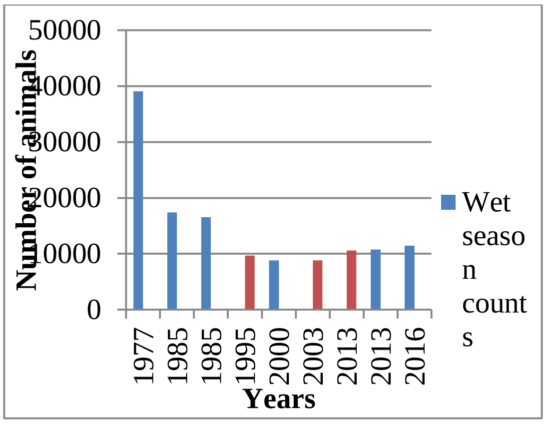
Burchell's zebra



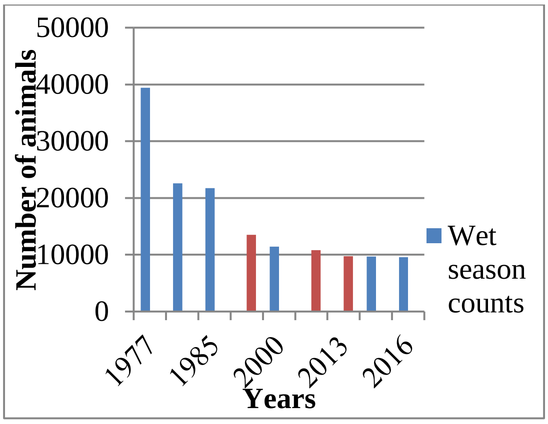
Giraffe



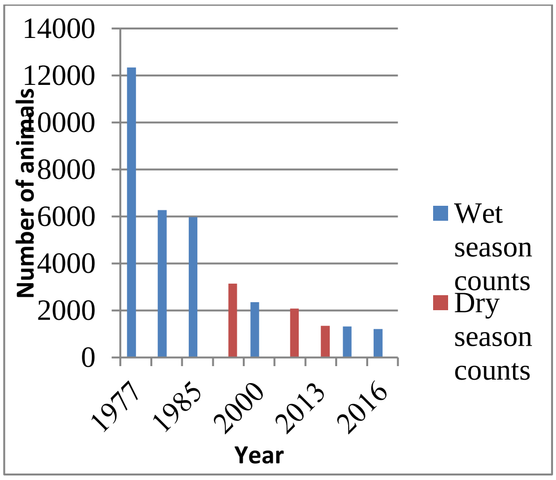
Elephant



Buffalo



Topi



Hartebeest

Figure 11b: Animal numbers trends from 1977 to 2016

The figure 4.11b shows pattern of decreasing numbers of animals best preferred by tourists for viewing in exception of the elephant that maintained substantive numbers.

4.5 Productivity assessment of livestock and wildlife species in the Maasai Mara

Wildlife and livestock demographic data to run the PRY model to obtain productivity and composition was obtained from the Maasai Mara National Reserve and adjacent conservancies and was summarized in tables 4.2, table 4.3, table 4.4, table 4.5, table 4.6 for livestock and table 4.7 for wildlife. The model is specific on figures according to sex and age appropriateness of animal for example, age at birth and maturity for both male and female.

Table 4.2: Responses from the ten conservancies adjacent to the Maasai Mara Game Reserve showing average birth weights (kg) of average animal per conservancy

Type of Animal	Sex	Selected conservancies studied									Average birth weights (kg)
		Siana, Nashulai	Olkinyei	Mara North	Olare Orok	Pardamat	Lemek	Motorogi	Naboisho	Olarro North	
		Average birth weights per ranch (kg)									
Zebu Cattle	Male	15	13	10	17	13	16	13	17	15	14.3
	Female	14	10	10	16	12	16	12	16	15	13.4
	Average	14.5	11.5	10	16.5	12.5	16	12.5	16.5	15	13.9
Sheep	Male	3	3	2	3	3	3	2	3	3	2.8
	Female	3	3	2	3	3	3	2	3	2.5	2.9
	Average	3	3	2	3	3	3	2	3	2.75	2.79
Goats	Male	3	3	2	3	3	3	2	3	3	2.3
	Female	3	3	2	3	3	3	2	3	2.5	2.75
	Average	3	3	2	3	3	3	2	3	2.75	2.79
Donkeys	Male	8	7	7	7	6	8	7	7	6	7.2
	Female	8	7	7	7	8	8	7	7	6	7.2
	Average	8	7	7	7	7	8	7	7	6	7.2

The average birth weight of zebu cattle in the 10 conservancies was 13.9 kilograms (kg) with a female weighing 13.5 kg and male 14.3 kg, sheep 2.79 kg (female weighing 2.9 kg and male 2.8 kg) and goats 2.79 kg (female weighing 2.75 kg and male 2.3 kg).

Table 4.3: Responses from the ten conservancies adjacent to the Maasai Mara Game Reserve showing average weaning weights (kg) of average animal per conservancy

Type of Animal	Sex	Selected conservancies studied									Average weaning weights (kg)
		Siana, Nashulai	Olkinyei	Mara North	Olar e Oro k	Pardama t	Lemek	Motorogi	Naboisho	Olarro North	
		Average birth weights per ranch (kg)									
Zebu Cattle	Male	36	45	45	43	43	45	43	43	44	43
	Female	31	40	40	39	38	40	39	39	42	38.7
	Averag e	33.5	42.5	42.5	41	40.5	42.5	41	41	43	40.8
Sheep	Male	8	9	8	8	8	8	9	8	8	8.2
	Female	8	9	7	8	8	8	8	8	8	8
	Averag e	8	9	7.5	8	8	8	8	8	8	8.1
Goats	Male	8	9	8	8	8	8	9	8	8	8.2
	Female	8	9	7	8	8	8	8	8	8	8
	Averag e	8	9	7.5	8	8	8	8	8	8	8.1
Donkeys	Male	28	30	32	28	28	30	33	28	30	29.7
	Female	25	30	30	28	28	30	30	28	29	28.7
	Averag e	26.5	30	31	28	28	30	31.5	28	29.5	29.2

The average weaning weight in zebu cattle in the conservancies was 40.8 kg (female weighing 38.7 kg and male 43 kg), sheep 8.1 kg (female weighing 8 kg and male 8.2 kg) and goats 8.1 kg (female weighing 8 kg and male 8. 2kg).

Table 4.4: Responses from the ten conservancies adjacent to the Maasai Mara Game Reserve showing average mature weights (kg) of average animal per conservancy

Type of Animal	Sex	Selected conservancies studied									Average mature weights (kg)
		Siana, Nashulai	Olkinyei	Mara North	Olar e Orok	Pardamat	Lemek	Motorogi	Naboisho	Olarro North	
		Average birth weights per ranch (kg)									
Zebu Cattle	Male	210	160	166	181	183	180	165	182	186.7	**179.3**
	Female	180	154.5	154	156	150	150	152	155	154.3	**156.2**
	Averag e	195	157.3	160	168.5	166.5	165	158.5	168.5	170.5	**167.8**
Sheep	Male	20	20	20	21	20	22	20	21	19	**20.3**
	Female	19.2	18	15	17	16	19	15	17	15	**16.8**
	Averag e	19.6	19	17.5	19	18	20.5	17.5	19	17	**18.6**
Goats	Male	18	20	20	21	20	20	17.5	21	18	**19.5**
	Female	16	18	16.7	17	15	18	15	17	14	**16.3**
	Averag e	17	19	18.4	19	17.5	19	16.3	19	16	**17.9**
Donkeys	Male	70	70	70	70	70	70	70	70	69	**69.9**
	Female	60	70	70	70	70	70	70	70	67	**68.6**
	Averag e	65	70	70	70	70	70	70	70	68	**69.2**

At maturity zebu cattle average was 167.8 kg (female weighing 156.2 kg and male 179.3 kg), sheep 18.6 (female weighing 16.8 and male 20.3 kg), goat 17.9 kg (female weighing 16.3 kg and male 19.5 kg).

Table 4.5: Livestock, demographic parameters and yields in the Maasai Mara the study area

Type of Animal	Age	Average milk yield /day (litres)	Lactation period(days)	Total yield	Age at 1st Parturition (months)	Parturition interval (months)	Litter size
Indigenous zebu Cattle	Young milker	3	240	720	44	13	1
	Mature cow	4	280	1120			
Goats	Young kidder	0.5	120	60	18	4	1 or 2
	Mature kidder	1	120	120			
Sheep	Young	0.5	120	60	18	3.5	1 or 2
	mature	1	120	120			

Zebu cows' produces one young one at calving (litter size), goats 1 or 2 kids while sheep produce 1 or 2 lambs. At maturity average milk yield per day in a zebu is 4 litres per day, with a total lactation period of 280 days, while goat and sheep produce 1 litre per day and had a lactation period of 120 days.

Table 4.6: Livestock mature age survival rates percentages and conception rates per conservancy

Conservancy	**Conception rates per conservancy (%)**	**Mature age survival rates of livestock per conservancy (%)**
Siana	77	80
Olkinyei	73	70
Nashulai	76	80
Naboisho	77	79
Olare Orok	77	80
Mara North	75	78
Pardamat	73	65
Olarro North	74	65
Lemek	71	62
Motorogi	74	66
Average	**74.7**	**72.5**

In all the livestock categories studied, the average conception percentage was 74.7 and a mature age survival rate of 72.5 percent. Highest survival rates were in Siana, Naboisho and Olare Orok that border the Maasai Mara National reserve while the lowest were at the furthest including Pardamat (65%), Olarro North (65%), and Lemek (62%).

Table 4.7: Average body weights, gestation, parturition and litter sizes (numbers) of selected wildlife in the Maasai Mara, the study area

Animal species	Highest possible age (months)	Average body weight at birth (kgs)		Average body weight at maturity(kgs)		Gestation period (days)	Age at first parturition (months)	Parturition interval (months)	Litter size	Browse/ Graze
		M	F	M	F					
Elephant	840	120	120	3000	2150	656	126	48	1	Mixed feeder
Buffalo	192	40	40	700	550	340	36	16	1	Grazer
Eland	240	29	29	850	450	270	38	11	1	Mixed feeder
Wildebeest	192	22	22	250	180	250	40	13	1	Grazer
Topi	180	11	11	140	126	240	18	12	1	Grazer
Hartebeest	240	12	12	150	120	240	18	13	1	Mixed feeder
Impala	180	5	5	60	40	197	24	12	1	Mixed feeder
Thomson's gazelle	180	2.5	2.5	23	18	180	10	7	1	Grazer
Grants gazelle	180	6	6	65	45	195	18	12	1	Mixed feeder
Dik dik	108	0.795	0.624	5.1	5.5	175	16.5	6	1	Browser
Water buck	192	13	13	236	186	255	30	10	1-2	Mixed feeder
Warthogs	240	0.6	0.665	82	65	165	18		1-8	Mixed feeder
Zebra (plains)	336	33	32.5	330	315	375	30	12	1	Mixed feeder
Giraffe	240	57	55	1185	825	450	45	18	1	Browser
Hippo	600	32	30	1500	1350	241	108	24	1	Grazer
Black rhino	600	41	40	1179	950	450	84	37.5	1	Browser
Reedbuck (common)	108	4.8	4.5	55.5	41	220	12	11.5	1	Browser
Duiker (common)	108	1.8	1.6	18	21	190	18	8.6	1	Browser
Steenbok	84	0.95	0.9	10.9	11	170	8	8	1	mixed feeder
Bushbuck	120	4	4	45	30	180	10	7	1	Browser
Oribi	144	2	1.7	17	15	210	10	12	1	Mixed feeder
Klipspringer	144	1	1	10	13	210	12	13	1	Mixed feeder
White rhino	600	41.5	40	2150	1500	480	84	40	1	Grazer
Ostrich	360	1.8	1.5	110	95	42	36	5	9	Grazer

Table 4.7 summarises the demographics of 24 wild animals in the Maasai Mara. These include the highest possible age, average body weight of at birth and at maturity, gestation period, age at first parturition, parturition interval and litter size. It also specifies the feeding category of the animal (mixed feeder, grazer or browser). The overall productivity of the different animals (from the PRY model) is presented in Table 4.8, Table 4.9 and

Table 4.10. Daily dry matter demand was calculated by using the body weights (appendix 11) and inputted into the model.

The produce related parameters that included the dry matter demand conception rates, mature age percentage, lactation period, weight (at birth, weaning and mature) and average milk yield per day were fed to the PRY model to yield productivity index of the livestock and wildlife studied. Composition of the animals was acquired from the survival rates, parturition intervals, age at first parturition and litter size inputted to the PRY model.

4.5.1 Productivity of grazers

Among the grazers, the hippopotamus had the lowest overall productivity with a feed energy efficiency (FEE) of 0.03 and the highest was of the Thompson's gazelle with 0.08. Others were white rhino with 0.04, cattle 0.04, ostrich 0.05, wildebeest 0.05, sheep 0.06, buffalo 0.06 and Topi 0.07. Among the wildlife grazers, Thompson's gazelle exhibits the highest feed efficiency while sheep is highest among livestock. The overall mean among grazers was 0.053 (Table 4.8 and figure 4.12). Comparison was drawn between the livestock and wildlife gazers where the wildlife showed a slightly higher FEE of 0.054 and livestock 0.05 with a P-value of 0.024. This indicated that the FEE of livestock and wildlife grazers were not significantly different.

Table 4.8a: P-value of wildlife and livestock grazers

	Test Value = 0					
	t	df	Sig. (2-tailed) (p)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
	26.000	1	.024	.05200	.0266	.0774

The Thompsons gazelle is placed at an advantage of improved grass quality through feeding facilitation. Studies in the Serengeti documented a regrowth of leafy grass with increased green biomass concentration as a result of wildebeest grazing. The gazelles are known to prefer these areas grazed by wildebeest previously for even up to six months after the passage of wildebeest moving into the dry season. Reproductive performance of other grazing herbivores is enhanced by grazing impacts of both the white rhino and the wildebeest as they promote improved grass quality during the wet season (Arsenault & Owen- Smith, 2002). This translated into the low productivity of the white rhino and the wildebeest and higher productivity in Thompson's gazelle in the Maasai Mara region, yet the numbers of these animals is decreasing. (Thirgood *et al.*, 2004) confirmed that from 1977 to 1997, the Maasai Mara wildebeest numbers decreased from 119000 to 22000, a 75% reduction, especially due to intensification of agriculture, thus interference with their migratory patterns, deaths, due to droughts and disease in the drought years, poor forage and predators.

Table 4.8b: Overall productivity of grazers' population in the Maasai Mara

	Animal species	Overall productivity-Value per animal per year per kilogram of Dry Matter (feed energy efficiency index)	Feed energy efficiency ranking
Thomson's Gazelle	*Eudorcas thomsonii*	0.08	1
Topi	*Damaliscus lunatus*	0.07	2
Buffalo	*Syncerus caffer*	0.06	3
Sheep	*Ovis aries*	0.06	3
Ostrich	*Struthio camelus massaicus*	0.05	4
Wildebeest	*Connochaetes taurinus*	0.05	4
Cattle	*Bos Taurus/indicus*	0.04	5
White Rhino	*Ceratotherium simum*	0.04	5
Hippopotamus	*Hippopotamus amphibious*	0.03	6
Means(Grazers)		**0.053**	

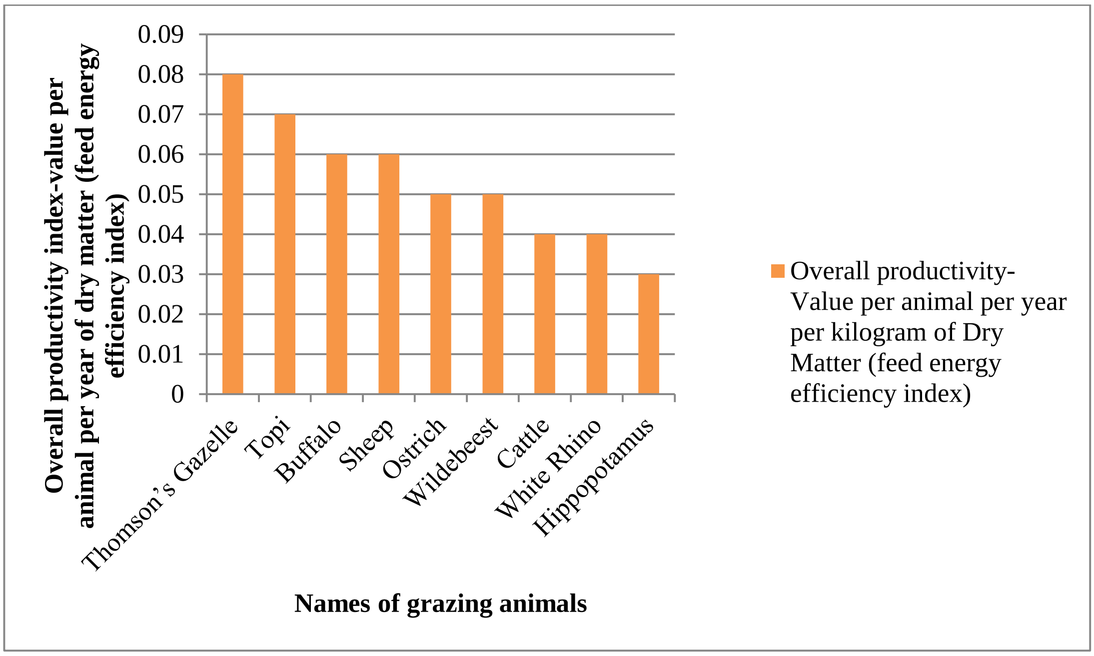


Figure 4.12: Overall productivity index (Feed Energy Efficiency) of selected grazers in Maasai Mara (Kenya)

The grazers were ranked according to their productivity index in Table 4.8b and figure 4.12. with the Thomson's gazelle leading with a FEE of 0.08 and hippopotamus having the lowest FEE of 0.03.

4.5.2 Productivity of browsers

The bushbuck showed the highest FEE of 0.09. Black Rhinos and dik diks on the other hand, had the lowest FEE of 0.03. In the livestock category, the only browser, the goat competed well with wildlife and was among the top in ranking with an FEE of 0.06. Duikers had an FEE of 0.05, giraffe 0.06, reedbuck 0.07. The overall mean FEE in the browsers category was 0.056 (Table 4.9b and figure 4.13). The P-value was 0.028 indicating that the differences in FEE in livestock and wildlife browsers were not statistically significant as indicated by the table 4.9a below.

Table 4.9a: P-value of wildlife and livestock browsers

	Test Value = 0					
	t	df	Sig. (2-tailed) (p)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
VAR00001	23.000	1	.028	.05750	.0257	.0893

Table 4.9b: Overall productivity of browsers population in the Maasai Mara

	Animal species	**Overall productivity-Value per animal per year per kilogram of Dry Matter (feed energy efficiency index)**	**Feed energy efficiency ranking**
Bushbuck	*Tragelaphus sylvaticus*	0.09	1
Reedbuck	*Redunca arundinum*	0.07	2
Goat	*Capra hircus*	0.06	3
Giraffe	*Giraffe camelopardalis*	0.06	3
Duiker	*Sylvicapra grimmia*	0.05	4
DikDik	*Rhynchotragus kirkii*	0.03	5
Black Rhino	*Diceros bicornis*	0.03	5
Means (Browsers)		**0.056**	

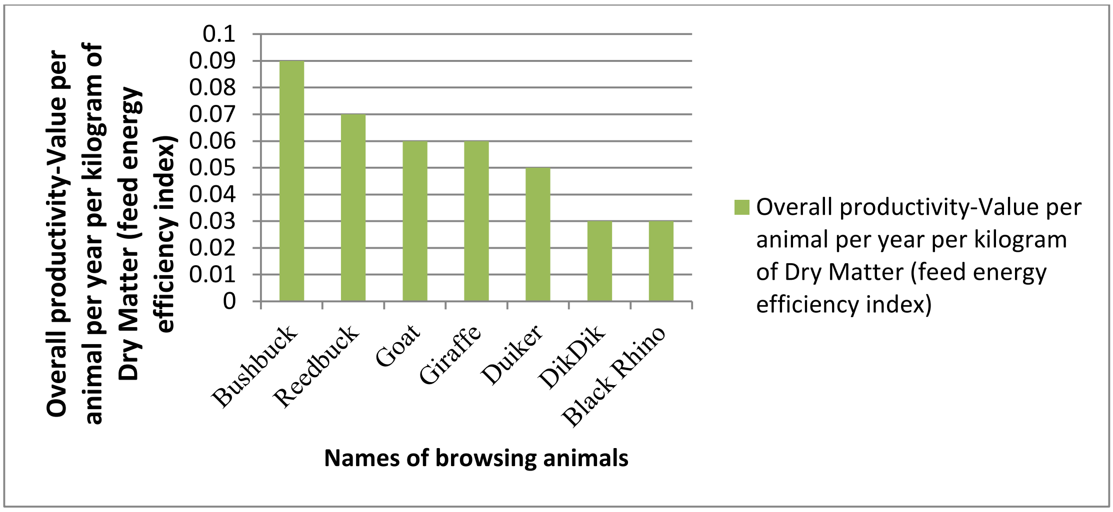


Figure 4.13: Overall productivity (FEE) of selected browsers in Maasai Mara (Kenya)

Overall productivity of browsers is higher than grazers with bushbucks having a productivity index of 0.09 and black rhino and dikdik at 0.03 as shown in figure 4.13 and table 4.9b. The browsers are more advantaged than grazers, since they browse from high growing plants even in dry season when there is limited grass.

4.5.3 Productivity of mixed feeders

Elephants had a FEE of 0.02, the lowest among all the animals studied. The warthog also a mixed feeder, on the other hand had the highest FEE of 0.10. Zebras, steenbok, eland, hartebeest all had high FEE of 0.07, while Oribi, grants gazelle, waterbuck had an FEE of 0.06. Impalas and klipspringer followed closely with an FEE of 0.06. Overall mean FEE among mixed feeders was 0.062 (Table 4.10 and figure 4.14).

Table 4.10: Overall productivity of mixed feeders population in the Maasai Mara the study area

Common name of animal	Animal species	Overall productivity-Value per animal per year per kilogram of Dry Matter (feed energy efficiency index)	Feed energy efficiency ranking
Warthog	*Phacochoerus aethiopicus*	0.10	1
Hartebeest	*Alcelaphus bucelaphus*	0.07	2
Steenbok	*Raphicerus neumanni*	0.07	2
Eland	*Tragelaphus oryx*	0.07	2
Zebra	*Equus burcheli*	0.07	2
Grants Gazelle	*Nanger granti*	0.06	3
Waterbuck	*Kobus ellipsiprymnus*	0.06	3
Oribi	*Ourebia ourebi*	0.06	3
Impala	*Aepyceros melampus*	0.05	4
Klipspringer	*Oreotragus oreostragus*	0.05	4
Elephant	*Loxodonta Africana*	0.02	5
Means (mixed feeders)		**0.062**	

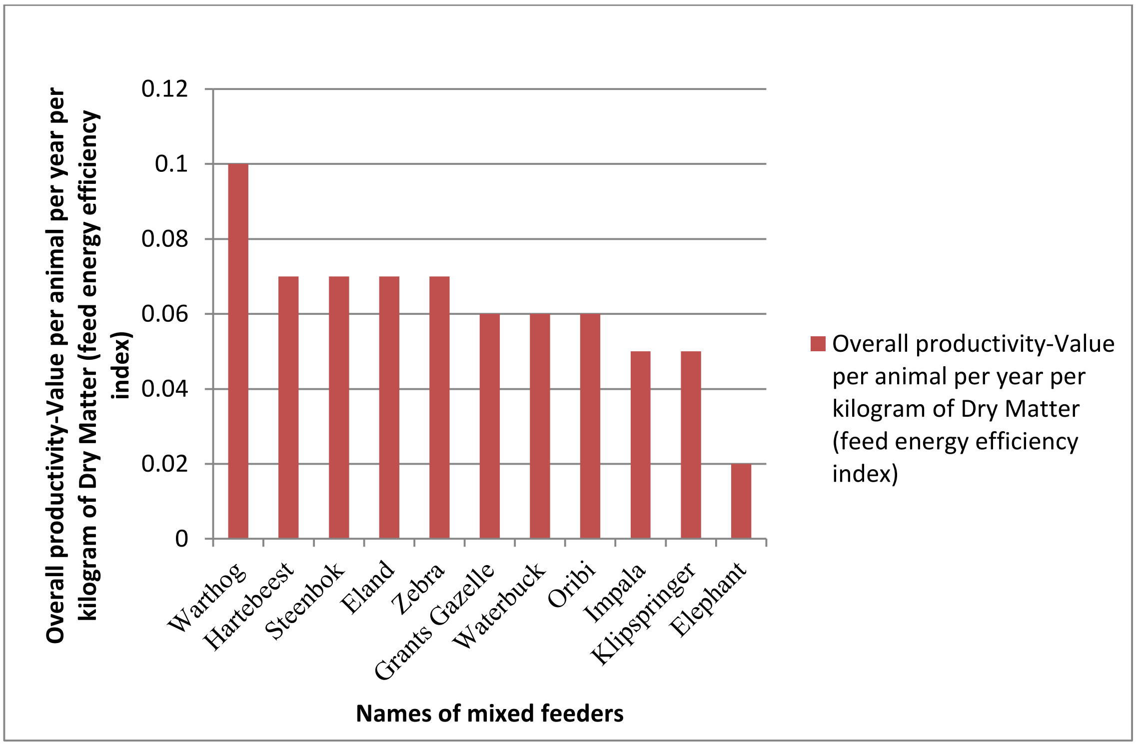


Figure 4.14: Overall productivity (FEE) of selected mixed feeders in Maasai Mara, the study area in Kenya

The warthog (0.10) led in productivity among the animals studied while the elephant's (0.02) performance was poorest. The mixed feeders compared to grazers and browsers led in performance with a mean score of 0.062. This was as a result of the mixed feeders having the ability to graze when grasses are available and browse in dry seasons as shown in figure 4.15.

4.5.4 Overall Productivity and Composition of mixed feeders, browsers, grazers

From the animals studied of the most common wildlife and livestock species in the region, mixed grazers had the highest productivity with a mean FEE of 0.062 followed by browsers 0.056 (FEE) and grazers 0.053 (FEE) as indicated in Figure 4.15.

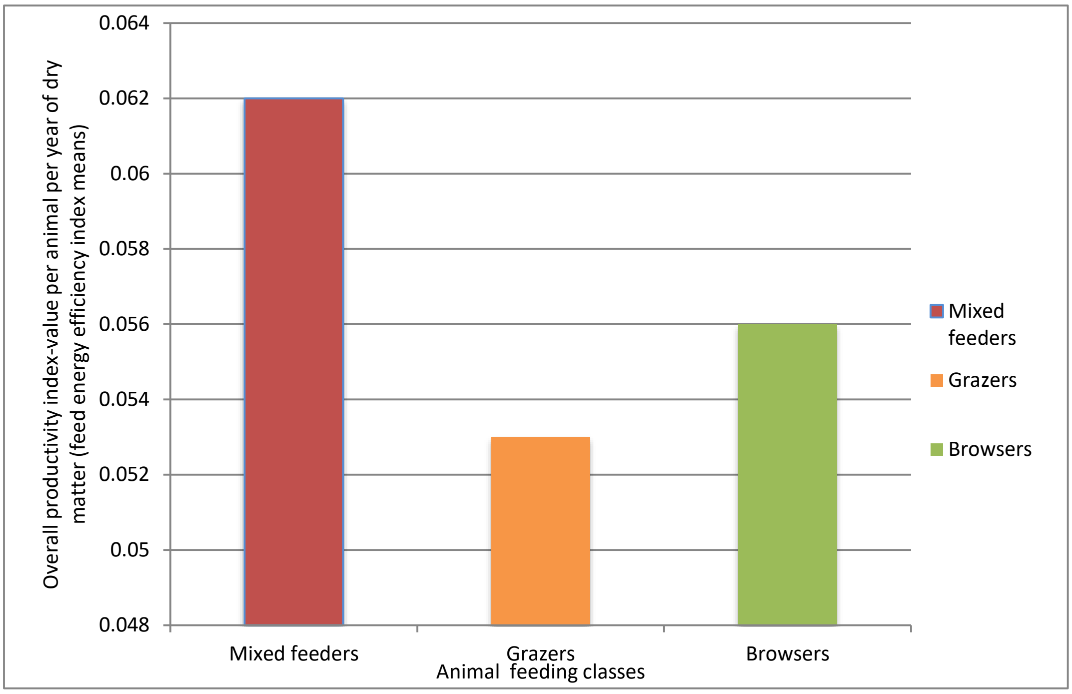


Figure 4.15: Overall Productivity means of mixed feeders, browsers and grazers in Maasai Mara (Kenya)

The least productive animal studied the elephant was from the mixed feeder category that contributes immensely to tourism, therefore a threat to the industry. The high productivity of mixed feeders could be attributed to the fact that during the wet season in the Maasai Mara, the mixed feeders can graze and browse on trees and shrub in the dry season when grass is scarce. Browsers have a higher productivity than grazers since there is browse during the dry season and very little grass to graze. In a study by (Ogutu & Norman, 2003) at the Kruger National Park in South Africa, annual rainfall variability affected grazers more than browsers due to the herbaceous layer responding more strongly to annual precipitation compared to the woody savannah vegetation component. In the same park, (Redfern *et al.*, 2003), found out that larger species of grazers are found further from water with reduced forage quantities with smaller grazers moving further from water with reduced forage quality. However browsers are relatively water independent and their distribution patterns are characterized by a weak relationship with distance to water therefore an advantage for survival during the dry season. Further, (Waal & Smit, 2003) adds that palatable species are acceptable as long as they retain leaves and only when other browse resources are depleted do they turn to unpalatable species.

When animals were classified into breeding females, surplus females and male youngstalk, the overall productivity of breeding females (Table 4.11) was lower than that of both surplus females and male youngstock with a mean FEE of 0.01 in breeding females, 0.1 surplus females and 0.1 in male youngstock. When classified into feeding categories, a similar trend was seen among browsers with both male youngstock and surplus females having a mean FEE of 0.11 and breeding females 0.01. Breeding females among grazers had a mean FEE of 0.02, surplus females, 0.08 and male youngstock 0.08 while mixed feeders had 0.01 in breeding females, 0.09 in surplus females and 0.01 for the male youngstock. The results in the Maasai Mara showed a similar trend to that studied at Lewa Wildlife Conservancy and Ol Pejeta Ranch in Laikipia by (Simiyu, 2004), where breeding females had the lowest mean FEE and male youngstock the highest. However due to controlled management practices like culling in at Lewa Wildlife Conservancy and Ol Pejeta Ranch, the productivity of wildlife is higher than that of the Maasai Mara.

The FEE of breeding females in elephants, white rhino and black rhino was 0, hence poor breeders, yet the dry matter intake required to produce the same is large with 172877 kg in elephants, 128484 kg in white rhino and 88987 kg in black rhino, hence a very low efficiency in feed energy conversion. Ostrich had an (FEE) of 0.02. The productivity (FEE) of wildlife was between 0 and 0.01 in breeding females, unlike the higher figures in livestock with 0.03 in cattle, 0.04 in goats and 0.05 in sheep. This could have been attributed to the management of the livestock. The non-productive females may be culled, maintaining the more effective breeders among the livestock unlike the wildlife in the wild. Culling of wildlife is not being done in the Maasai Mara therefore the productivity is naturally constituted.

Table 4.11: Selected animal species composition and their productivity indices in the Maasai Mara, Kenya

Animal species (common name)	Composition within species classes (Frequency in %)			Productivity in classes of animal populations .Value per animal per year per kilogram of Dry Matter (feed energy efficiency index)			Overall productivity-Value per animal-year (feed energy efficiency) per kilogram of Dry Matter (feed energy efficiency index)
	Breeding female	Surplus female	Male youngstock	Breeding female	Surplus female	Male youngstock	
Elephant	16	34	50	0	0.05	0.04	0.02
Klipspringer	55	19	26		0.05		0.05
Impala	11.4	38.6	50	0.01	0.08	0.08	0.05
Oribi	12	38	50	0.01	0.12	0.12	0.06
Grants Gazelle	10.5	39.5	50	0.01	0.10	0.10	0.06
Waterbuck	9.5	40.5	50	0.01	0.09	0.09	0.06
Zebra	7.5	42.5	50	0.01	0.09	0.10	0.07
Steenbok	53	20	27				0.07
Eland	8.9	41.1	50	0.01	0.08	0.10	0.07
Hartebeest	9.2	40.8	50	0.01	0.12	0.12	0.07
Warthog	1.6	48.4	50	0.01	0.10	0.11	0.10
Means (mixed feeders)	**17.7**	**36.6**	**45.7**	**0.01**	**0.09**	**0.1**	**0.062**
Hippopotamus	10	40	50	0.01	0.04	0.05	0.03
White Rhino	13.8	36.2	50	0	0.06	0.06	0.04
Cattle	46.9	3.1	50	0.03	0.06	0.06	0.04
Ostrich	1.1	48.9	50	0.02	0.05	0.05	0.05
Wildebeest	12.1	37.9	50	0.01	0.07	0.07	0.05
Sheep	40.6	9.4	50	0.05	0.08	0.08	0.06
Buffalo	13.9	36.1	50	0.01	0.10	0.10	0.06
Topi	10.8	39.2	50	0.01	0.12	0.12	0.07
Thomson's Gazelle	7.4	42.6	50	0.01	0.13	0.13	0.08
Means (grazers)	**17.4**	**32.6**	**50**	**0.02**	**0.08**	**0.08**	**0.053**
Black Rhino	12.9	37.1	50	0	0.05	0.05	0.03
DikDik	9.9	40.1	50	0.01	0.20	0.20	0.03
Duiker	12.9	37.1	50	0.01	0.09	0.08	0.05
Giraffe	12.9	37.1	50	0.01	0.08	0.09	0.06
Goats	40.8	9.2	50	0.04	0.08	0.08	0.06
Reedbuck	15	35	50	0.01	0.13	0.13	0.07
Bushbuck	9.9	40.1	50	0.01	0.14	0.14	0.09
Means (browsers)	**16.3**	**33.7**	**50**	**0.01**	**0.11**	**0.11**	**0.056**
Overall means	**17.1**	**34.3**	**48.6**	**0.01**	**0.1**	**0.1**	

In table 4.11, the percentage of breeding females' and also productivity in breeding females in wildlife was lower than that of livestock.

4.5.5 Productivity of selected populations of wildlife herbivores species most preferred by tourists in the Maasai Mara

Among the animals most preferred by tourists as per the value weight given by tourists informally interviewed as they viewed wildlife in the park, the zebra, Topi, hartebeest had an overall FEE of 0.07. Buffalo and giraffe followed closely with an FEE of 0.06, wildebeest 0.05, hippopotamus 0.03 and elephant 0.02. The most preferred specie, wildebeest was third in FEE ranking while the least preferred, the topi and hartebeest rank highest in FEE. The second specie in preference (zebra) after the wildebeest was among the highest rated animal with an FEE index of 0.07 (Table 4.12). According to (Simiyu, 2004) the zebra had a high FEE because of the high returns from its hide. In the Maasai Mara the Zebra is highly valued as it migrates with the wildebeest whose migration is highly valued by tourists. With the high productivity, there is potential of the zebra being one of the most preferred animal in terms of returns if managed well.

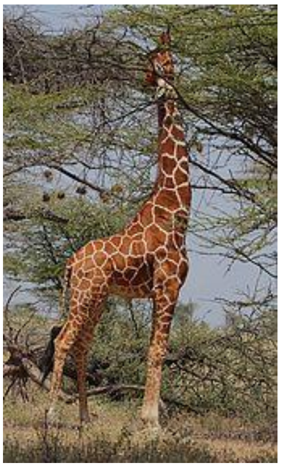
Table 4.12: Productivity of selected wild herbivores species most preferred by tourists in the Maasai Mara area of Kenya

Animal species	Productivity in classes			Value per animal-year per kilogram of Dry Matter (feed energy efficiency index)	Feed Energy Efficiency ranking
	Breeding female	Surplus female	Male youngstock		
Wildebeest	0.01	0.07	0.07	0.05	**3**
Zebra	0.01	0.09	0.10	0.07	**1**
Hippopotamus	0.01	0.04	0.05	0.03	**4**
Giraffe	0.01	0.08	0.09	0.06	**2**
Elephant	0	0.05	0.04	0.02	**5**
Buffalo	0.01	0.10	0.10	0.06	**2**
Topi	0.01	0.12	0.12	0.07	**1**
Hartebeest	0.01	0.12	0.12	0.07	**1**

Plate 4.1: Elephant herd grazing near Talek gate in the Maasai Mara, Narok County during the wet season

Plate 4.2: Hippopotamus in the Mara River, Narok County, Kenya

Browser



Giraffe browsing on acacia leaves

Grazers

Wildebeests grazing

Hippo grazing

Buffalos grazing

Plate 4.3: Some grazers and browsers in the Maasai Mara National Reserve, Kenya

4.6 Overall Livestock and wild animals' species Composition in the Maasai Mara

An overall picture of composition of animals in the study area showed a high percentage of male young stock with 48.6 % of the total population, surplus female 34.3 % and 17.1 % were breeding females yet only a few males are required for breeding. There was an indication of poor performance in breeding females both in productivity and composition of wildlife.

On the other hand, the composition of breeding females in livestock were much higher compared to wildlife as shown by the goats with 40.8 %, sheep at 40.6 % and cattle 46.9% of the population, all attributed to the direct management of livestock. The respondents agreed that culling of livestock was not common but the sterile females and excess males in the population were fattened for sale for meat, controlling the population balance to some extent. But the composition of males in all animal species was nearly 50% of the entire population except the steenbok and Klipspringer with 27% and 26% respectively.

The composition of breeding females in steenbok is 53% and Klipspringer 55% was thus high potential breeders and this was good gesture, considering that they are rare animals in the Maasai Mara.

The mean percentage composition of grazers was 17.4%, 32.6% and 50% for breeding females, surplus females and male youngstock respectively. A slightly higher trend was seen in mixed feeders with 17.7%, 36.6%, 45.7% and a lower one in browsers with 16.3%, 33.7%, 50% in for breeding females, surplus females and male youngstock respectively The composition of mixed feeders places them at an advantage with the higher percentage of breeding females of 17.7%, followed closely by grazers with 17.4% and browsers 16.3%.

This is demonstrated in figure 4.16.

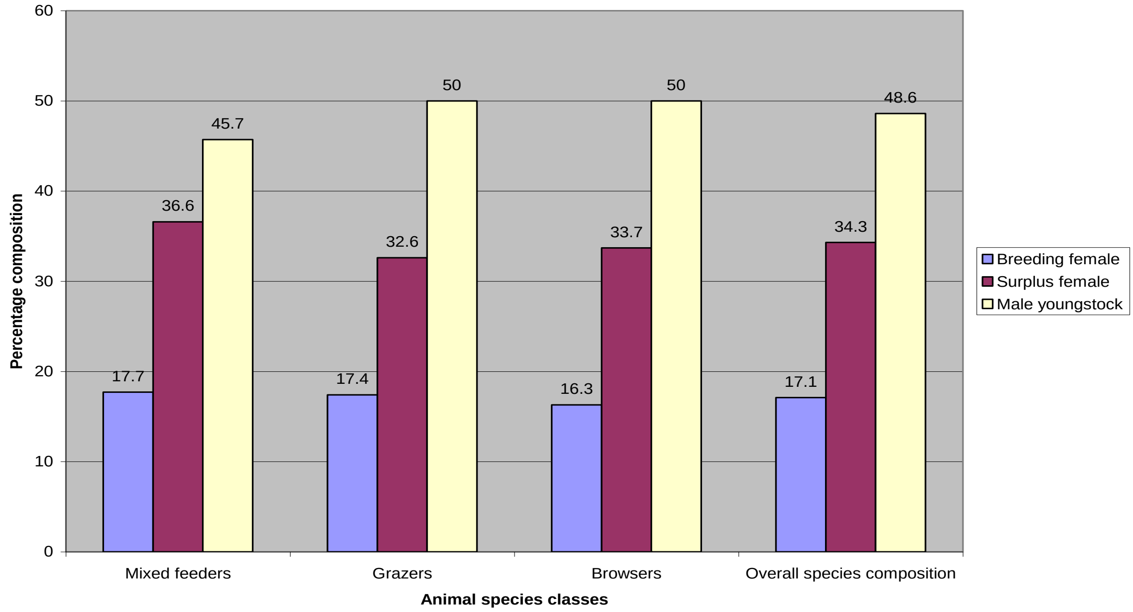


Figure 4.16: Composition of grazers, mixed feeders and browsers (%) in the Maasai Mara, Narok County, Kenya

Figure 4.16 showed that, the composition of breeding females was the lowest across the categories, while the highest composition was in the male youngstock category. This has an implication in the future of the animals as few males are required to breed females. In a population where breeding female's composition is low, the population growth is low, thus impacting on the decreasing wildlife populations in the Maasai Mara.

Comparisons in composition (%) of livestock and wildlife yielded a P-value of 0.013 therefore they were not statistically significant.

Table 4.13: P-value of wildlife and livestock composition

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed) (p)
					Lower	Upper			
Pair 1	VAR00001 - VAR00002	-29.46667	5.98025	3.45270	-44.32242	-14.61091	-8.534	2	.013

In productivity, browsers ranked second, while in composition breeding females in grazers ranked second, thus more breeding females in grazers than browsers. From a general perspective, mixed breeders were best adapted and suited to the Maasai Mara area due to their higher productivity and composition compared to browsers and grazers.

4.7 Relationship between climate and the populations trends, their composition and productivity indices

Declining population was observed in most animals including buffalo, eland, topi, giraffe, hartebeest, grants gazelle, Thomsons gazelle, waterbuck, zebra, wildebeest, warthog, donkeys *except* ostrich, elephant, impala, and livestock, cattle, shoats (sheep and goats) between 1977 and 1997 as per the wet and season dry counts. The figures of impala, cattle and shoats were notably high in 1997 with 76721,209584,174998 respectively. Elephant were at 4688 and ostrich 615. This conclusion agreed with the findings of (Ottichillo *et al.,* 2001b; Ottichillo *et al.,* 2001a; Ottichillo, 2000) who reported on declining wildlife population in the Maasai Mara ecosystem.

(Ojwang *et al.,* 2006) evaluated the net primary productivity as per the satellite monitoring that showed seasonal and long term variability in biomass production in the Maasai Mara, with increases in rainfall in 1970's leading to high increases in buffalo and wildebeest populations. However there was drought between 1983 and 1984 followed by high rainfall in the second half of 1980's, thus high productivity.

The last part of the 1980's was good as far as rainfall was concerned, leading to average to above average net primary production of forage. Decreasing animal populations occurred due to the 1992-1993 drought especially the wildebeest and zebra. This concurred with the findings of (Serneels *et al.,* 2001), where most vegetation types are affected by drought stress and have high change vector magnitudes during serious drought years. They noted that during drought years, vegetation cover is very sparse and the quality is poor with quick recoveries of grasslands and low value of change of vector magnitude in years of average or abundant rainfall. (Bahrani & Bahrani, 2003), expressed that, drought stress is one of the limiting factors in the production of forage and crops in the arid and semi-arid regions. In a study carried out on productivity of indigenous and exotic cattle with improved conditions, productivity was high from 1993 to 1998 but primary productivity was low between 1998 and 2000. Between 2000 and 2002, cattle numbers increased by 2 folds in the Maasai Mara ecosystem, though with high concentration in the game reserve. (Odhuba, 1987) indicated that there was high fertility of beef cattle when there was increased rainfall during the month before conception.

In a study in Kruger National Park, South Africa by (Ogutu & Norman, 2003), extreme decline in dry season rainfall and temperature rise influenced population declines of the sable antelope, roan antelope, kudu, warthog, waterbuck and eland from census records from 1977 to 1996. High abundance levels were however maintained in the impala, zebra, giraffe and wildebeest. In Laikipia, the rains were below average in the years 1999, 2000 significantly reducing pasture availability for both the pastoralists and commercial ranchers (Mwanje *et al.*, 2001).

The general trend in the study was that the wildlife populations decreased, while livestock populations increased with an exception of the donkey. This can be explained by the composition of breeding females that was low in the population versus productivity rates and also climatic variability. Cattle have 46.9% of the population being breeding females, with a productivity rate of 0.04, therefore has potential of increases in population. Shoats (goats and sheep) have an overall high productivity of 0.06 and an average composition percentage of 40.7% in the breeding females, thus have potential of population increase. Elephants, with the lowest productivity of 0.02, had 16% of the population being breeding females while warthog, with the highest productivity of 0.10 has only 1.6% of the population being breeding females, a reason that contributes to their numbers decreasing coupled with the rising temperatures and declining rainfall that reduces forage quantity and quality.

The wildlife had percentages of breeding females decreasing below 16% of the total population, with productivities between 0.02 and 0.10, coupled with variabilities in climate hence decreasing populations. Composition and productivity in breeding females in the Maasai Mara are shown in Figures 4.17 a, b, c and 4.18. Productivity, composition, and quality can be adversely affected by Climate variability, with potential impacts not only on forage production but also on other ecological roles of grasslands (Giridhar & Samireddypalle, 2015). Quality, quantity and distribution of rainfall, river flow and groundwater may be affected by temperature and weather changes. Greater peak run-offs and less groundwater recharge due to higher intensity precipitation are also occurring. Reduced groundwater recharge, reduced river flow with longer dry periods will ultimately affect water availability, agriculture and drinking water supply (Sejian *et al*., 2016).

The year 1979 was dry but had high populations in the wet season and low populations in the dry season except for the wildebeest which migrates to the Maasai Mara during the dry season. The preceding two years were wet and contributed to high primary productivity, with a lot of forage leading to corresponding high secondary productivity hence high populations.

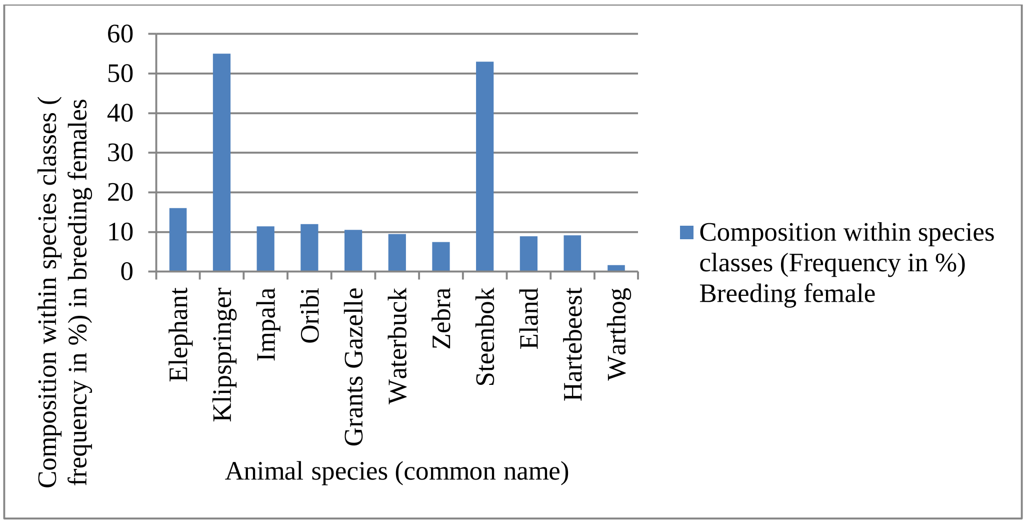


Figure 4.17a: Composition of breeding females within selected mixed feeders in Maasai Mara, Narok County, Kenya

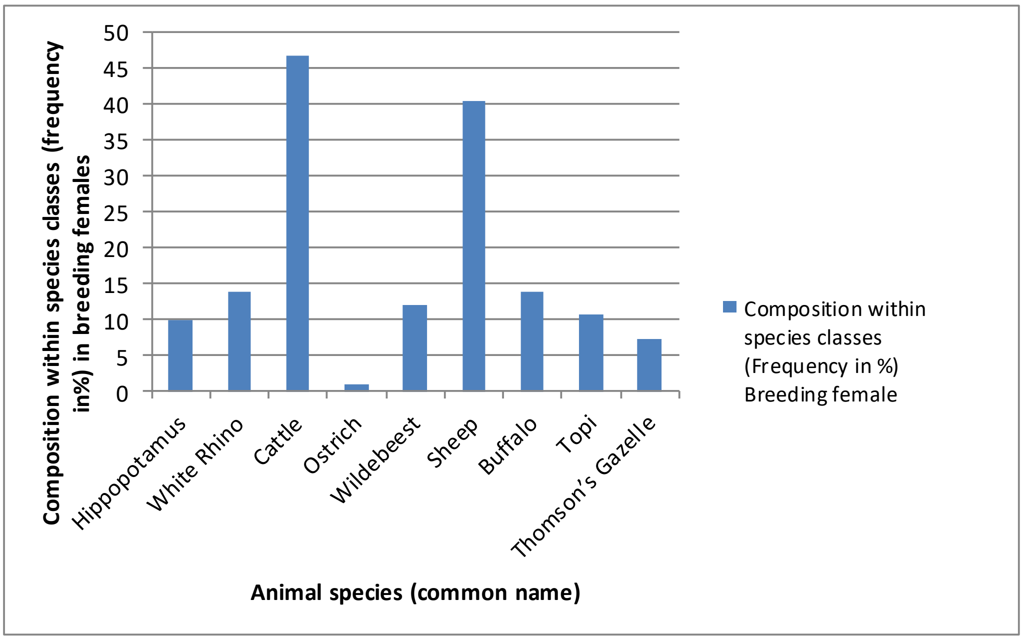


Figure 4.17b: Composition of breeding females within selected grazers in Maasai Mara, Narok County, Kenya

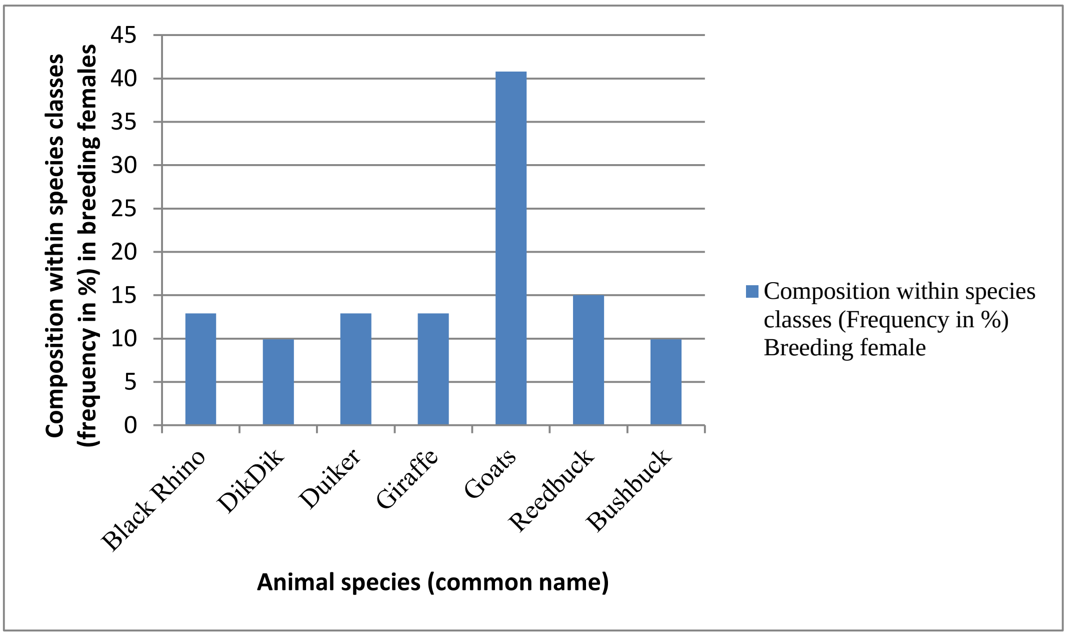


Figure 4.17c: Composition of breeding females within selected browsers in Maasai Mara, Narok County, Kenya

The animals with the highest percentage of breeding females as seen in figure 4.17a wereklipspringer and steenbok. They have a potential of population increase with the high numbers of breeding females. Livestock have a higher composition of breeding females compared to wildlife (figure 4.17b) with cattle and sheep in the grazers' category having over 40% of the population being breeding females while in the browser category, goats (livestock) lead in percentage of breeding females with 40.8%. This explains the increasing population numbers in the livestock over the years.

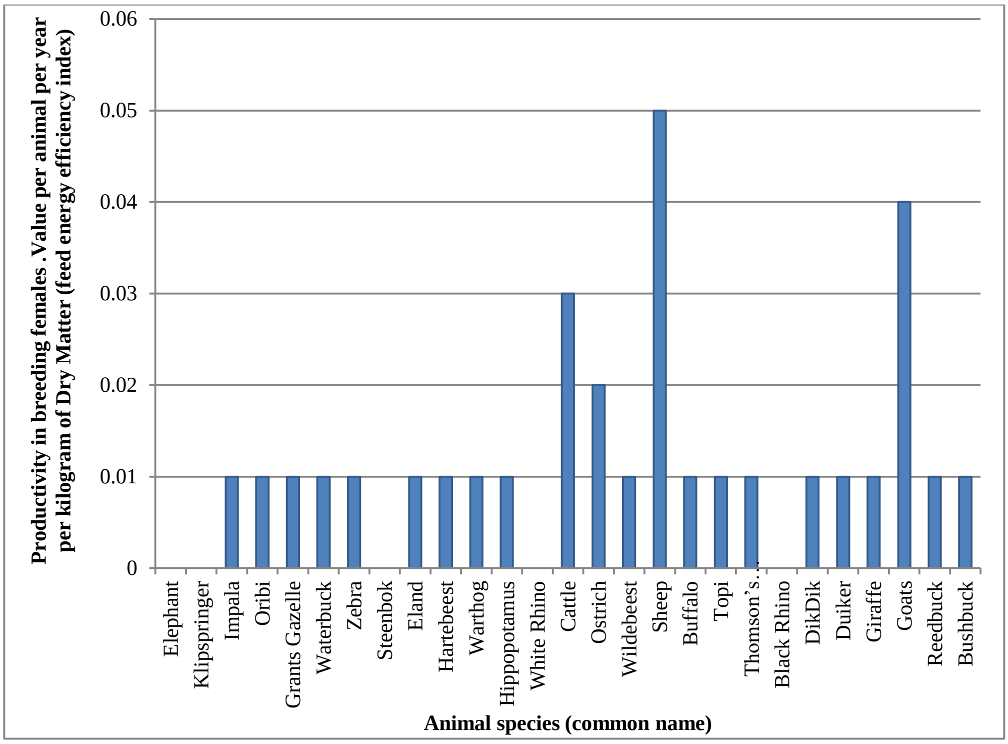


Figure 4.18: Productivity index in breeding females within selected animal species (FEE) in Maasai Mara, Narok County, Kenya

Cattle, sheep and goats in the livestock category exhibited high productivity index (Feed Energy efficiency), followed closely by the ostrich (figure 4.18). From analysed animal counts (Appendices 3, 4, 5,), sheep and goats numbers increased. Wildlife numbers decreased except for elephant and ostrich. Animals best preferred by tourists in the Maasai Mara according to this study also had high percentage declining populations, yet their composition of breeding females was low and the productivity index (FEE) was also low. This trend showed that the numbers of these high valued animals is decreasing and threatened.

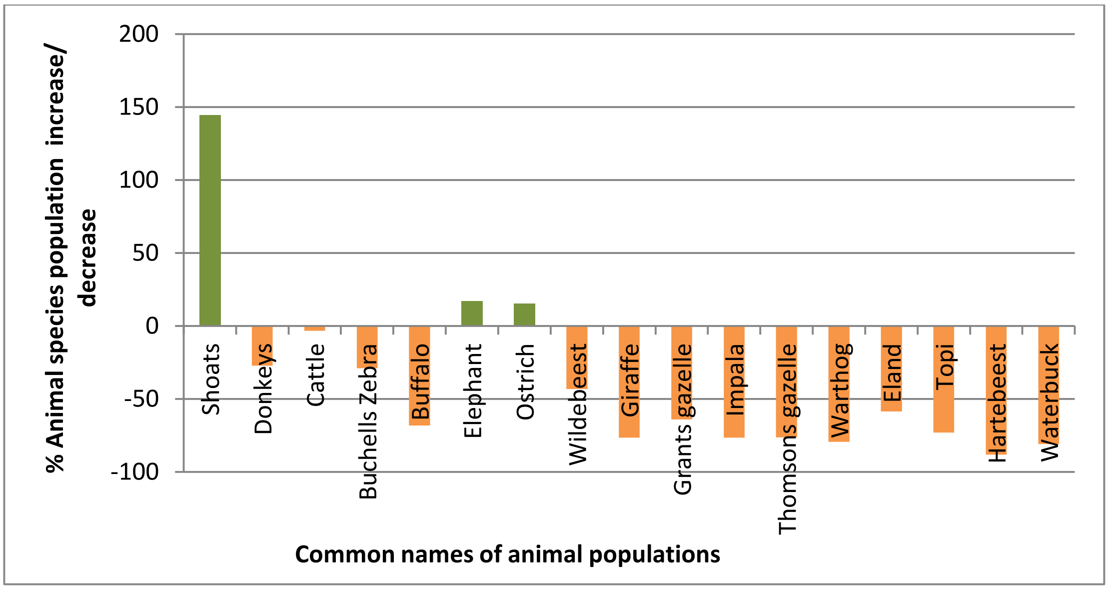


Figure 4.19: Selected wildlife and livestock species trends between years 1977-1980 and 2011-2016 in Maasai Mara, Narok County, Kenya.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the findings

The summary of the present research based on the objectives of this study were as follows:

1. Rainfall was erratic in the study years from 1975 to 2016. From 1975 to 1976 rainfall decreased by 8.3mm, 1976 to 1985 increased by 29.9mm. Decreases of 31.9 mm were witnessed from 1985 to 2000 where there were 3 droughts in 1983-1984, 1995-1996 and 1999-2000. Between the year 2000 and 2003 rainfall increased by 28.9mm but deceased by 14.7mm by 2013 and again increased by only 5mm by year 2016. Temperatures increased by 1.6°C from 1975 to 2016 with decreases in noticeable wet years of 1985 and 2003.Landcover changes corresponded with the climatic variations with 259325 hectares (ha) of grasslands in 1976, 271235 ha in 1985, 202919 ha in 1995, 209919 ha in 2000, 228585 in 2003 and 230168 ha in 2016.Therefore in wet years the temperatures were low, high rainfall with high percentages of grasslands, the impact being higher numbers of wildlife and livestock with the abundance of forage. Dry years were characterised by low rainfall with decreases in animal populations due to decrease in forage as depicted by the landcover landsat images. However the general trend of increases in temperature over the period from 1975 to 2016 and erratic rainfall reduced forage amount and quality leading to decreases in animal numbers among other factors.

During this period (1975 to 2016) the animals studied had decreased in

number apart from the Elephant, Ostrich and shoats. The animals most preferred by tourists, the highest income earner in the Maasai Mara decreased as follows; Wildebeest -43.1%, Zebra -28.8%, Giraffe - 76.5%, Buffalo – 68.2%, Topi –73%, Hartebeest -88%.

2. The productivity indexing of livestock and wildlife in the study area through the Prying livestock productivity model showed that, in both wildlife and livestock studied, mixed feeders had the highest productivity index with a mean Feed Energy Efficiency (FEE) of 0.062, while grazers had the lowest (FEE) of 0.053.This was attributed to the mixed grazers feeding ability to graze and browse on trees and shrubs when grass is scarce in the dry season. Productivity in breeding females in livestock was also higher than in wildlife due to controlled management system among livestock.
3. When Prying livestock productivity model was ran to give composition of selected livestock and wildlife in the study area, overall composition of animals showed a high percentage of male youngstock with 48.6 % and 17.1 % breeding females, yet only a few males are required for breeding. Breeding females perform poorly in both productivity and composition of wildlif**e** while those of livestock are higher with goats at 40.8 %, sheep 40.6 % and cattle 46.9% of the population attributed to the direct management of livestock.

5.2 Conclusion

Climatic factors have influenced livestock numbers in Maasai Mara. The rainfall and temperature of Maasai Mara data collected and analysed showed that the population of wildlife decreased in dry years and increased in the wet years due to availability of adequate palatable forage. In wet years the land cover especially grasslands and shrub lands was abundant with forage for both livestock and wildlife. In the years 1975 to

2016 the temperature pattern showed increases with erratic rainfall. Total area under forage decreased therefore leading to decreases in wildlife numbers.

Within the livestock and wildlife productivity index, the elephant population had the lowest productivity with feed energy efficiency (FEE) of 0.02 while warthogs had the highest of 0.10 in the mixed feeders' category and also among all animals studied. When different categories were compared, mixed feeders led in productivity with a mean FEE of 0.062, while browsers had a productivity index of 0.056 and grazers 0.053.

The animal composition in the Maasai Mara was dominated by male youngstock (50%) except in (steenbok) (27%) and 26% in klipspringer while their breeding females ranked highest at 53% for steenbok and 55% for klipspringer. However, livestock had high percentages of breeding females compared to wildlife attributed to the controlled management practices with cattle having 46.6%, sheep 40.6% and goats 40.8% of their population being dominated by breeding females.

5.3 Recommendations

5.3.1 Recommendations for management action

- Drought resistant forage should be encouraged to provide good nutritional feed to livestock and wild animals' to cope with climate variability to increase the wildlife and livestock numbers.
- Number of water points need to be introduced depending on the total area and per animal water requirement and also supplement water to cope with dry seasons/droughts.

5.3.2 Recommendations for policy intervention

- Animal populations and their composition need to be maintained depending on the carrying capacity of the land, to avoid overstocking. Regular annual monitoring of land carrying capacity of herbivores need to be emphasized to maintain this unique ecosystem.

5.3.3 Recommendations for further studies

- From the productivity and composition of the various animals, favourable breeding programs of wildlife with biotechnological applications may be studied to control extinction of species and to maintain this unique biological diversity within Kenya.
- The trend of animals, land cover, vegetation composition and water availability within Maasai Mara and other national reserves/parks/conservancies, arid and semi-arid lands of Kenya may be studied.

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APPENDICES

4.3 RESEARCH QUESTIONNAIRES

4.3.1 QUESTIONNAIRE FOR FARMERS (PASTROLISTS) CONSERVATIONISTS

1. What kind of animals do you keep?
2. What are the weights for the following?

Animal species	Weight at birth			Weight at weaning			Weight at maturity/Adult			Others
	M	**F**	**average**	**M**	**F**	**Average**	**M**	**F**	**Average**	
Cattle										
Sheep										
Goats										
Donkeys										
Others (specify)										

4. How do you utilize the following animals?

Animal species	Uses
Cattle	
Sheep	
Goats	
Donkeys	
Others (specify)	

5 (a) How much of the products are collected from the various animals?

Animal Species	Products					
	Sex	**Beef amount /head(Kg)**	**Hairs/year (Kg)**	**Wool /year (Kg)**	**Transport (work hours)**	**Others**
Cattle	Male					
	Female					
Sheep	Male					
	Female					
Goats	Male					
	Female					
Donkey	Male					
	Female					
Others (specify)	Male					
	Female					

5(b) Which animals are used for milk? When do you milk and how much do you milk per day? How long are the animals milked per season?

Animal species	**Age**	**Yield / day (litres)**	**Lactation period**	**Total yield/ lactation (litres)**
Cattle	Heifer			
	Cow			
Goats	Young kidder			
	Mature kidder			

6. How long does it take from one kidding, calving, to the other (lactation period)?

Animal species	**Lactation interval (months)**
Cattle	
Sheep	
Goats	
Donkey	
Others (specify)	

7. How many young ones do the animals get per year (12 months)? How many young ones does the animal have at one given time?

Animal species	**Age**	**Age at first parturition**	**Parturitions per year**	**Litter size**
Cattle	Young breeding female			
	Mature breeding female			
Sheep	Young breeding female			
	Mature breeding female			
Goats	Young breeding female			
	Mature breeding female			
Donkey	Young breeding female			
	Mature breeding female			
Others (specify)	Young breeding female			
	Mature breeding female			

8. When you put a certain age group (cohort) into mating, how many will be pregnant and how many will not be at last month to parturition?

9. When do you remove Males/ females from the herd for whatever reasons?

Animal species	**Sex**	**Mature**		**Young**	
		Numbers	**Reasons**	**Numbers**	**Reasons**
Cattle	Male				
	Female				
Sheep	Male				
	Female				
Goats	Male				
	Female				
Donkeys	Male				
	Female				
Others (specify)	Male				
	Female				

10. Do you move out of Narok or even move into the park for pasture and for how long?

Area livestock is moved to	**Duration**

11. What are the problems faced when you graze in the park areas according to;
    (a) Mortalities?
    (b) Diseases?

12. Which wildlife species graze/browse and mix freely in feeding harmoniously with livestock both in the farm, conservancy, and communal grazing area and also in the park?

Wildlife species that browse/ graze and mix freely in feeding harmoniously with livestock	**Seasons**

13. Which wildlife animal species come to the conservancies and during which seasons?

Wildlife species that come to the conservancies/farms	**Seasons**

14. Which wild animals used to come to the conservancies and no longer come? When were they last seen?

Animal species	**Seasons when they used to comes to the conservancies/farms**	**Year last seen**	**Reasons why they no longer come**

15. What is the average price of a mature female/male?

Animal species	**Female**				**Male**			
	Season (prices)/kg				**Seasons (prices)/kg**			
Cattle Sheep Goat Donkey								

16. Do you sell other animal products and at what cost in a delivery?

Animal species	**Product price/ tonne/year**		
	Manure/ delivery	**Hides and skins/ piece**	**others**
Cattle Sheep Goat Donkey			

17. Which years did you experience extremely wet or dry, seasons? What effect did it have on the livestock, wildlife and plants?

Year	**Wet season**	**Dry season**	**Effect on**		
			Livestock	**Plants**	**Wildlife**

18. After birth how many animals die at the different ages including?

Animal species	**Sex**	**Number of births per year**	**Number of animals that die before or at weaning**	**Number of animals that die at maturity**
Cattle	Male			
	Female			
Sheep	Male			
	Female			
Goats	Male			
	Female			
Donkeys	Male			
	Female			
Others (specify)	Male			
	Female			

19. What do the following animals feed on and when?

Animal species	**Grazing seasons**				**Browsing seasons**				**Combined (mixed feeding)**			

4.3.2 QUESTIONNAIRE FOR LIVESTOCK OFFICERS

1. What kind of animals are kept in Narok County?

2. What are the numbers of the following animals?

Animal species	Sex	Month/season	Maximum age
Cattle	Male		
	Female		
Sheep	Male		
	Female		
Goats	Male		
	Female		
Donkeys	Male		
	Female		
Others(specify)	Male		
	Female		

2. What are the weights for?

Animal species	Weight at birth			Weight at weaning			Weight at maturity/Adult			Others
	M	F	average	M	F	Average	M	F	Average	
Cattle										
Sheep										
Goats										
Donkeys										
Others (specify)										

4. How are the uses of the following animals?

Animal species	Uses
Cattle	
Sheep	
Goats	
Donkeys	
Others (specify)	

5 (a) How much of the products are collected from the animals?

Animal Species	Products					
	Sex	Beef amount /head(Kg)	Hairs/year (Kg)	Wool /year (Kg)	Transport (work hours)	Others
Cattle	Male					
	Female					
Sheep	Male					
	Female					
Goats	Male					
	Female					
Donkey	Male					
	Female					
Others (specify)	Male					
	Female					

5(b) Which animals are used for milk? When are they milked and how much milk is produced per day per animal? How long is the lactation period?

Animal species	Age	Yield / day (litres)	Lactation period	Total yield/ lactation (litres)
Cattle	Heifer			
	Cow			
Goats	Young kidder			
	Mature kidder			

6. How long is the lactation interval?

Animal species	Lactation interval (months)
Cattle	
Sheep	
Goats	
Donkey	
Others (specify)	

7. How long are the parturition intervals of the following animals and what are their litter sizes?

Animal species	Age	Age at first parturition	Parturitions per year	Litter size
Cattle	Young breeding female			
	Mature breeding female			
Sheep	Young breeding female			
	Mature breeding female			
Goats	Young breeding female			
	Mature breeding female			
Donkey	Young breeding female			
	Mature breeding female			
Others (specify)	Young breeding female			
	Mature breeding female			

8. When you put a certain age group (cohort) into mating, how many will be pregnant and how many will not be at last month to parturition?

9. When do you cull Males/ females from the herd for whatever reasons?

Animal species	Sex	Mature		Young	
		Numbers	Reasons	Numbers	Reasons
Cattle	Male				
	Female				
Sheep	Male				
	Female				
Goats	Male				
	Female				
Donkeys	Male				
	Female				
Others (specify)	Male				
	Female				

10. Do farmers migrate to other areas outside Narok and also into the park in search of pastures and for how long?

Area livestock is moved to	Duration
Wildlife species that browse/ graze and mix freely in feeding harmoniously with livestock	**Seasons**

11. What are the problems faced when livestock are grazed in the park areas according to;
   (a) Mortalities?
   (b) Diseases?

12. Which wildlife species graze/browse and mix freely in feeding harmoniously with livestock both in the farm, conservancy, communal grazing area and in the park?

13. Which wildlife animal species come to the conservancies and during which seasons?

Wildlife species that come to the conservancies/farms	Seasons

14. Which wild animals used to come to the conservancies and no longer come? When were they last seen?

Animal species	Seasons when they used to come to the conservancies/farms	Year last seen	Reasons why they no longer come

15. What is the average price of a mature female/male?

Animal species	Female				Male			
	Season (prices)/kg				**Seasons (prices)/kg**			
Cattle Sheep Goat Donkey								

16. What other animal products are sold and what is the price per delivery/piece as follows?

Animal species	Product price/ tonne/year		
	Manure/ delivery	**Hides and skins/ piece**	**others**
Cattle Sheep Goat Donkey			

17. Which years did you experience extremely wet or dry, seasons? What effect did it have on the livestock, wildlife and plants?

Year	Wet season	Dry season	Effect on		
			Livestock	**Plants**	**Wildlife**

18. After birth how many animals die at the different ages including:-

Animal species	Sex	Number of births per year	Number of animals that die before or at weaning	Number of animals that die at maturity
Cattle	Male			
	Female			
Sheep	Male			
	Female			
Goats	Male			
	Female			
Donkeys	Male			
	Female			
Others (specify)	Male			
	Female			

19. What do the following animals feed on and when?

Animal species	Grazing seasons				Browsing seasons				Combined (mixed feeding)			

4.3.3 QUESTIONNAIRE FOR KENYA WILDLIFE SERVICE STAFF

1. What kind of wildlife (herbivores) are found in Narok County especially in the Maasai Mara game reserve?

2. What are the numbers of these wildlife herbivores according to species?

Animal species	**Sex**	**Month/season**	**Maximum age**
	Male		
	Female		
	Male		
	Female		
	Male		
	Female		
	Male		
	Female		

3. What are the weights for wildlife herbivores according to species?

Animal species	**Weight at birth**			**Weight at weaning**			**Weight at maturity/Adult**			**Others**
	M	**F**	**average**	**M**	**F**	**Average**	**M**	**F**	**Average**	

4. How are the uses of the following animals?

Animal species	**Uses**

5. How much of the products are collected from the animals?

Animal Species	**Products**					
	Sex	**Beef amount /head(Kg)**	**Hairs/year (Kg)**	**Wool /year (Kg)**	**Transport (work hours)**	**Others**
	Male					
	Female					

6. How long are the lactation intervals of the following wildlife herbivores according to species?

Animal species	**Lactation interval (months)**

7. How long are the parturition intervals of the following animals and what are their litter sizes?

Animal species	**Age**	**Age at first parturition**	**Parturitions per year**	**Litter size**
	Young breeding female			
	Mature breeding female			

8. When you put a certain age group (cohort) into mating, how many will be pregnant and how many will not be at last month to parturition?

9. When do you cull Males/ females from the herd for whatever reasons?

Animal species	**Sex**	**Mature**		**Young**	
		Numbers	**Reasons**	**Numbers**	**Reasons**
	Male				
	Female				
	Male				
	Female				

10. When do the livestock migrate into the park in search of pastures and for how long do they forage in the park?

Seasons when livestock forage in the park?	**Duration**

11. What are the problems faced when livestock are grazed in the park areas according to;

(a) Mortalities?

(b) Diseases?

What problems are encountered among wildlife herbivores when livestock are grazed in the park?

12. Which wildlife species graze/browse and mix freely in feeding harmoniously with livestock both in the farm, conservancy and communal grazing area and in the park?

Wildlife species that browse/ graze and mix freely in feeding harmoniously with livestock	**Seasons**

13. Which wildlife animal species migrate to other areas and during which seasons? Where do they migrate to?

Wildlife herbivores species that migrate	**Seasons of migration**	**Areas Wildlife herbivores migrate to**

14. Which wild animals have become extinct? When were they last seen?

Animal species	**Animals that have become extinct**	**Year last seen**	**Reasons for extinction**

15. What is the average price of a mature female/male?

Animal species	**Female**				**Male**			
	Season (prices)/kg				**Seasons (prices)/kg**			
Cattle Sheep Goat Donkey								

16. What other animal products are sold and what is the price per delivery/piece as follows?

Animal species	**Hides and skins/ piece**	**Others**

17. Which years did you experience extremely wet or dry, seasons? What effect did it have on wildlife herbivores and plants?

Year	**Wet season**	**Dry season**	**Plants**	**Wildlife Herbivores**

18. After birth how many wildlife herbivores die at the different ages including:-

Animal species	**Sex**	**Number of births per year**	**Number of animals that die before or at weaning**	**Number of animals that die at maturity**
	Male			
	Female			
	Male			
	Female			

19. What do the following wildlife herbivores feed on and when?

Animal species	**Grazing seasons**				**Browsing seasons**				**Combined (mixed feeding)**			

4.3.4 QUESTIONNAIRE FOR COUNTY COUNCIL OFFICERS

1. What kind of wildlife herbivores and livestock are found in Narok county?
2. What are the numbers of:-

Animal species	**Sex**	**Month/season**	**Maximum age**
	Male		
	Female		
	Male		
	Female		

3. What are the weights for?

Animal species	**Weight at birth**			**Weight at weaning**			**Weight at maturity/Adult**			**Others**
	M	**F**	**average**	**M**	**F**	**Average**	**M**	**F**	**Average**	

3. How are the uses of the following animals?

Animal species	**Uses**

5 (a) How much of the products are collected from the animals?

Animal Species	**Products**					
	Sex	**Beef amount /head(Kg)**	**Hairs/year (Kg)**	**Wool /year (Kg)**	**Transport (work hours)**	**Others**
	Male					
	Female					
	Male					
	Female					

5(b) Which animals are used for milk? When are they milked and how much milk is produced per day per animal? How long is the lactation period?

Animal species	**Age**	**Yield / day (litres)**	**Lactation period**	**Total yield/ lactation (litres)**
Cattle	Heifer			
	Cow			
Goats	Young kidder			
	Mature kidder			

6. How long is the lactation interval?

Animal species	Lactation interval (months)

7. How long are the parturition intervals of the following animals and what are their litter sizes?

Animal species	Age	Age at first parturition	Parturitions per year	Litter size
	Young breeding female			
	Mature breeding female			

8. When you put a certain age group (cohort) into mating, how many will be pregnant and how many will not be at last month to parturition?

9. When do you cull Males/ females from the herd of wildlife herbivores/livestock for whatever reasons?

Animal species	Sex	Mature		Young	
		Numbers	Reasons	Numbers	Reasons
	Male				
	Female				

10. Do farmers migrate to other areas outside Narok and also into the park in search of pastures and for how long?

Area livestock is moved to	Duration

11. What are the problems faced when livestock are grazed in the park areas according to;

(a) Mortalities?

(b) Diseases?

12. Which wildlife species graze/browse and mix freely in feeding harmoniously with livestock both in the farm, conservancy, communal grazing area and in the park?

Wildlife species that browse/ graze and mix freely in feeding harmoniously with livestock	Seasons

13. Which wildlife animal species come to the conservancies and during which seasons?

Wildlife species that come to the conservancies/farms	Seasons

14. Which wild animals used to come to the conservancies and no longer come? When were they last seen?

Animal species	**Seasons when they used to come to the conservancies/farms**	**Year last seen**	**Reasons why they no longer come**

15. What is the average price of a mature female/male (Wildlife herbivores/livestock)?

Animal species	**Female**				**Male**			
	Season (prices)/kg				**Seasons (prices)/kg**			
Cattle Sheep Goat Donkey								

16. What other animal products are sold and what is the price per delivery/piece as follows?

Animal species	**Hides and skins/ piece**	**Others**

17. Which years did you experience extremely wet or dry, seasons? What effect did it have on the livestock, wildlife and plants?

Year	**Wet season**	**Dry season**	**Effect on**		
			Livestock	**Plants**	**Wildlife**

18. After birth how many animals die at the different ages in both wildlife herbivores and livestock:

Animal species	**Sex**	**Number of births per year**	**Number of animals that die before or at weaning**	**Number of animals that die at maturity**
	Male			
	Female			

19. What do the following animals feed on and when?

Animal species	**Grazing seasons**				**Browsing seasons**				**Combined (mixed feeding)**			

20. What is the pattern of cess collection from the Maasai Mara game reserve over the past 30 years?

Year	Cess collection in months											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec

4.3.5 QUESTIONAIRE FOR THE KENYA METEOROLOGICAL DEPARTMENT

Climate data

(i) Climate data from 1975 to 2016.

(ii) How many stations (climatic data)

(a) Owned by the Kenyan Meteorological Department (KMD)

(b) Private?

- Do the Stations avail data to KMD?
- Is the data incorporated to KMD data?

(iii) How many stations are there in Narok?

How is data availed to KMD?

(iv) What are the rare climatic phenomena's that have occurred in Kenya since 1975?

(a) What phenomena's have specifically affected Narok County?

(v) What are the patterns of the following:-

(a) Rainfall

(b) Temperature

CLIMATIC DATA

YEAR	**CLIMATIC DATA**																																			
	Jan			**Feb**			**Mar**			**Apr**			**May**			**June**			**July**			**Aug**			**Sept**			**Oct**			**Nov**			**Dec**		
	R	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**		**R**	**T**	

R- Rainfall T- Temperature

APPENDIX 1: MONTHLY AND ANNUAL AVERAGE TEMPERATURE FIGURES FROM 1975 TO 2013 IN NAROK

Year	Average temperatures in the months and years												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Averages**
1975	17.5	17.85	18.4	18.1	16.95	15.75	15.35	15.55	16.15	16.75	16.3	17	16.8
1976	17.05	17.95	18.45	17.7	18.15	15.65	15.8	15.8	16.65	17.15	18	17.8	17.2
1977	18.2	17.95	18.6	18.3	17.4	16	15.15	15.75	16.6	18.55	17.8	16.95	17.3
1978	17.05	17.6	18.2	18.1	16.85	15.5	15.35	15.95	16.7	17.5	17.35	18.5	17.1
1979	17.25	17.8	17.8	18.15	17.85	16.5	15	15.85	16.8	18.1	18.2	18.15	17.3
1980	18.15	18.1	18.5	18.55	18.2	16	14.75	15.9	17.5	18.1	18.05	17.6	17.4
1981	18.1	18.85	19.3	18.2	17.7	16.4	15.5	16.2	17.2	18.05	17.7	18.25	17.6
1982	18.6	19.3	19.3	19.05	17.95	16.4	15.85	15.8	17.35	21.4	18.3	17.3	18.1
1983	17.95	18.75	19.35	18.95	17.25	16.25	15.5	16.4	16.3	17.5	16.9	16.45	17.3
1984	16.35	16.95	17.3	17.8	16.5	15.35	14.9	15.05	15.8	16.1	18.25	15.65	16.3
1985	16.2	16.4	17.85	17.25	16.95	15.55	14.95	14.9	16.35	17.3	16.8	16.85	16.4
1986	17.25	17.85	18.45	18.55	17.05	15.35	14.6	14.95	16	17.75	17.3	17.4	16.9
1987	17.8	17.8	18.35	18.1	18.3	16.25	15	15.9	17	17.55	17.65	16.85	17.2
1988	17.8	18	18.4	17.7	16.85	15.3	15.3	15.35	17.1	16.9	16.7	16.6	16.8
1989	17.05	16.3	17.45	16.95	16.95	14.85	14.65	14.8	16.45	16.1	17.15	17.55	16.4
1990	16.05	18.05	17.4	17.95	17.1	15	14.75	15.5	16.05	17.25	16.7	17.2	16.6
1991	18.2	18.95	18.5	17.9	18.05	16.35	14.8	16.1	16.3	17.2	16.85	17.15	17.2
1992	17.65	18.05	18.9	18.35	17.25	16.5	15.2	15.5	16.75	17.35	16.95	17.45	17.2
1993	17.2	17.1	17	18.2	17.9	16.5	14.7	15.55	16.25	17.55	17.5	17.3	16.9
1994	18.1	18.1	18.05	18.45	17.3	16.5	15.9	15.9	16.3	17.7	18.1	17.35	17.3
1995	18.35	18.4	19.45	18.65	17.85	17.2	16.05	16.25	17.2	17.85	17.65	17.05	17.7
1996	18	18.35	18.85	18.45	18	16.95	15.35	16.2	16.65	17.95	17.4	17.45	17.5
1997	18.35	19.15	18.9	18.4	17.1	16.7	16	16.3	16.95	18.85	18.05	18.3	17.8
1998	18.4	18.7	18.7	19.6	18.8	16.45	15.05	15.65	16.8	18.15	16.65	17	17.5
1999	18.5	18.2	19.05	18.5	17.15	16.2	16.15	16.65	17.2	17.75	17.9	17	17.5
2000	17.6	18.4	18.7	18.75	17.85	17.15	16.35	16.55	17.4	18.3	18.05	17.9	17.8
2001	17.65	17.65	17.8	18.2	17.75	16.3	18.2	16.2	17.45	18.45	17.75	19.55	17.7
2002	18.55	19.6	18.1	18.96	17.3	15.4	15.45	16.45	16.95	18.6	18.1	18.05	17.6
2003	17.5	17.95	18.7	18.65	18	16.6	15.45	16.5	16.9	17.95	17.8	17.75	17.5
2004	18.6	18.6	18.55	18.35	17.15	15.35	15.1	15.85	17.3	18.1	18.15	18.65	17.5
2005	15.7	18.7	19.25	18.6	18.2	16.05	15.7	16.5	17.65	17.78	17.6	17.85	17.5
2006	19.3	19.9	19.4	18.9	18.7	18.4	17.7	17.1	16.9	18.9	19.1	18.3	18.6
2007	18.5	18.1	18.15	18.4	18	16.7	15.5	16.5	17.15	17.4	17.35	17.55	17.4
2008	18.05	17.95	18.15	17.6	17.25	16.35	16.05	16.85	18	18.45	18.05	18.1	17.5
2009	18.75	18.7	20	19.2	18.5	17.05	15.4	17.15	18.25	19.2	18.75	18.65	18.3
2010	18.7	19.25	18.4	19.1	18.75	17	16.15	17.1	17.35	18.7	17.55	17.95	18
2011	18.2	18.85	18.8	19.11	18.25	18.1	17.45	16.9	17.65	18.15	18	18.1	18.1
2012	17.8	18.1	18.7	19.15	18.72	16.5	16.25	16.9	17.45	18.45	17.7	17.75	17.8
2013	18.1	17.95	19.15	18.75	19.1	16.2	18.2	15.9	19.5	17.7	19.1	19.6	18.3
2016	18.4	19.5	19.2	19	17.9	17.4	16	17.9	18.2	21.5	18.5	17.3	18.4

Source: (Kenya Meteorological Department, 2016)

APPENDIX 2: RAINFALL DATA FIGURES FROM 1975 TO 2016 IN NAROK

YEAR	MONTHS												YEARLY TOTALS	YEARLY MEANS
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC		
1975	40.7	5.9	101.2	80.1	67.9	6.8	54.3	4.1	72.9	60.2	9.4	79.3	**582.8**	**48.6**
1976	36.4	12.8	16.5	96.3	60.8	60.3	17.1	26	29.1	11.1	78.5	38.5	**483.4**	**40.3**
1977	92.4	96.5	40.7	246.5	126	8.8	42.2	45.9	22.9	46.5	130.6	118.8	**1017.8**	**84.9**
1978	135.3	144.4	368.7	122.9	28	13.1	1.3	25.6	17.8	8.3	20	125.8	**1011.2**	**84.3**
1979	86.7	173.9	137.8	162.6	101	49	22.2	5.3	8.2	4	39.4	52.1	**842.2**	**70.2**
1980	90.4	10.8	91.3	179	171.9	11.7	1.8	4.4	12.4	33.6	117.7	39.7	**764.7**	**63.7**
1981	12.7	66.7	111.5	84.5	113	13.9	19.1	2.3	15.5	4.1	29.9	38.6	**511.8**	**42.7**
1982	23.1	60.2	29.5	130.5	103.1	36.1	8.7	2.5	50.9	68.6	159.6	93.1	**765.9**	**63.8**
1983	22.9	62.5	19.9	124.1	84.8	52.5	22.4	38.9	26.9	51.6	38.5	91.7	**636.7**	**53**
1984	45.3	4.4	24	88.2	6	0.9	21.5	8.7	16.2	59.4	52.8	120.5	**447.9**	**37.3**
1985	10	157.6	78.8	287.3	51.9	56.1	19.7	2.6	15.3	3.7	81.4	78.2	**842.6**	**70.2**
1986	46.9	15.5	25.7	129.1	78.3	9.4	7.4	-	12.4	10.7	54.7	95.4	**485.5**	**44.1**
1987	157.8	59.2	174.4	85	142.8	53.3	55	13.1	26.4	0.5	81	12.4	**860.9**	**71.7**
1988	164.6	8.3	168.5	272.2	54.4	10.5	17.4	40.2	5.2	18.5	7	56.6	**823.4**	**68.6**
1989	210.3	119.6	96.4	137.4	90.2	21.6	31.7	45.3	78.4	5.1	25	225.4	**1086.4**	**90.5**
1990	35.9	122.9	163.3	152.5	84.9	14.2	2.5	25.4	14.7	61.8	24.8	29.3	**732.2**	**61**
1991	55.2	-	79.1	130.2	-	44.3	9.1	11.2	3	63.7	22.8	62	**480.6**	**48**
1992	14.4	84.3	49.8	126.4	35.8	18.2	-	6.2	11.8	38	12.8	48.9	**446.6**	**40.6**
1993	258.2	106.3	38.2	15.8	151.1	90.5	0.8	34.4	0.6	24.3	52.7	48.3	**821.2**	**68.4**
1994	58.4	118.1	109.1	140	103.1	16.2	8.9	46	-	21.5	135	25.9	**782.2**	**71.1**
1995	39.7	56.2	141.6	66.3	142.8	32.9	7	-	61	19	38.2	34.3	**639**	**58**
1996	81.7	124.2	140.6	85.9	18.2	113.8	89.2	35.8	25.3	8.8	52.5	40.1	**816.1**	**68**
1997	37.1	6.3	54.9	247.6	144.1	26.6	9.1	34.5	10	38.8	254.3	126	**989.3**	**82.4**
1998	205.6	172.9	13.9	131	191.8	61.2	3.3	31.5	40.7	10.5	27.6	0.9	**890.9**	**74.2**
1999	37.5	5.2	291.5	64.8	21.7	3.9	2.9	23.5	20.1	9.5	73	102.5	**656.1**	**54.7**
2000	17.6	18	60.5	71.3	18.7	2.4	4.6	11.4	15.1	9.3	143.9	86.8	**459.6**	**38.3**
2001	232.9	80	56.1	136	26.2	22.6	51.5	24.2	21.3	33.1	19.3	35.6	**738.8**	**61.6**
2002	166.1	59.2	95	120.6	140.4	2.9	9.6	10.1	12.2	47.6	186.7	194.8	**1045.2**	**87.1**
2003	103.6	73	54.9	156.4	261.4	8.6	2.5	79.3	8.9	19.9	22.1	15.4	**806**	**67.2**
2004	25.3	79.3	121.8	235.4	78.8	3.2	-	-	43.6	9.3	28.1	78.4	**703.2**	**70.3**
2005	25.1	45.8	114.5	81.7	126.7	7.8	21.6	12.5	7.6	-	18.4	13.6	**475.3**	**43.2**
2006	101.3	61	123.4	210.8	59.1	1.6	21.6	32	21.7	1	271	156.8	**1061.3**	**88.4**
2007	105.9	143.2	59.5	89.9	97.2	25.6	10.8	22.4	69.4	9	30.3	39.7	**702.9**	**58.6**
2008	8.6	99	201.3	88.9	7.8	1.4	9.2	23.1	35.1	56.7	86.3	1.6	**619**	**51.6**
2009	52.9	24.4	22.6	103.9	107.7	36.7	0.5	3.1	17.2	33.7	53.5	123.8	**580**	**48.3**
2010	150.5	103.4	93.3	69.4	113.9	11.1	5.1	36.9	59.6	49.2	63.5	38.1	**794**	**66.2**
2011	59.8	34.4	97	16.1	54.8	33.1	19.6	47.9	86.2	155.8	-	146.4	**751.1**	**68.3**
2012	1.7	60.6	43.8	239.5	87.4	8.6	22.6	48.8	3.1	16.6	56.9	218.1	**807.7**	**67.3**
2013	63.4	73.6	102.9	18.3	60.6	2.7	16.4	20.3	91.3	-	15.2	113	**577.7**	**52.5**
2014	-	24.8	146.4	11.8	34.1	37.1	25.5	25.2	58.1	54.7	76.3	127.7	**621.7**	**56.5**
2015	67	50.8	23.4	160.6	167.8	59.2	26	13	7.2	63.6	190.4	156.6	**985.6**	**82.1**
2016	103.2	122.3	74.4	82.6	90.5	32.7	14.6	23.2	68	9.2	31	37.8	**689.5**	**57.5**

Source :(Kenya Meteorological Department, 2016)

APPENDIX 3: ESTIMATED COUNTS OF SELECTED LARGE HERBIVORES IN THE MAASAI MARA ECOSYSTEM FROM 1977-2016 DURING WET AND DRY SEASONS

END DATE OF SURVEY	BURCHELL's ZEBRA		ELAND		ELEPHANT		GIRAFFE		TOPI		WILDEBEEST		BUFFALO	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
30-Nov-77	66757.89		5423.94		1755.52		8914.01		39443.65		542825.8		39056.29	
9-Apr-78	68523.2		5228.35		1766.25		8610.39		38266.18		98647.29		37286.28	
1-Jun-79		67867.24		4667.13		1801.13		7724.45		34795.95		91305.42		32287.09
31-Oct-80		72218.99		4093.66		1845.19		6792.77		31085.31		480065.3		27308.74
1-Jun-81		66622.79		3890.78		1863.57		6455.56		29724.93		80541.49		25581.2
1-Jun-82		65957.01		3581.13		1895.39		5931.68		27591.24		76006.02		22980.04
7-Feb-83	65482.66		3392.92		1917.51		5607.07		26255.72		73168.03		21420.81	
1-Jun-84		64539.23		3081.21		1960.26		5056.9		23966.48		68310.59		18875.5
27-Apr-85	63863.7		2898.69		1989.91		4725.95		22572.26		65361.01		17406.96	
1-Dec-85	63405.68		2790.5		2009.57		4525.99		21723.06		63569.59		16543.98	
11-May-86	63061.51		2716.35		2024.09		4387.09		21129.94		62321.32		15955.78	
15-Aug-86		79592.13		2674.32		2032.75		4307.61		20789.38		395796.3		15623.56
12-Nov-86	79781.9		2636.76		2040.77		4236.08		20482.08		393166.4		15327.3	
28-Apr-87	62291.71		2569.76		2055.8		4107.23		19926.59		59797.97		14800.39	
1-Jun-88		61388.43		2426.28		2091.56		3825.03		18700.99		57243.78		13678.38
16-May-89	60575.76		2318.64		2122.24		3606.32		17742.06		55259.27		12841.59	
20-Aug-90		81327.07		2198.14		2161.56		3351.82		16615.48		359665.6		11908.73
24-Apr-91	58857.53		2142.56		2181.83		3229.84		16071.09		51838.04		11479.29	
20-Aug-91		81287.22		2118.02		2191.27		3174.8		15824.48		352735.3		11289.73
25-Mar-92	58009.79		2075.9		2208.24		3078.3		15390.54		50460.76		10964.27	
28-Aug-92		81049.8		2048.18		2219.97		3013.17		15096.49		346335.2		10749.95
12-Nov-93	80517.49		1979.81		2250.95		2845.3		14334.09		339603.7		10220.53	
25-May-94	55934.12		1954.04		2263.41		2778.47		14028.61		47737.51		10020.43	
1-Jun-95		54920.63		1911.25		2285.04		2661.15		13489.38		46672.25		9687.19
8-Aug-96		78342.68		1871.28		2306.04		2540.58		12930.77		327061.5		9374.4

31-May-97	52868.26		1849.55		2317.51		2467.37		12589.15		44908.96		9203.48	
26-Aug-97		77179.29		1843.94		2320.41		2447.15		12494.37		323077.5		9159.33
1-Jun-98		51811.04		1828.26		2328.25		2385.97		12206.7		44164.01		9035.44
1-Jun-99		50740.99		1812.64		2335.07		2313.89		11865.52		43500		8911.89
6-Nov-00	49183.02		1799.09		2337.99		2224.55		11438.73		42667.33		8804.89	
1-Jun-01		48562.24		1796.37		2336.95		2193.41		11288.77		42373.32		8783.93
7-Dec-02	46891.99		1795.79		2328.31		2120.38		10933.96		41671.79		8783.08	
1-Jun-03		46360.03		1797.51		2323.87		2100.06		10834.32		41472.61		8798.88
30-May-04	45260.2		1803.78		2312.3		2062.03		10646.38		41093.16		8854.94	
13-May-05	44211.54		1812.98		2298.45		2030.3		10487.8		40767.9		8937	
13-Sep-05		63991.41		1816.95		2292.96		2020.09		10436.3		302042.2		8972.46
1-Jun-06		43060.83		1826.52		2280.37		2000.04		10334.36		40447.08		9058.61
23-May-07	42002.87		1842.02		2261.32		1975.95		10210.17		40181.54		9199.43	
1-Jun-08		40900.47										39931.2		
2-Nov-08	57892.04		1869.81		2229.71		1946.32		10053.54		296774.4		9456.64	
1-Jun-09		39841.79										39712.94		
26-Oct-09		55991.46		1891.57		2206.54		1929.84		9963.8		295342.7		9661.9
1-Jun-10		38799.45									39516.35			
25-Oct-10		54079.94		1915.88		2181.88		1915.57		9883.83		293971		9895.12
1-Jun-11		37775.34										39338.14		
13-Oct-11		52254.95		1941.35		2157.19		1903.72		9815.39		292709.9		10143.65
1-Jun-12		36768.42										39174.61		
1-Nov-12	50305.42		1971		2129.67		1892.57		9748.99		291398.2		10437.98	
1-Jun-13		35785.58		1988.06		2114.36		1887.07		9715.35		39023.42		10609.61
30-Nov-13	48362.71		2003.05		2101.16		1882.62		9687.78		290109.1		10761.9	
15-Sep-14		46975.67		2027.46		2080.19		1875.97		9645.92		289188.3		11012.29
1-Jun-15		33888.44		2049.84		2061.44		1870.3		9609.8		38743.9		11244.55
16-Jan-16	33313.07		2069.93		2044.96		1865.4		9578.43		38659.37		11455.11	

Source: (DRSRS, 2016)

The dry season in the Maasai Mara is between June to October while the wet season is between November and May.

APPENDIX 4: ESTIMATED COUNTS OF SELECTED MEDIUM AND SMALL HERBIVORES IN THE MAASAI MARA ECOSYSTEM FROM 1977-2016 DURING WET AND DRY SEASONS

END DATE OF SURVEY	OSTRICH		GRANTS GAZELLE		WARTHOG		THOMSONS GAZELLE		KONGONI (HARTEBEEST)		IMPALA		WATERBUCK	
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
30-Nov-77	438.24		24521.65		8640		119616.01		12342.3		103936.5		4568	
9-Apr-78	448.79		24105.87		8239		116931.06		11905.4		102445.5		4284.5	
1-Jun-79		482.9		22852.91		7103		108865.62		10628.2		97845.69		3511.7
31-Oct-80		525.18		21463.05		5970		99960.38		9281.14		92532.1		2786.5
1-Jun-81		542.43		20939.14		5576		96613.3		8792.46		90463.21		2546.1
1-Jun-82		571.62		20100.33		4983		91263.48		8031.87		87065.06		2195.7
7-Feb-83	591.31		19563.85		4626		87846.73		7559.58		84830.43		1992.7	
1-Jun-84		627.75		18621.52		4042		81851.56		6756.94		80772.51		1673.5
27-Apr-85	651.65		18031.81		3705		78102.71		6272.36		78134.63		1496.5	
1-Dec-85	666.82		17665.99		3506		75777.93		5978.74		76454.79		1395.2	
11-May-86	677.67		17407.18		3370		74133.63		5774.31		75244.36		1327.2	
15-Aug-86		683.99		17257.24		3293		73181.29		5657.15		74534.33		1289.2
12-Nov-86	689.73		17121.08		3224		72316.58		5551.56		73883.66		1255.7	
28-Apr-87	700.23		16872.71		3102		70739.76		5361.01		72681.84		1196.5	
1-Jun-88		723.75		16313.22		2841		67191.39		4941.69		69898.33		1073.3
16-May-89	742.21		15862.19		2645		64337.47		4614.23		67569.72		983.83	
20-Aug-90		763.37		15312.84		2425		60876.42		4229.3		64619.14		886.68
24-Apr-91	773.11		15037.69		2322		59152.79		4042.76		63090.14		842.89	
20-Aug-91		777.34		14910.5		2277		58359.06		3958.05		62371.21		823.75
25-Mar-92	784.45		14682.19		2198		56940.34		3808.55		61061.18		791.15	
28-Aug-92		788.96		14523.78		2146		55961.29		3706.84		60137.29		769.86
12-Nov-93	799.03		14095.78		2015		53343.81		3440.97		57580.35		717.88	

25-May-94	802.2		13915.66		1964		52257.07		3333.26		56478.48		698.44	
1-Jun-95		806.1		13581.91		1877		50272.62		3140.82		54399.73		666.25
8-Aug-96		807.08		13208.39		1792		48105.65		2937.22		52024.27		636.16
31-May-97	805.58		12961.3		1742		46708.9		2809.77		50431.19		619.67	
26-Aug-97		804.82						46309.82		2773.91		49966.83		615.39
1-Jun-98		801.4		12662.3		1689		45062.68		2663.51		48488.95		603.28
1-Jun-99		794.79		12369.53		1644		43500.88		2528.84		46580.99		590.91
6-Nov-00	781.36		11955.59		1592		41381.77		2352.65		43892.21		579.34	
1-Jun-01		774.88		11793.48		1575		40580.66		2288.03		42847		576.61
7-Dec-02	754.68		11362.11		1540		38526.19		2127.34		40100.48		574.01	
1-Jun-03		747.48		11225.65		1531		37898.85		2079.71		39244.56		574.54
30-May-04	731.55		10944.14		1516		36637.15		1985.92		37502.02		577.58	
13-May-05	715.19		10676.03		1506		35473.62		1901.76		35873.62		582.86	
13-Sep-05		709.18		10581.53		1503		35071.88		1873.21		35307.4		585.27
1-Jun-06		696.1		10381.61		1499		34235.3		1814.57		34122.99		591.27
23-May-07	677.64		10110.47		1496		33127.92		1738.59		32546.8		601.4	
2-Nov-08	649.27		9711.98		1498		31551.15		1633.46		30294.25		620.44	
26-Oct-09		629.72		9446.18		1502		30528.72		1567.06		28834.28		635.93
25-Oct-10		609.74		9179.87		1509		29524.6		1503.08		27405.61		653.74
13-Oct-11		590.43		8925.97		1517		28583.7		1444.16		26075.22		672.91
1-Nov-12	569.6		8654.58		1528		27592.96		1383.06		24687.06		695.8	
1-Jun-13		558.29		8507.81		1535		27062.64		1350.72		23950.83		709.23
30-Nov-13	548.68		8383.41		1541		26615.73		1323.65		23334.74		721.2	
15-Sep-14		533.67		8189.05		1551		25921.51		1281.88		22386.65		740.95
1-Jun-15		520.5		8018.32		1561		25314.98		1245.65		21568.27		759.36
16-Jan-16	509.1		7870.2		1570		13143.421		1214.51		20869.1		776.12	

Source: (DRSRS, 2016)

APPENDIX 5: SELECTED LIVESTOCK ESTIMATED COUNTS IN THE MAASAI MARA ECOSYSTEM FROM 1977-2016 DURING WET AND DRY SEASONS

END DATE OF SURVEY	SHEEP AND GOATS		DONKEYS		CATTLE	
	Seasons		Seasons		Seasons	
	wet	dry	wet	dry	wet	dry
30-Nov-77	479592.1		15657.41		658541.5	
9-Apr-78	468855.45		15367.24		649984.3	
1-Jun-79		439645		14560.41		626755.7
31-Oct-80		413245.9		13797.48		606256.3
1-Jun-81		405096		13549.71		600200.8
1-Jun-82		394264.2		13200.57		592592.2
7-Feb-83	388825.44		13007.53		589094.8	
1-Jun-84		382195.4		12720.86		585427.5
27-Apr-85	379991.64		12569.89		584541.5	
1-Dec-85	379390.32		12484.17		584413.6	
11-May-86	379322.02		12425.94		584463.9	
15-Aug-86		379417.8		12392.73		584529.2
12-Nov-86	379590.6		12362.71		584602.4	
28-Apr-87	380115.84		12307.79		584745.8	
1-Jun-88		382281.4		12178.15		584872.4
16-May-89	385039.87		12061.09		584450.5	
20-Aug-90		389859.1		11897.97		583010.1
24-Apr-91	393099.77		11809.51		581976.6	
20-Aug-91		394849.5		11768.06		581473.3
25-Mar-92	398486.58		11694.46		580610.9	
28-Aug-92		401459.8		11645.38		580110.9
12-Nov-93	411943.05		11532.21		579729.4	
25-May-94	417741		11499.03		580293.9	
1-Jun-95		431418.4		11474.16		583197
8-Aug-96		452598.1		11525.46		590508
31-May-97	470924.45		11618.37		598409.8	
26-Aug-97		476976.5		11655.11		
1-Jun-98		498559.5		11801.85		611718.8
1-Jun-99		531997.5		12056.14		628749.7
6-Nov-00	590439.33		12519.17		658537.4	
1-Jun-01		616754.5		12722.17		671458.6
7-Dec-02	694785.62		13270.86		706658.7	
1-Jun-03		721404.9		13433.95		717352

30-May-04	778121.23		13730.22		737434.9	
13-May-05	833027.02		13938.34		752782.3	
13-Sep-05		852248		13989.55		757036.6
1-Jun-06		892150.7		14053.17		763673.9
23-May-07	943367.4		14030.24		766828.5	
2-Nov-08	1008783.81		13742.86		757647	
26-Oct-09		1043705		13380.02		742029.5
25-Oct-10		1070608		12889.44		719188.7
13-Oct-11		1088530		12320.8		691570.3
1-Nov-12	1099857.86		11629.96		657084.8	
1-Jun-13		1103017		11231.4		636872.5
30-Nov-13	1104313.01		10884.84		619151.7	
15-Sep-14		1104286		10335.06		590808.7
1-Jun-15		1102786		9851.63		565692.4
16-Jan-16	1100902.76		9437.84		544077	

Source: (DRSRS, 2016)

APPENDIX 6: AVERAGE LIVESTOCK PRICES IN KENYA SHILLINGS IN THE CONSERVANCIES (MATURE ANIMAL)

Beef prices: wet season 400 ksh/ kg dry season 350 ksh/ kg

Sheep and goat prices: wet season 320 ksh/ kg dry season 300 ksh/ kg

ANIMAL SPECIES	SEASON	SIANA/NASHULAI		PARDAMAT/ MOTOROGI/ OLKINYEI		MARA NORTH/ OLARE OROK		NAIBOSHO		OLARRO NORTH		LEMEK		AVERAGE PRICES	
		M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
CATTLE	**WET**	25000	20000	23000	20000	23000	17500	23500	17700	23000	18000	23000	18000	**23417**	**18533**
	DRY	10000	10000	12000	10000	12000	10000	15000	12000	15000	10000	10000	10000	**12333**	**10333**
SHEEP	**WET**	2000	2000	2000	2000	2000	2000	2300	2000	2300	1500	2100	2000	**2117**	**1917**
	DRY	1000	1000	1200	1000	1200	1000	1200	1000	1200	1000	1000	1000	**1133**	**1000**
GOATS	**WET**	2400	2400	2200	2200	2200	2200	2300	2000	2300	1700	2200	2000	**2267**	**2083**
	DRY	1800	1500	1200	1000	1200	1000	1200	1000	1200	1200	1000	1000	**1267**	**1117**
DONKEY	**WET**														
	DRY	4000	4000	3000	3000	3000	3000	3250	3250	4000	4000	3000	3500	**3375**	**3458**

APPENDIX 7: AVERAGE PRICES OF HIDES AND SKINS IN THE CONSERVANCIES

Animal species	PRICE PER CONSERVANCY IN KSHS							Average prices in Kshs
	Siana Nashulai	Pardamat/ Motorogi	Mara North/ Olare Orok	Naibosho	Olarro North	Lemek	Olkinyei	
Cattle	1000	800	800	800	1000	800	800	**867**
Sheep	50	50	50	50	50	40	50	**48**
Goats	50	50	50	50	50	40	50	**48**

APPENDIX 8: PHOTOS OF WILD ANIMAL SPECIES DURING WET AND DRY SEASONS WITHIN THE STUDY AREA (MAASAI MARA)

a) Thomson's gazelle (*E. thomsonii)*

b) Oribi (*O. ourebi*)

c) Topi (D. lunatus)

d) Dik dik (*M. Kirkii)*

e) Bushbuck (*T. sylvaticus)*

f) Coke's hartebeest (*A. buselaphus)*

g) Grants gazelle (*N. granti)*

h) Eland (*T. oryx)*

i) Impala (*A. melampus*)

j) Klipspringer (*O. oreotragus)*

k) Zebra (*E. burchellii)*

l) Waterbuck (*K. ellipsiprymnus)*

m) Steenbok (*R. neumanni)*


n) Cattle (*B. primigenius indicus)*


o) Reedbuck (*R. arundinum)*


p) Giraffe (*G. camelopardalis*)

q) White Rhino (*C. simum)*

r) Black Rhino (*D. bicornis)*

s) Wildebeest (*C. taurinus)*

t) Duicker (*S. grimmia*)

u) Goats (*C. hircus*)

v) Sheep (*O. aries)*

w) Ostrich (*S. camelus*

APPENDIX 9: CHECKLIST OF HERBIVORE SPECIES STUDIED IN THE MAASAI MARA NATIONAL RESERVE AND CONSERVANCIES

Animal (common name)	***Family***	***Genus***	***Species***
Buffalo	*Bovidae*	*Syncerus*	*S. caffer*
Bushbuck	*Bovidae*	*Tragelaphus*	*T. sylvaticus*
Coke's hartebeest/ Kongoni	*Bovidae*	*Alcelaphus*	*A. buselaphus*
Dikdik	*Bovidae*	*Madoqua*	*M. Kirkii*
Eland	*Bovidae*	*Taurotragus*	*T. oryx*
Grant's gazelle	*Bovidae*	*Nanger*	*N. granti*
Impala	*Bovidae*	*Aepyceros*	*A. melampus*
Klipspringer	*Bovidae*	*Oreotragus*	*O. oreotragus*
Duiker	*Bovidae*	*Sylvicapra*	*S. grimmia*
Bushbuck	*Bovidae*	*Tragelaphus*	*T. sylvaticus*
Thomson's gazelle	*Bovidae*	*Eudorcas*	*E. thomsonii*
Oribi	*Bovidae*	*Ourebia*	*O. ourebi*
Topi	*Bovidae*	*Damaliscus*	*D. lunatus*
Reedbuck	*Bovidae*	*Redunca*	*R. arundinum*
Waterbuck	*Bovidae*	*Kobus*	*K. ellipsiprymnus*
Wildebeest	*Bovidae*	*Connochaetes*	*C. taurinus*
Steenbok	*Bovidae*	*Raphicerus*	*R. neumanni*
Sheep	*Bovidae*	*Ovis*	*O. aries*
Goats	*Bovidae*	*Capra*	*C. hircus*
Indigenous Cattle (zebu)	*Bovidae*	*Bos*	*B. primigenius indicus*
Elephant	*Elephantidae*	*Loxodonta*	*L. Africana*
Zebra	*Equidae*	*Equus*	*E. burchellii*
Giraffe	*Giraffidae*	*Giraffa Brisson*	*G. camelopardalis*
Hippopotamus	*Hippopotamidae*	*Hippopotamus*	*H. amphibius*
Black rhinoceros	*Rhinocerotidae*	*Diceros*	*D. bicornis*
White Rhino	*Rhinocerotidae*	*Ceratotherium*	*C. simum*
Ostrich	*Struthionidae*	*Struthio*	*S. camelus massaicus*
Warthog	*Suidae*	*Phacochoerus*	*P. aethiopicus*

APPENDIX 10: CHECKLIST OF COMMON PLANTS IN THE MAASAI MARA NATIONAL RESERVE AND CONSERVANCIES

Common name)	**Family**	**Genus**	**Species**
Bloodily	Ameryllidaceae	*Scadoxus*	*S. multiflores*
Sumac	Anacardiaceae	*Rhus*	*R. natalensis*
Reclining date palm	Arecaceae	*Phoenix*	*P. reclinata*
Wild sisal	Asparagaceae	*Sanseveria*	*S. species*
Cordia ovalis	Boraginaceae	*Cordia*	*C. ovalis*
African greenheart (tree)	Canellaceae	*Warburgea*	*W. ugandensis*
Giant diospyros	Ebenaceae	*Diospyros*	*D. abyssinica*
Euclea	Ebenaceae	*Euclea*	*E. dinovorum*
Euphorbia	Euphorbiaceae	Euphorbia	*E. candelabra trees*
Croton shrub	Euphorbiaceae	*Croton*	*C. dichogamus*
Acacia	Fabaceae	*Acacia*	*A. brevispica,* *A. hockii,* *A. Senegal* *A. seyel* *A. gerrardii,* *A. drepanolobium (whistling thorn)* *A. xanthlophloea.*
Grewia	Malvaceae	*Grewia*	*G. species*
African olive	*Oleaceae*	*Olea*	*O. Africana*
Thatching grass	Poaceae	*Hyparrhenia*	*H. rufa*
Foxtail/ bristle grasses	Poaceae	*Setaria*	*S. phleoides.*
Wiregrasses	Poaceae	*Aristida*	*A. species*
Red oat grass	Poaceae	*Themeda*	*T. triandra*
Fountain grasses	Poaceae	*Pennisetum*	*P. species*
Sacaton grasses.	Poaceae	*Sporobolus*	*S. species*
Sweet pitted grass	Poaceae/Gramineae	*Bothriochloea Kuntze*	*B. insculpta*
Tecleas Shrub	Rutaceae	*Teclea*	*T. species*
Sodom apple (shrub)	Solanaceae	*Solanum*	*S. incanum*
Balanites	Zygophyllaceae	*Balanite*	*B. species*

APPENDIX 11: DAILY DRY MATTER DEMAND OF LIVESTOCK AND WILDLIFE STUDIED IN MAASAI MARA AS PER BODY WEIGHTS

Animal species (Common name)	Average body weight at birth (kgs) and daily dry matter demand (weight* 0.025)				Average body weight at maturity (kgs) and daily dry matter demand (weight* 0.025)			
	Male	Daily dry matter demand	Female	Daily dry matter demand	Male	Daily dry matter demand	Female	Daily dry matter demand
Elephant	120	3	120	3	3000	75	2150	53.75
Buffalo	40	1	40	1	700	17.5	550	13.75
Eland	29	0.725	29	0.725	850	21.25	450	11.25
Wildebeest	22	0.55	22	0.55	250	6.25	180	4.5
Topi	11	0.275	11	0.275	140	3.5	126	3.15
Hartebeest	12	0.3	12	0.3	150	3.75	120	3
Impala	5	0.125	5	0.125	60	1.5	40	1
Thomson's gazelle	2.5	0.0625	2.5	0.0625	23	0.575	18	0.45
Grants gazelle	6	0.15	6	0.15	65	16.25	45	1.125
Dik dik	0.795	0.0199	0.624	0.016	5.1	0.128	5.5	0.138
Water buck	13	0.325	13	0.325	236	5.9	186	4.65
Warthogs	0.6	0.015	0.665	0.017	82	2.05	65	1.625
Zebra (plains)	33	0.825	32.5	0.813	330	8.25	315	7.875
Giraffe	57	1.425	55	1.375	1185	29.625	825	20.625
Hippo	32	0.8	30	0.75	1500	37.5	1350	33.75
Black rhino	41	1.025	40	1	1179	29.475	950	23.75
Reedbuck	4.8	0.12	4.5	0.113	55.5	1.388	41	1.025
Duiker	1.8	0.045	1.6	0.04	18	0.45	21	0.525
Steenbok	0.95	0.024	0.9	0.023	10.9	0.273	11	0.275
Bushbuck	4	0.1	4	0.1	45	1.125	30	0.75
Oribi	2	0.05	1.7	0.043	17	0.425	15	0.375
Klipspringer	1	0.025	1	0.025	10	0.25	13	0.325
White rhino	41.5	1.038	40	1	2150	53.75	1500	37.5
Ostrich	1.8	0.045	1.5	0.038	110	2.75	95	2.375
Zebu cattle	14.3	0.358	13.5	0.338	180	4.5	157	3.925
Sheep	2.8	0.07	2.9	0.073	20.3	0.508	16.8	0.42
Goats	2.3	0.058	2.75	0.069	19.5	0.488	16.3	0.408