ANALYSIS OF NEXUS BETWEEN CLIMATE VARIABILITY, HERD MOBILITY AND LIVESTOCK DISEASE INCIDENCES IN THE RANGELANDS OF NORTHERN KENYA

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A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN RANGE MANAGEMENT

DEPARTMENT OF LAND RESOURCE MANAGEMENT AND AGRICULTURAL TECHNOLOGY

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2023

DECLARATION

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

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ANALYSIS OF NEXUS BETWEEN CLIMATE VARIABILITY, HERD MOBILITY AND LIVESTOCK DISEASE INCIDENCES IN THE RANGELANDS OF NORTHERN KENYA

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To

Fridah, Nancy, Billy, Rayon, Precious, Olivia and Glen. For your love, prayers and understanding during the period of my studies.

ACKNOWLEDGEMENTS

I take this opportunity to thank my supervisors; Prof. Moses Nyangito, Prof. Oliver Wasonga and Dr. Rawlynce Bett for their helpful assistance, advice and moral support offered throughout proposal development, research and thesis writing period. The support of the Samburu County Directorate of Veterinary Services also came in handy through being allowed unlimited access to all veterinary documents available in their archives and the staff taking part in the collection of participatory epidemiology data in the field. For this I want to pass my gratitude and appreciation to Dr. Boreya Lekenit, Dr. Edward Lolokuru, Dr. Samuel Leterewa, Dr. Kiambi Muchira and Mr. Joseph Mahehu as well as County Department of Agriculture, Livestock and Fisheries staff in Samburu County. My gratitude and appreciation to the research assistant and enumerators who took part in this research including Paul Olekinyile Lelenguiyah, Lavias Lekuuk, David Loote, Paul Loserian, Titika Leisido, Cylas Naiz and Eliphas Lentukunye. The contribution of pastoral and agro-pastoral communities in Samburu County could not be ignored for having participated in the household questionnaire survey hence providing valuable information. This research was funded by the Kenya Climate Smart Agriculture Project (KCSAP) under the Ministry of Agriculture, Livestock, Fisheries and Cooperatives. The Higher Education Loans Board scholarship catered for the tuition fees during my PhD studies. I am grateful for the support.

I extend my gratitude and appreciation to all of the above individuals, communities and organizations.

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LIST OF ABBREVIATIONS AND ACRONYMS

AD	-	Anno Domini (Latin for "in the year of our Lord")
AI	-	Avian Influenza
AHA	-	Animal Health Assistant
AHS	-	African Horse Sickness
ANOVA	-	Analysis of Variance
ASALs	-	Arid and Semi-Arid Lands
ASF	-	African Swine Fever
ASTGS	-	Agricultural Sector Transformation and Growth Strategy
AU-IBAR	-	African Union-InterAfrican Bureau for Animal Resources
BSc.	-	Bachelor of Science
BSE	-	Bovine Spongiform Encephalitis
BC	-	Before Christ
BT	-	Blue Tongue
CAHWs	-	Community Animal Health Workers
CBD	-	Convention on Biological Diversity
CBPP	-	Contagious Bovine Pleuropneumonia
CCD	-	Convention to Combat Desertification
CCPP	-	Contagious Caprine Pleuropneumonia
cDNA	-	Complementary Deoxyribonucleic Acid
CDRs	-	Community Disease Reporters
CDVS	-	County Director of Veterinary Services
CIDP	-	County Integrated Development Plan
CLMC	-	County Livestock Marketing Council
COP	-	Conference of Parties
CSF	-	Classical Swine Fever

DALF	-	Department of Agriculture, Livestock and Fisheries
DCA	**-**	Detrended Correspondence Analysis
DFID	-	Department for International Development
Dr.	-	Doctor
DRC	-	Democratic Republic of Congo
DVS	**-**	Director of Veterinary Services
ECF	**-**	East Coast Fever
ELSE	**-**	Ethiopia/Kenya Boarder Enhanced Livelihoods in Southern Ethiopia
ENSO	-	El Niño/ Southern Oscillations
EWS	**-**	Early Warning System
EWX	**-**	Early Warning Explorer
FAO	-	Food and Agriculture Organization
FEWS-NET	-	Famine Early Warning Systems Network
FGD	-	Focus Group Discussions
FMD	-	Foot and Mouth Disease
FMDV	-	Foot and Mouth Disease Virus
GCMs	**-**	Global Circulation Models
GDP	**-**	Gross Domestic Product
GF-TADs	-	Global Framework for the Progressive Control of Trans-boundary Animal Diseases
GHGs	**-**	Green House Gases
GIS	-	Geographical Information System
GOK	-	Government of Kenya
HPAI	**-**	Highly Pathogenic Avian Influenza
HS	-	Haemorrhagic Septicaemia

IAEA	**-**	International Atomic Energy Agency
IBM	-	International Business Machines Corporation
IIED	**-**	International Institute for Environment and Development
ILRI	**-**	International Livestock Research Institute
IPCC	-	Intergovernmental Panel on Climate Change
ITCZ	-	Inter-Tropical Convergence Zone
ITK	-	Indigenous Traditional Knowledge
JJA	**-**	June-July-August
KCSAP	-	Kenya Climate Smart Agriculture Project
KENTTEC	-	Kenya Tsetse and Trypanosomiasis Eradication Council
KMD	-	Kenya Meteorological Department
KEVEVAPI	-	Kenya Veterinay Vaccines Production Institute
KVB	-	Kenya Veterinary Board
LMAs	-	Livestock Marketing Assiciations
LSD	-	Lumpy Skin Disease
LST	-	Land Surface Temperature
MAM	**-**	March-April-May
MDGs	-	Millennium Development Goals
MENA	-	Middle East and North Africa
MENR	-	Ministry of Environment and Natural Resources
M.Env.S	-	Master of Environmental Studies
MSc.	-	Master of Science
NAMA	**-**	Nationally Appropriate Mitigation Action
NAP	-	National Action Plan
NCD	-	Newcastle Disease
NCCAP	-	National Climate Change Action Plan

NCCRS	-	National Climate Change Response Strategy
NDC	-	Nationally Determined Contribution
NDMA	-	National Drought Management Authority
NDVI	-	Normalized Differential Vegetation Index
NEMER	-	Near and Middle East Region
NGOs	-	Non-Governmental Organizations
NYS	-	National Youth Service
OIE	-	Office International des Epizooties
OND	-	October-November-December
PE	-	Participatory Epidemiology
PhD	-	Doctor of Philosophy
PPEs	-	Personal Protective Equipments
PPR	-	Peste des Petits Ruminants
Prof.	-	Professor
QBO	-	Quasi-Biennial Oscillation
QGIS	-	Quantum Geographical Information System
RESCAD	-	Regional Strategy for Animal Disease Control
RFE	-	Rainfall Estimate
RP	-	Rinderpest
RSU	-	Regional Support Unit
RVF	-	Rift Valley Fever
RVIL	-	Regional Veterinary Investigation Laboratories
SADC	-	South African Development Community
SCG	-	Samburu County Government
SDGs	-	Sustainable Development Goals
SGP	-	Sheep and Goat Pox

SNV	-	Netherlands Development Organization
SPSS	-	Statistical Package for Social Sciences
SRS	-	Severe Respiratory Syndrome
TADs	-	Trans-boundary Animal Diseases
UK	-	United Kingdom
UN	-	United Nations
UNDP	-	United Nations Development Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
USAHA	-	United States Animal Health Organization
USD	-	United States Dollars
USGS	-	United States Geological Survey
VIL	-	Veterinary Investigation Laboratory
WAHIS	-	World Animal Health Information System
WFP	-	World Food Programme
WHO	-	World Health Organization
WISP	-	World Institute for Sustainable Pastoralism
WRL	-	World Reference Laboratory

ABSTRACT

Arid and semi-arid lands occupy at least one-third of the planet's land area, while in Africa, they comprise about two-thirds of the continent. These ecosystems are subject to diverse drivers including rainfall variability, fire, and grazing and browsing that end up creating a dynamic and patchy rangeland landscape that is inherently unpredictable in space and time. Pastoral herd mobility is a key coping strategy in the arid and semi-arid rangelands where grazing and water resources are highly variable in space and time. The spatial and temporal climate variability dictate herd mobility, and therefore understanding this interrelationship is key to sustainable management of rangelands and livestock production, especially in the face of the changing climate. The constraints that come with herd mobility includes ineffective veterinary services delivery system, inadequate infrastructure and inefficient information dissemination mechanism. This study was undertaken in Samburu County in Kenya, an area characterized by varying climatic conditions, land uses and agro-ecological zones to analyze local perceptions on climate variability and pastoralists coping strategies, determine the interrelationship between rainfall and temperature variability and the mobility of herds and determining the effects of seasonality on livestock disease incidences. To achieve the research objectives, Household surveys, Key informant interviews, 20-years data for temperature, rainfall, normalized difference vegetation index (NDVI) and geo-referenced data (GIS) together with field data obtained through household interviews and community participatory mapping were utilized. Drought was perceived to be more severe while rains to have been decreasing. A statistically significant association was noted on the perception on the trend of rainfall and the study sub-locations ($\chi2$= 19.438, df= 1, p= 0.000), temperature ($\chi2$= 15.215, df= 1, p= 0.000), floods ($\chi2$= 18.301, df= 1, p= 0.000) and drought ($\chi2$= 22.016, df= 1, p= 0.000). Pasture availability was said to be the most important factor when it comes to decision-making on where pastoralists will move their animals as mentioned by 100% of the respondents. This was followed by water availability (97.4%), conflicts (79.4%), type of livestock kept (79.1%) and emergence of livestock diseases (72.8%). Pastoralists coping strategies included migration, eating wild fruits, reducing the herd size as well as herd splitting. Wet-season and dry-season grazing areas characterize the Samburu pastoral system. It was only in Samburu central endowed with good rainfall that the pastoralists graze around their homes all year round. The spatial analysis indicate that rarely do livestock in Samburu east graze around homesteads due to low rainfall received and degraded pastures. The herds spatial distribution patterns followed pasture availability as shown by vegetation NDVI patterns. Areas with higher NDVIs of over 0.3 attracted herds concentration but with high *in situ* mobility to maximize on grazing of the most nutritious pastures. Irregular rainfall pattern makes animals to move around the area in search of grass and water, and grazing patterns are always shifting. Among the livestock, goats were identified to have the most economic importance. On the other hand Pestes des Petits Ruminants (PPR), Foot and Mouth Disease (FMD) and Camel Trypanosomiasis diseases were identified to have the highest impact on pastoral livelihood. Pestes des Petits Ruminants (PPR), Contagious Caprine PleuroPneumonia (CCPP) and Foot and Mouth Disease (FMD) were reported to have been increasing by 57.3% of the respondents (n=199), 66.0% (n=229) and 54.6% (n=189) of the respondents respectively. Spatial analysis indicated that all the disease hotspots were closely related to the distribution of herds during different seasons of the year. Correlations between the mean annual rainfall and selected livestock diseases was significant for East Coast Fever (ECF) (r = -0.767, p = 0.001, N = 15), Cattle Helminthiasis (r = 0.639, p = 0.010, N = 15), Cattle Anaplasmosis (r = 0.631, p = 0.012, N = 15) and Camel Pox (r = -0.646, p = 0.044, N = 10). There was a strong relationship between seasonality and livestock disease epidemiology. In conclusion, there has been general change in rainfall and temperature trends which have had negative impacts on the pastoralists and their livelihoods. This study proposes grazing management embedded in observed herd mobility and grazing resource use patterns as a strategy towards adapting the pastoral communities to the changing climate and the focusing of disease control efforts towards the hotspots in the wet season and dry season grazing areas.

Keywords: Pastoralism; Herd mobility; Climate variability; Coping strategies; Participatory Epidemiology; Spatial Analysis

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background

The practice of livestock keeping by the pastoralists who inhabit at least one half of the earth's surface enables utilization of the World's most uninhabitable areas characterized by highest degree of climatic variations (ILRI *et al.* 2021; Zinsstag *et al.*, 2016; Galaty and Johnson, 1990). Pastoralism is defined as a practice of animal production involving mobility of herds in time and space across expansive areas in search of scarce resources in the rangelands (Desta, 2016; Macopiyo, 2005). Rangelands occupy arid and semi arid lands (ASALs) and covers more than one-third of the World's land surface while at the same time supporting more than one-third of those that inhabit the African continent (Adriansen, 1999). Such rangelands make remarkable contributions to national, regional and World economic development through promotion of livestock production opportunities, wildlife conservation, promotion of tourism development and protection of culture (Mulianga, 2009).

In the Eastern part of Africa, rangelands have two main rainfall seasons with the long rains mostly occurring between the months of April and June and the short rains being received in the months of October, November and December (Pas-Schrijver, 2019; Galvin *et al*., 2001; Mutai and Ward, 2000). These lands cover 80, 50 and 40% of Kenya, Tanzania and Uganda respectively and have provided livelihoods for millions of pastoralists in East Africa (Fratkin, 2001; Orindi *et al.*, 2007; Nyariki *et al.*, 2009). Pastoralists in these rangelands are accustomed to the climatic variations that have occurred in these areas throughout history, especially as it commonly occurs in ASALs. However, resource-based conflicts, emerging diseases and other factors that poses challenges on access to pasture and water and livestock survivability has increased vulnerability of pastoral production system (Zinsstag *et al.*, 2016; Moenga *et al*., 2016). Climatic variability and change will increase the fluctuations of feed and fodder availability, further amplifying these risks. With increasing demands for livestock and livestock products, upward trend of world population and changes in land utilization to conservation and agriculture, access of livestock keeping communities to enough feeds for their livestock has been constrained (Galvin *et al*., 2001; Mulianga, 2009). The major cause of these changes is reduced space that restricts seasonal mobility of their herds to exploit resources that vary spatially and temporally across the landscapes as dictated by both natural and climatic factors of the production system (Adriansen, 1999; Mulianga, 2009; Lengoiboni, 2011). Such mobility could either be regular and limited to short distances or irregular which involves large scale and trans boundary movements (Macopiyo, 2005).

The livelihood and production system that has proven to be the most able to adapt to the extreme climatic unpredictability and marginal landscapes of the drylands is pastoralism (Zinsstag et al., 2016; World Institute on Sustainable Pastoralism (WISP), 2006). Pastoralism makes the most environmentally and economically sustainable use of these ecologically sensitive areas to support the lives and livelihoods of local populations. Pastoralists control access to water and pastures in the drylands by seasonal mobility and rely on cattle and livestock products for nutrition and money (Pas-Schrijver, 2019). Pastoralists animals are grazed on communally managed or open-access pastures. Pastoralists employ indigenous knowledge, which is handled by traditional authorities that are also the guardians of their indigenous knowledge systems, to manage their livestock, water, land, and pasture (Pas-Schrijver, 2019). Hence, pastoralism is a system with its own set of laws and institutions for carrying out those laws. It is a conventional production system, and conventional governance structures have proved necessary for its long-term sustainability. The social norms and the institutional framework that supports them have developed over time to be appropriate for dryland management over the long term.

Pastoralism depends on the intricate interplay of the environment's resources, thriving local institutions for administration, and animals that have suited to it. Natural resources, institutions, and the livestock are the three primary pillars of pastoralism; all three are greatly influenced by seasonality patterns, whose function is continually knocked out of whack by climatic change.

Pastoralists divide their land into dry and wet grazing zones to manage it. During the rainy season, they graze in drier portions of the rangeland, then shift to wetter portions during the drought, when the feed and water resources are depleted (Pas-Schrijver, 2019). For generations, this nomadic movement has maintained pastoral life, but today their livelihood is in jeopardy as climate change takes front stage. Climate change in the rangelands manifests itself in floods and recurrent droughts, which destroys livelihoods by causing high livestock mortality, compromising peoples' adaptive capacity and resilience in Kenya's drylands.

Kenya's Drylands make approximately 84% of the nation's total land area, are home to around 10 million people, sustain more than 80% of the nation's ecotourism activities, and may support up to 60% of the nation's livestock (ILRI *et al.* 2021; Davies, 2007). According to the Netherlands Development Agency (SNV), 2008, the sector contributes 12 percent of Kenya's GDP and 42% of its agricultural GDP. Also, it is a significant source of foreign currency and is closely related to all other aspects of the economy (SNV,2008). Approximately 11.4 percent of household consumption spending nationwide is on food made from animals. In Kenya, pastoralists generate more than 80% of the meat that is consumed (SNV, 2008).

In Kenya, regular mobility usually occurs mainly as the dry seasons sets in. There are two such seasons in the ASAL areas of this country and they occur in the months of July to September and January to March (Pas-Schrijver, 2019; Mutai & Ward, 2000). During these periods, pastoralists maintain their seasonal routes dictated by pasture and water presence. As the pastoralists move, they encounter various challenges such as competition for resources leading to resource-based conflicts, livestock diseases and predation from wild cats (Blench, 2000; Moenga et al., 2016). Livestock disease cases are usually presumably higher due to the fact that veterinary services in the dry season grazing areas are limited or not available at all (Zinsstag *et al.,* 2016). At the same time, livestock from all over the various pastoral communities converge in such areas, hence the risk of spread of diseases also rise.

Indigenous knowledge is important in the management of rangeland resources such as water and pasture, that are essential for livestock-based economies. The guardians of this knowledge are the traditional institutions that mediate and uphold the standards, laws, and regulations that govern pastoral systems.

Animal health services are very important for the role they play in preventing, controlling and eradicating diseases that negatively affects the marketability of livestock and livestock products (Zinsstag *et al.,* 2016; Moenga et al., 2016). Both infectious and contagious diseases are rapid spreading and have huge economic effects and therefore needs quick interventions in case of outbreaks. Trans boundary animal diseases (TADs) are very contagious pandemic diseases which can result to quick infections and major economic losses within a very short span of time (Government of Kenya (GoK), 2015). Such diseases are categorised as notifiable in Kenya and include Contagious Caprine Pleuro-pneumonia (CCPP), Contagious Bovine Pleuro-Pneumonia (CBPP), Foot and Mouth Disease (FMD), African Swine Fever (ASF), Newcastle Disease (NCD), Peste des Petits Ruminants (PPR) among others (GoK, 2015). They are also transboundary in nature and this makes it important for inter-county and inter-country efforts for them to be effectively controlled. Some of them are transmitted by vectors and they include East Coast Fever (ECF), Trypanosomiasis and Rift Valley Fever (RVF) whose transmission involves ticks, tsetse flies and mosquitoes respectively (GoK, 2015; Moenga *et al*., 2016).

Many factors influence the spread of livestock diseases. The risk of pathogen transmission and occurrence in a livestock population is increased by herd mobility and trade channels for livestock and livestock products (Bett *et al*., 2008). The occurrence of epizootic infections is significantly correlated with the increase in the frequency of herd mobility, the inadequacy of animal health surveillance and response systems and the various conflict situations that arise in these areas. The degree of risk also has a direct relationship with the distribution of diseases within a County or the Country in general (Moenga *et al*., 2016). Herd mobility exposes livestock to new infections. Such animals could also be carrying other pathogens to their new grazing areas hence creating a vicious circle.

During herd mobility, the inaccessibility of pastoral areas, inadequacy or unavailability of livestock health services (veterinary drugs outlets, crushes, dips etc.) can make livestock keepers to turn to unorthodox methods of treating their sick animals either through ethnological practices or using substandard or expired drugs, this may work against disease control efforts.

It is therefore important to understand how herd mobility and climate variability contribute to disease hotspots. It is through the understanding, characterization and documentation of these hotspots that proper livestock disease control measures can be put in place.

1.2 Statement of the Problem

Climate variability and change have continued to affect pasture and water availability within the rangelands that the pastoralists depended on for thousands of years (GoK, 2017; Wasonga *et al*., 2011; Fer *et al.*, 2017; Mcsweeney *et al.*, 2010; Lelenguyah *et al.*, 2014).

This has resulted to continuous mobility of pastoralists with their herds in search of grazing and water resources (Adriansen, 1999; Ellis and Galvin, 1994). Since the availability of these resources dictate their movement patterns, pastoralists from different ethnic groups have always found themselves converging and competing for the same resources (Lengoiboni, 2011; Mulianga, 2009). This has often resulted in resource-based conflicts and also led to spread of animal diseases. Within the study area, the morbidity cases for CCPP and PPR in 2015 were 15% and 11% respectively while the mortality cases for the two diseases were 10.17% and 6.17% respectively (County Director of Veterinary Services (CDVS), 2015). Livestock, especially sheep and goats, are crucial in supporting pastoral livelihood security within pastoral areas. However, given the extensive production system practiced in the rangelands characterized by extensive herd mobility and coupled with weak disease control initiatives, sheep and goats are under threat from a myriad of trans-boundary diseases such as CCPP, sheep pox, goat pox, PPR among others. Specifically, PPR is a disease that is prevalent and deadly to small stock. Across the adjoining Counties of Turkana, Samburu, West Pokot and Baringo, their County livestock development plan for 2013 – 2017 cite increased disease and vectors prevalence as causing significant animal losses and a major challenge in livestock production (Akoyo and Songok, 2013).

Despite the disease challenge and the continued loss of animals, little or no attention has been directed towards getting solutions to pastoralism-related livestock disease outbreaks and their control. Particularly, the nexus between climate variability and herd mobility in creating livestock disease hotspots has not been analysed to spur targeted disease control measures in these poorly inaccessible pastoral landscapes. It is through the understanding, characterization and documentation of these hotspots that proper livestock disease control measures can be put in place. This study intended to investigate the patterns of herd mobility and resource use with the variable climate, its impact on livestock disease control and consequently propose disease control interventions and strategies for Northern Kenya that will ensure that climate variability and herd mobility do not become a constraint to livestock disease control.

1.3 Justification of the Study

Globalization provides a need for continuous information sharing on animal diseases across all countries so as to regulate trade in animal and animal products. Kenya's ASALs are often remote regions occupied by marginalized pastoralists who are often underrepresented in information systems and service delivery, despite the fact that the highest animal populations in the country. Therefore, these people not only suffer a deficiency in service delivery but also pose a major epidemiological risk to major livestock populations in Kenya as a whole. Livestock diseases do not spare even the drought tolerant camels, which the residents perceive to be also at risk (Onono *et al.,* 2010).

Among the pastoral communities in Samburu County as in other arid lands, sheep and goats form a key livestock resource of major economic importance (Samburu County Government (SCG), 2018). This livestock resource is an integral part of food and livelihood security. Consequently, any major disease event especially TADs including CCPP, PPR, sheep pox, goat pox among others within this segment of the livestock resource poses a tremendous threat to food and livelihood security with major negative impacts on trade and the national economy.

Appropriate policies are a critical component in stabilizing pastoral systems' livelihoods, particularly those focused toward climate change mitigation. A strong business environment that facilitates enterprises and investments in pastoral systems will be fostered by policies that are well-crafted, responsive to the demands of pastoralist communities, integrating traditional knowledge, and recognising the role of customary institutions. As a result, communities will be better equipped to deal with climate change. With new climate change laws and institutional frameworks in place to assist communities and individuals in developing economic, social, and environmental resilience to climate change shocks, Kenya has a strong policy environment. Yet, the lack of a strong pastoralist agenda in the policy frameworks leaves pastoralists and their primary livestock economic system vulnerable, leading to inadequate resilience solutions.

Pastoralists do not have effective membership in national and county-level climate strategies and finacing platforms in the following areas: (1) The National Climate Change Response Strategy (NCCRS) was published in 2010. Kenya is a signatory to the UN Framework Convention on Climate Change (UNFCCC), hence the strategy is a commitment to the UNFCCC. Its main goal is to make sure that adaptation and mitigation actions are factored into all government planning, budgeting, and development goals. The pastoralists' concerns are not adequately addressed in the text, and participation in its revision is required; (2) to mainstream Climate Smart County Integrated Development Plans (CIDPs); (3) The National Livestock Policy is a document that governs the livestock industry in the ASALs. This policy appreciates the potential of ASALs in animal production and suggests promoting sound range management practices and disease prevention as one of its methods; (4) County climate change legislation is in progress in most of the Counties. This gives communities the opportunity to develop tailored plans to improve their resilience; Therefore evidence based information at a scale is required to incorporate livestock climate resilience concerns.

Whereas vision 2030 document proposes the establishment of four disease free zones in Kenya (GoK, 2007), this seems to be receiving very little attention. If this was to be implemented, more resources would have been allocated towards the control of livestock diseases and the disease burden among pastoralists' herds would have reduced dramatically. The 23rd session of the African Union assembly in Malabo, Equatorial Guinea on 26th - 27th June 2014, the heads of state and governments committed to ensuring that 30% of pastoral households are resilient to climate and weather related risks (African Union, 2014). Goal 13 of the Sustainable Development Goals urges governments to take urgent action towards combating climate change and its effects by building resilience and enhancing adaptive capacity to climatic hazards (United Nations, 2015). Policy framework for pastoralism in Africa (African Union, 2010) strategy 1.3 (ii) advocates for equitable access to services including animal health to pastoralists. Various other policy documents including the Kenya veterinary policy (GoK, 2015), the National livestock policy (GoK, 2008), the National climate change response strategy (NCCRS) for Kenya (GoK, 2010), Sessional Paper No. 8 of 2012 on National Policy for the Sustainable Development of Northern Kenya and other Arid Lands (GoK, 2012) and the Samburu County integrated plan 2018 - 2022 (SCG, 2018) recognises animal health services as being necessary in preventing, controlling and eradicating diseases that negatively affect the market value and acceptability of livestock and livestock products. These policy documents emphasizes on notifiable and TADs being given more attention.

It is in this context that this study sought to address a knowledge gap on the links and impacts of climate variability and pastoral mobility on livestock disease control in Kenya's rangelands with the aim of proposing measures and approaches to deal with the situation. Further, the results of this study are expected to guide towards policy development on livestock disease control interventions that may be required to enhance pastoralism.

1.4 Objectives

1.4.1 Broad objective

The broad objective of this study was to investigate the nexus between climate variability, herd mobility and livestock disease incidences in Northern Kenya rangelands to inform effective targeting of veterinary interventions in time and space for improved livestock production and productivity.

1.4.2 Specific objectives

The specific objectives of this study were to:

i. Analyze local perceptions on climate variability and coping strategies in the study area.
ii. Determine the relationship between seasonal climate variability and herd mobility patterns in Samburu County.
iii. Determine the effects of seasonality on livestock disease incidences and hotspots in the study area.

1.4.3 Research questions

1. What are the perceptions, impacts and coping strategies to climate variability in the Samburu pastoral production system?
2. What is the relationship between seasonal climate variability and herd mobility patterns in Samburu County?
3. What effects and relationships exists between climate variability, livestock disease incidences and hotspots in the study area?

CHAPTER TWO

2.0 GENERAL LITERATURE REVIEW

2.1 The Rangeland Ecosystems and Pastoral Production Strategies

Arid and semi-arid lands occupy at least one-third of the planet's land area, while in Africa, it is about two-thirds of the continent (ILRI *et al.* 2021; Manzano *et al*., 2021; Adriansen, 1999; Galvin *et al*., 2001; Lesorogol, 2008, WISP, 2008). Rangelands include various vegetation formations ranging from grasslands (including Savannas), bushlands, woodlands and shrub lands. Therefore, pastoralists appreciates the space, time and the ecological ranges that such habitats are located in the ASALs, including the transitions between these systems themselves (Lambin *et al.,* 2001). Rangeland plant composition ranges from 100% grass savannas, through shrub lands, to grasses and browse occurring in thick forests (Lambin *et al.* 2001). The disturbances within these areas range from rainfall variability, to fire, and grazing and browsing and they end up creating a dynamic and patchy rangeland landscape (Catley *et al.*, 2013; Ellis and Galvin 1994). Other rangelands types are either classified depending on edaphic or climatic factors (Sankaran *et al.* 2005) but, they equally face disturbances from the activities of resident and migratory wild animals combined with anthropogenic factors which impact on their vegetation structure. On another perspective, research has shown that, grazing livestock serve to maintain the rangelands and are actually not a major contributor to the soil erosion and biodiversity loss in the tropics (Adriansen *et al.,* 1999).

Precipitation is an important determinant of vegetation cover in the rangelands and poses a challenge to anthropogenic land-use (Ellis and Galvin 1994). Both crop production and pastoral land uses are mainly influenced by rainfall patterns. In these areas, various rainfall regimes favors different land uses. For instance, a unimodal rainfall regime favors crop production as a result of a more regular planting season whereas a multimodal pattern of precipitation in arid areas, like the one commonly found within Kenyan rangelands is favorable to grass and shrubs regeneration hence more reliable for pastoralism (Ellis and Galvin 1994). Many arid and semi-arid areas have very unpredictable precipitation patterns which determine both the production and productivity of both crops and livestock (Mace 1993; Ellis and Galvin 1994). For this reason, the degree of aridity of a rangeland determines the land use patterns of such a land. For instance, pastoralism is commonly practiced in the ASALs of Africa (Blench, 2000). This practice ensures that such lands are also utilized for productive purposes (Galaty and Johnson, 1990).

Livestock keepers in ASALs have a tendency to move with their animals from one area to another grazing the animals instead of adopting a sedentary life and fend for forage for their animals. This can be interpreted as a strategy to ensure that their animals have enough feeds all year round (Fratkin, 2001; Ng'ethe, 1992). Climate variations have a negative effect on the presence or absence of pastures in time and space thus dictating the seasonal herd mobility patterns adopted by pastoralists (Fratkin, 2001). During the dry seasons of the year, pastoralists move with their livestock to regions that receive high rainfall that sustains pasture (Oba and Lusigi, 1987). As the rain season begins, they start their journey back home for their animals to graze on the regenerated pasture and at the same time provide milk for the young and the old that were left behind (Blench, 2000). These strategies of pasture and browse utilization by the pastoralists are the most economical, not-withstanding, the huge differences in the distributions of these grazing areas (Goodhue and McCarthy, 1999; Scoones and Graham, 1994; Toulmin, 1993).

2.2 Types and Status of Land use

In Samburu County, low-potential rangelands make up 77.5% of the entire land area. These lands are predominantly found in the Nyiro, Wamba, and Waso areas, where they are subject to communal and ranch tenure systems. Nomadic pastoralism dominates land use in these rangelands. The County has roughly 140,900 hectares (7 percent) of medium to prospective agricultural land. This area is located in the Kirisia and Lorroki area, which receive 600-900 mm of rainfall each year. A total of 6,000 hectares are being used for farming and planting wheat, barley, maize, beans, as well as a number of different fruits and vegetables. Lowland rangelands, which make up 77.5% of the total area of the County, are mostly used for nomadic pastoralism. Group ranches and communities own land in the rangelands. The acreage of land being farmed is gradually increasing, while dairy farming is gaining popularity (SCG, 2018; SCG, 2013).

Overgrazing and its associated environmental deterioration are a problem with communal land ownership in the rangelands (Zinsstag *et al.,* 2016). As more land is cultivated in the highlands, plant cover declines, and soils becomes more vulnerable to erosional forces. This trend calls for concerted efforts to promote agroforestry, fodder agribusiness and other forms of soil and water conservation (Edward and Bahal'okwibale, 2017).

Livestock production is the primary means of subsistence for the indigenous inhabitants. According to the 2009 census of the population, there were 184,666 heads of cattle, 550,750 goats, 387,698 sheep, 32,824 camels, 26,822 donkeys, and 37,749 native chickens in the livestock population (DALF, 2018). In addition 187 pigs, 21,057 beehives, and 4,962 commercial chickens were also reported. Livestock, and mainly small stock (sheep and goats) are the primary means of sustenance for pastoralists while at the same time being commonly used during the traditional ceremonies.

The pastoral communities in these areas keeps livestock either using the traditional system or the modern system. The traditional system can further be categorised as either pastoral or agro-pastoral. This system is mainly practised in the ASAL areas of the County which makes up to 92% of the total land mass. The modern system of livestock keeping being practiced in the highland areas of the County involves mainly mixed farming and mainly involves production of livestock for commercial purposes.

Rangelands used for pastoralism and wildlife currently occupy 77.5% of the total land mass of 21,022.01km^2 in the County (SCG, 2013; SCG 2018). Gazetted indigenous forests cover 15.5% (328,000 Ha) of the County. Crop production both in small scale and large scale farming is common in the highland areas around Kirisia and Lorroki and occupies about 60km$^{\mathbf{2}}$. The land is mainly split into group ranches and are communally owned with every member having the same rights, with the exception of some tracts of land in Kirisia and Lorroki, where people have title deeds, leased titles, and group representative titles (group ranches).

There exist four conspicuous land use patterns in Samburu County. These are Forestry, mixed farming, tourism and pastoralism. Local people are mainly livestock keepers, keeping mainly indigenous breeds of cattle, sheep and goats. Pastoralism is the major livelihood of the Samburu community who are the majority of the inhabitants of the County. Some people are small scale mixed farmers planting mainly maize and beans.

2.3 Pastoral Production System and Herd Mobility in the Rangelands

Pastoral-nomadism is known to be the most common use of arid and semi-arid lands in at least 12.5% of this planet's land surface, but was traditionally more widespread (Reid *et* *al.,* 2008). In ASALs, traditional land-use practices are more common since they help in tracking fluctuations in the availability of resources on a temporal and spatial basis, and as a result the anthropogenic impacts on the ecosystem are spread across a large area (Ellis and Galvin 1994). Risk reduction by the pastoralists were traditionally done through a number of adaptations including herd mobility and migrations towards pasture and water resources, herding different species of livestock, and other cultural methods including herd splitting and distribution to the less fortunate in the society.

The existence of pastoralism in East Africa can be traced back to sometime between 3000 BC and 2000 BC or more years ago (Blench, 2000). To cushion themselves against the effects of climate variability, pastoralists typically employ various herd management techniques. Among the Samburu people of Kenya, for example, keeping a variety of species of animals including browsers (camels and goats) and grazers (cattle and sheep) is practised to ensure optimal utilization of pasture and browse (Galvin *et al.,* 2001). Such a practice of keeping multiple species also ensures that the owners are cushioned against losses brought about by species specific outbreaks of diseases, especially the TADs (Galaty and Johnson 1990; Reid *et al.,* 2008). The number of animals kept per species is dependent on various factors including culture, ecological factors, including the terrain of the area and the individual decisions of the owners (Cooke 2007). During the successive years after a long dry spell, sheep and goats reproduce to a greater extent than cattle and camels and therefore, the population of the small stock is able to replenish itself faster than the larger stock following deaths resulting from drought (Oba and Lusigi, 1987)). This is because their gestation periods is very short compared to that of the larger stock. Therefore, small stocks are of great use during difficult times of the year. They can be easily sold in the markets and the money used to purchase food, they can as well be slaughtered to feed the family as well as given out to those who seek assistance from the family. Generally, sheep and goats can easily be used for day to day running of pastoral life.

The relationship between pastoralists and the land they occupy is usually on spatiotemporal terms through herd mobility. Their grazing land is divided so as to have areas allocated for drought season and for rainy season (Fratkin, 2001) and this encourages predetermined mobility patterns that are dependent on both water and pasture availability. Wet season grazing areas results from regular precipitation and are dominated by annual vegetation. Dry season grazing areas on the other hand are inclusive of arable land in the highlands and have readily available watering points. They were traditionally preserved for grazing during droughts (Oba and Lusigi, 1987).

In the argument put forward by Oba and Lusigi (1987), pastoralists experience a lot of stress during drought periods. This is because the mechanisms that they are going to employ to cope with the drought are mainly dependent on their knowledge about the past droughts. It is during such periods that herders move from low pasture areas to areas with plenty of pastures then move back during the start of rain season when regeneration of vegetation starts (FAO, 1999). The pastoralists' mobility pattern is mainly focused towards coming into close contact with friendly communities especially those that speak the same language with them (Fratkin, 2001). Through this, it is usually possible to ensure safety of livestock and using the same herders to look after their animals.

The experience of the pastoralists revolves within their knowledge about the terrain, herd composition and changes in the plant composition from season to season (Bollig and Schulte, 1999). Such experience and knowledge about the environment aids them in their selection of the areas suitable for grazing and the routes to follow to access those areas (Galaty and Johnson, 1990). This is with a view to enhancing nutritional value of the animals from pasture and browse. Pastoralists are known to keep a distance of up 25 km from the watering points to enable them to water their livestock periodically (Thébaud and Batterbury, 2001). Herd movement patterns are also predetermined with camping sites situated in areas that are close to watering points and pasture zones (Macopiyo, 2005; Said, 2003). Herders are also able to send information from these camping sites back to their homes regarding the status of their food situation, pasture and occurrence of livestock diseases in those areas. Pastoralists must always strike a balance between their knowledge about the environment, vegetation changes, biomass, rainfall and diseases to ensure flexibility embedded in mobility in management of range resources (Blench, 2000).

Among the pastoralists, they tend to increase the number of animals when there are plenty of rains since they expect to lose some of them once the drought sets in (Galaty and Johnson 1990). The size and composition of the herd varies in different years and seasons depending on existing environmental conditions, but as a general rule there's a tendency to ensure that females are higher in number to enhance reproductive capacity and among the cattle to ensure steady milk production for the family and the herders.

2.4 Rainfall and Temperature Trends in Kenya

Kenya's climate is complicated in both time and space. Extreme climatic events, including frequent floods and periodic dry seasons are as they are in many other sections of the tropics. Kenya's weather and climate are changing as a result of global warming, which is currently affecting the entire planet (IPCC, 2013). As a result, adequate adaptation and mitigation strategies should be implemented to protect people from the current and future detrimental effects of climate change. Kenya is situated between 5^o North and 5^o South latitudes, with the equator virtually splitting it in half, and longitudes 34^o and 42^o east. The overall area is approximately 569,137 square kilometers. The "long rains" season, which happens in March to May (MAM), and the "short rains" season, which comes in October, November, and December (OND), follow a bimodal seasonal pattern of rainfall. The rain seasons are separated by a dry season in January to March (JAM) and June to August (JJA).

The long rainy season is critical to Kenya's agricultural production, which accounts for 26% of the country's Gross Domestic Product (GDP) and another 27% indirectly through ties with other sectors. The industry employs well over 40% of the populace, and more than 70% of Kenyans reside in rural areas (GoK, 2019). As a result, the MAM rainfall forecast, as well as its subsequent performance, are critical to the agricultural industry as well as the economy as a whole.

The annual north and south migration of the sun across the equator is the principal driver of weather in Kenya. The Inter-Tropical Convergence Zone (ITCZ) is influenced by this migration (Kenya Meteorological Department (KMD), 2020). Figure 2.1 depicts the country's climatological zones.

The months of June to August have lower temperatures, whereas the month of March has the highest temperatures. Kenya's wind patterns are such that the month of May through August are also marked by moderate to severe southerly winds, particularly in the country's eastern and northern regions. The rest of the year, wind regimes are rather calm, bringing in damp or dry air depending on the season.

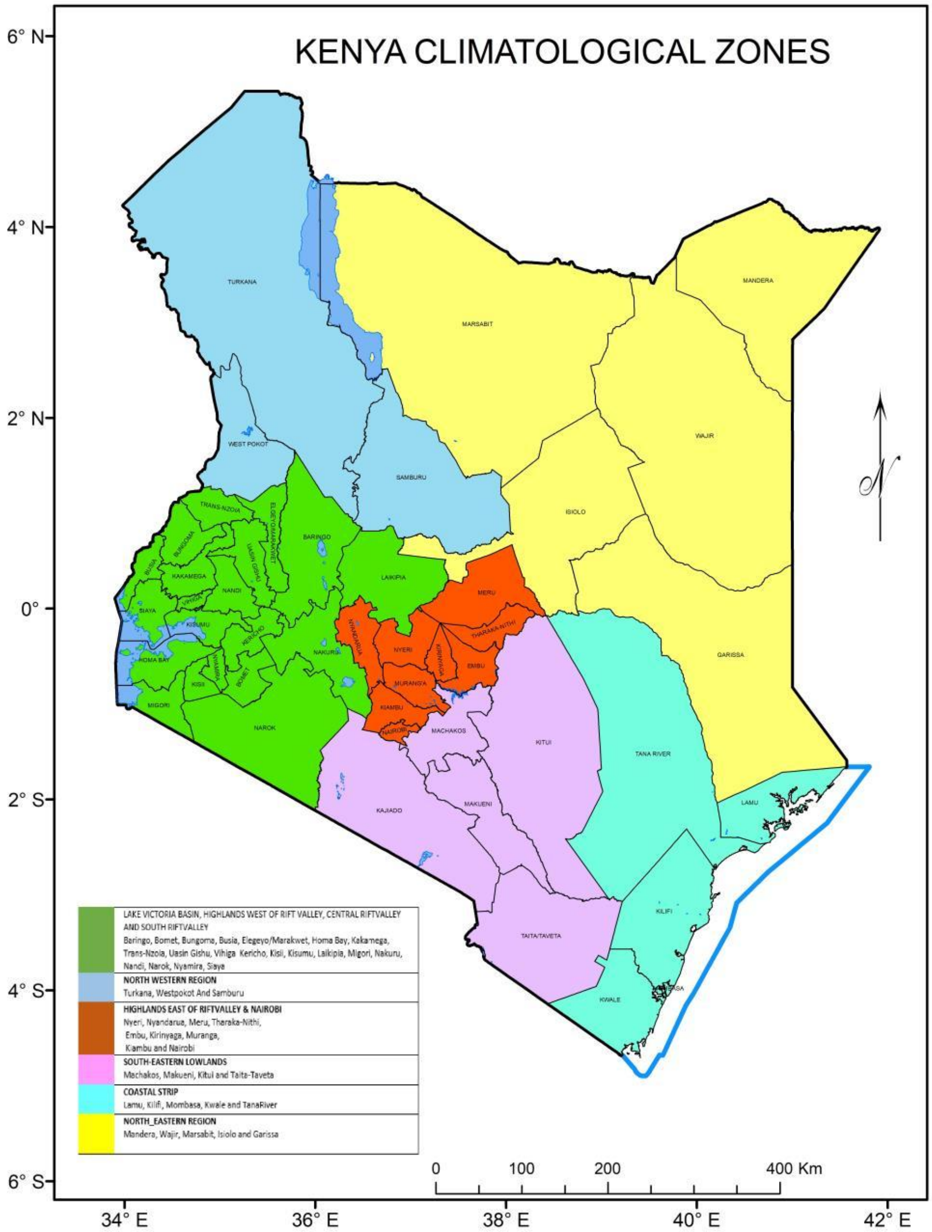


Figure 2.1: Climatological zones of Kenya (Source: Kenya Meteorological Department (KMD), 2020)

United States Geological Survey (USGS) released a report on climate change trends for Kenya which postulates that there has been a general upward trend in the mean annual temperature by 1.0^{o}C (USGS, 2010) and the projection further indicates that there is going to be a continuous increase by between 1.0^{o}C and 2.8^{o}C by 2060s and between 1.3^{o}C and 4.5^{o}C by 2090s (USGS, 2010; McSweeney *et al.,* 2010; Fer *et al.,* 2017; Mendelsohn *et al*., 2000). On the other hand, observations of diurnal temperature changes has indicated significant upward trends of both hot days and hot nights frequency. Specifically 15.6% of the days per annum which is equivalent to 57 days yearly has witnessed these upward trends in Kenya for 43 years (1960 and 2003). On the other hand, the number of nights that are hot have increased by 31% which is equivalent to 113 days within the same period (McSweeney *et al.,* 2010).

Rainfall trends analysis within the same period didn't show any statistically significant trends. However, future predictions have suggested that there will be statistically significant increases in mean annual rainfall by between -1 to +48% by 2090s (Ayugi *et al*., 2016; McSweeney *et al.,* 2010).

2.5 Historical trends of Droughts and Flood incidences in Kenya

Droughts and floods are prevalent in Kenya like in many areas of tropical Africa. These two phenomena are caused by the same factors and when they occur, they can be categorized depending on their intensity as either mild, moderate or disastrous. They commonly occur in ASAL regions of Kenya and cause a lot of losses. Floods for instance can lead to huge damage to property as well as human lives, plants and animals losses. For the case of droughts, they are known to have negative impacts on vegetation hence impacting negatively on both human and animal life since food will not be available. Droughts are also known to be among the major causes of forest fires which can be either viewed negatively or positively. Negatively would be due to loss of biodiversity and positively in the sense that they burn the forest debris and make room for new generation of plants. Drought incidences are well documented in Kenya especially in the Rift Valley Counties where a review of documents indicates that it occurred in 1928, 1933-34, 1939, 1942-44, 1952-55, 1960-61, 1965, 1984-85, 1987, 1992-94, 1999-2000 and 2005-06 (Orindi *et al*., 2007; Lelenguyah *et al*, 2016;). The duration of dry spells varies from one area to another depending on the agro-ecological zone of that area. Generally, they vary from between 16 – 20 months in the ASALs and 4 – 7 months in the highlands (Lelenguyah *et al*, 2013; 2016).

Higher total rainfall has resulted from increased rainfall intensity and the extension of the short-wet season into January and February, despite a decline in the average number of rainy days during the season from 60 to 30. All around the country, but especially near the coast, the intensity of the rain has increased (Parry et al., 2012; Hayes, 2007). Since 1960, the west-central part of Kenya receiving 500 mm or more of rain has reduced, and it is expected to continue declining for the next 30 years (McSweeney *et al.,* 2010). Over the previous 30 years, average annual temperatures have risen at a pace of 0.34°C each year (Climate Service Center Germany, 2016). Extreme occurrences such as droughts and floods are becoming more common as a result of these developments.

Kenya has been identified as one of the most catastrophe-prone nations in the world, ranking first among East African nations and sixth worldwide (year average, 2000-2009) in regard to the number of persons impacted by natural disasters (Guha-Sapir et al., 2013). It was ranked seventh in 2012 for the number of fatalities or injuries brought on by natural disasters, with climatological and hydrological factors accounting for half of the deaths and injuries. Every ten years there are big droughts, and every three to four years there are minor droughts or floods that cause damage. The highest economic devastation (8 percent of GDP per five years) and human suffering have been brought on by droughts. In the last 100 years, 28 droughts have been documented, with the number of droughts increasing (Huho and Mugalavai, 2010).

Droughts can affect the entire country, although the ASALs are usually the hardest hit. While droughts afflict the majority of people, floods have resulted in the most human deaths. They are more localized than droughts, seasonally affecting parts of Nyanza and western provinces, particularly in the Coastal areas, the Tana River drainage basin, and the Lake Victoria basin (Parry *et al.,* 2012). ASALs are subjected to flash floods on a regular basis. Since 1950, the country has had six major floods, each resulting in a loss of 5.5 percent of GDP every seven years.

2.6 Effects of Climate Change on severity of Droughts

The definition of a county, country, or region's climate depends heavily on climatic change and variability. In accordance with the United Nations Framework Convention on Climate Change (UNFCCC), climate change is defined as a change in the climate that is directly or indirectly related to any anthropogenic activity that modifies the composition of the earth's atmosphere and that is additional to natural variability seen over comparable time periods. On the other hand, climate variability is defined as the deviation from the norm or the degree of the variance between climatic events (UNFCCC, 2012). Therefore, variations in climate are associated with the natural processes in the ecosystem but on the other hand, climate change is mainly caused by human actions on the environment (Allan *et al.,* 2021). These actions include releasing of greenhouse gases (GHGs) to the environment, forests and vegetation destruction and use of fossil fuels. Both climate variability and change are currently affecting Kenya as a Country and most of the Countries in the World. They both have economical and societal effects and can lead to disruptions of these systems. Rainfall variability causes the worst effects to the economy and the society.

Drought has far reaching effects to both crop production and livestock keeping, but considering the susceptibility of these two practices, livestock keeping especially in ASALs is more affected by drought (Orindi *et al.,* 2007). There is a common agreement that drought intensity (duration or length and effects) tends to be increasing and this can be attributed to climate change. In a report published by Orindi *et al*. (2007), the 2006 and the 2000-2001 droughts are described as the two droughts with the most severe effects since 1940's. In addition, the authors of this report notes that a number of precipitations failed between these years. The exact losses resulting from these droughts could not be quantified since no records were available. Both pastoralists and crop farmers cope with the effects of drought differently. While crop farmers will try to prioritize which crops to plant while at the same time reduce land area set aside for planting (Meza-Morales, 2010), pastoralists will embark on migration to dry season grazing areas, livestock off-take through sale and diversification of livelihoods hence diversified sources of income (e.g. bee keeping and poultry production).

2.7 Climate Variability and Change Projections for Kenya

Based on a number of General Circulation Models (GCMs), the characteristics of climate changes in Kenya will include rising of the sea levels, increasing temperatures of between 2.5^{o}C - 5^{o}C and increasing rainfall amounts by up to 25% (Mendelsohn *et al*., 2000). These changes will result to various effects including high evaporation and avapo-transpiration rates, changes in patterns of rainfall leading to shortage of water, and enhanced levels of resource based conflicts. There will also be increased flood events and depreciating quality of water in the highlands due to contamination of water sources by chemicals from the farmlands and sewerage. But according to Inter-governmental Panel on Climate Change (IPCC, 1990), impacts of climate change on water resources cannot be ascertained. The severity of the said impacts will be dependent on the management of the mentioned changes by the Counties, Countries or regions where the situations are witnessed.

The predicted increase in the average temperatures will significantly change the rainfall patterns, evapo-transpiration and the general hydrological cycle of the affected areas. Rising sea levels and enhanced severe cases of droughts, floods and storms are other effects expected to be witnessed as a result of changing temperatures. Other impacts includes rising public health concerns, disrupted ecological equilibrium and affected primary productivity. Enhanced precipitation has been affecting the levels of Kenya lakes as witnessed in the 1960s and other episodes in the recent years particularly in lakes Nakuru, Baringo, Bogoria, Naivasha and Victoria.

In Kenya, climatic variations are attributed to the global climatic systems such as the El-Niño/South Oscillation (ENSO) phenomenon and Quasi-Biennial Oscillation (QBO) (Fer *et al.*, 2017). Precipitations and temperatures are the worst affected climatic parameters and they in turn affect sea levels and melting of glaciers. Precipitation in Kenya tends to follow seasons which currently occurs between April through June and October through to December and being affected by the seasonal migrations of the Inter-Tropical Convergence Zone (ITCZ). The July and August rains are attributed to the rising moistures in the Atlantics and the Democratic Republic of Congo (DRC) (Fer *et al.*, 2017).

Variability of climate in Kenya can also be attributed to the increasing size of dry land and desertification and to the rising and falling of rivers and lakes levels. A case in point are the above mentioned lakes which are said to have spread over larger areas during the Holocene period (Wasonga *et al.,* 2011; Ngaira, 1996). A case study of lake Baringo from 1970 to 1995 by Ngaira (1996) showed that it has been fluctuating based on the amount of rain that the region has received.

2.8 Vulnerability of Pastoralism to Climate Variability and Change

Although climate change is a global phenomenon, it has been found that its impact and size vary across numerous levels and scales. It has different effects at the local, regional, national, and international levels. Despite the fact that climate change and extreme weather events would pose the greatest risk for Kenyans, little studies on climate change susceptibility have been conducted in the country.

According to Parkins and MacKendrick (2007), differences in family susceptibility at the local level can be obscured by measures of climate-related shocks and stresses taken at the national level. Deressa et al. 2008's national-level (macroscale) evaluation might have underestimated local differences in vulnerability as a result, as vulnerability levels may differ even among families at the County level. There are significant differences amongst households in terms of food insecurity, coping and adaption skills, credit availability, access to government services and safety nets, and access to natural resources at the County level. Variability at the local level is frequently neglected in nationwide vulnerability analyses in such circumstances. As a result, understanding the geographical dimensions of household vulnerability from countrywide assessments is difficult. This emphasizes the importance of scale in vulnerability assessments and the importance of conducting vulnerability assessments at the local level. The current study must be based on these principles in order to comprehend pastoralists' sensitivity to climate change and variability in Northern Kenya.

There has been a general change in the way pastoralists adapt to climate variability and change. For example, among a section of pastoralists, ways geared towards drought resilience forms part of their culture and and are also enshrined in their resource management practices (Riché, *et al.*, 2009). Challenges with regard to environmental degradation, inter-community scramble for scarce pasture and water resources leading to curtailed herd mobility and animal health challenges constrains pastoralists adaptation to the changing climate. Other factors negatively impacting on pastoralists include inadequate informational services, high illiteracy levels, limited access to financial services to support alternative livelihoods.

For instance, in Ethiopia, Afar clans among the Baadu were moved 150km away westwards and displaced from their cultural grazing land by the Issa clan (Rettberg, 2010). The invasion of the rangelands by invasive plant species, such as *Prosopis juliflora*, which inhibits undergrowth, is another aspect that makes the issue more complicated (Rettberg, 2010). First imported in the 1980s to cover bare lands in different parts of the Country, *Prosopis* spp. is a drought- and salt-tolerant plant that has completely outgrown its intended purpose of providing cover. Climate unpredictability and change could endanger rural households' capacity to make a living since rural communities rely solely on the sale of livestock (Masike and Urich, 2008).

2.9 Transboundary Animal Diseases and Pastoralism

Trans-boundary animal diseases are those that affect a large number of nations' economies, trade, and/or food security; they can readily extend to further countries and take on epidemic proportions; and their management/control, including exclusion, calls for cooperation among several nations. TADs are highly contagious and can spread quickly across national borders, resulting in major socioeconomic implications. All TADs have the potential to be fatal to the infected animal, although the severity of the sickness varies based on factors such as the animal type and breed, age, diet, and disease agent. In sensitive animals, several TADs have mortality rates of 50 to 90 percent (Otte *et al.,* 2004).

TADs are characterized by the fact that they can cause national emergencies and that their relevance often extends beyond national borders. For many countries, they are critical to food security, long-term economic growth, and trade. TADs are non-tariff restrictions on the export of animals and animal-products that have a significant economic impact. They are highly contagious and feared cattle illnesses over the world, as well as being economically significant and a major impediment to international trade (Otte *et al.,* 2004).

Foot and mouth disease (FMD) in Europe, (Thrusfield, *et al.* 2005), classical swine fever in the European Countries and the Caribbean (1996–2002) (Vargasteranet *et al*., 2004), rinderpest in the 1980s in Africa (Rweyemamuet al., 2000), PPR in Bangladesh and India, and CBPP in Southern Africa and Eastern Africa (Balkhy and Memish, 2003) are classical TADs examples.

Rinderpest was previously one of the most feared livestock sickness in the world. It mostly affects cattle species, with the most virulent strains capable of killing up to 95 percent of infected animals in naive herds. Rinderpest had been eradicated from Western Europe by the turn of the century, had never established itself in Australia or South America despite sporadic introductions, and remained endemic in Sub-Saharan Africa and Asia. Major African pandemics, the most recent in the early 1980s, wreaked havoc on the pastoral areas of Western and Eastern Africa (Rich and Roeder, 2009).

2.9.1. The OIE list of TADs

The World Animal Health Organization (OIE) is recognized by the World Trade Organization as the leading international authority on animal diseases and zoonoses. The veterinary authorities of member countries are required to inform OIE of any changes in the situation involving these diseases in their nation because OIE has a list of diseases that are thought to be so important due to their effect on livestock populations, capacity for spread, and threat to the well-being of humans (FAO/OIE, 2004).

Lists A and B were expressly used to categorize the OIE-listed diseases, with list A disorders being TADs by classification. List A diseases are contagious illnesses that have the potential to rapidly and severely proliferate over international boundaries, have significant socioeconomic or health-related implications, and are heavily involved in the global trade of livestock and livestock products.

Foot-and-mouth disease (FMD), ASF, CBPP, RVF, avian influenza (AI), NCD, Classical swine fever (CSF), and PPR are some of the most signicant TADs (Otte et al., 2004; FAO/OIE, 2004) (Table 2.1).

Table 2.1: Major Trans-boundary Animal Diseases

Disease	Animals affected	Regions with major incidence
FMD	Cattle, buffalo, sheep, goats and pigs	Parts of Africa, Middle East and Asia
PPR	Sheep and goats	Africa, Middle East and Asia
CSF	Pigs	South and South-East Asia
ASF	Pigs	Sub-Saharan Africa, West Africa, parts of Europe and Latin America
Blue tongue (BT)	Sheep, cattle	Australia, USA, Africa, Middle East, Asia and Europe
RVF	Sheep, cattle and goats	Africa
CBPP	Cattle	Eastern, Southern and West Africa, parts of Asia
LSD	Cattle	Africa
BSE	Cattle	UK and other parts of Europe
NCD	Poultry	Asia and Africa
Highly pathogenic avian influenza (HPAI)	Poultry	Asia, Europe and Africa

Source: FAO/OIE, 2004

2.9.2 Distribution of major TADs around the globe

Live infected animals and contaminated animal products are the most typical methods for spreading animal diseases to a new area. Other introductions occur as a result of contaminated biological goods, for instance germplasm, vaccines, or as a result of diseased persons entering the country (in case of zoonotic diseases). Diseases could be transported across geographical borders through animal and bird migration, or through natural transmission including veterinary arthropod vectors or wind. Rinderpest (RP) has historically been widespread in Europe, Asia, and Africa, but it has never been seen in North America, Central America, the Caribbean Islands, Australia, or New Zealand. In Mongolia, RP was first formally recorded in 1910, when annual losses were estimated to be at 120,000 cattle and yaks. Europe, Russia, the Middle and Far East, India and Pakistan, Africa, and the Arabian Peninsula have all had rinderpest at some point in the past. With the exception of a single incursion in Brazil, Rinderpest has not been found in any South American country. Throughout most of the twentieth century, rinderpest was a major problem in the territory that became modern-day Pakistan (Roeder and Taylor, 2002).

The OIE declared global rinderpest freedom in May 2011 after rinderpest stopped to circulate in animals. Rinderpest moved from the Indian to the Atlantic Ocean after being introduced into eastern Africa in the late 1800s, causing the first great African rinderpest pandemic. The virus spread quickly along Africa's eastern coast, infecting both domestic and wild grazing animals.It took until 1905 for it to reach southern Africa, which it did in 1896. In the nineteenth and twentieth centuries, rinderpest was still present in Abyssinia (now Ethiopia and Eritrea); however, once public security was restored in Sudan, local trade resumed over the border, and rinderpest became a serious threat to Sudanese livestock.Kenya, Eritrea, and Sudan were all afflicted, with rinderpest viral infection spreading to Uganda, Tanzania, and what is now Rwanda and Burundi on a regular basis, with a noteworthy outbreak emerging in 1920 and lasting in overt form until 1926 on Kenya's Ugandan border. After a serious epidemic in Somalia in 1928, rinderpest was brought under control to some extent by 1930, though it was regularly imported from Abyssinia after that (FAO & OIE, 2011).

A prohibition on the importation of livestock from the Horn of Africa into the entire Arabian Peninsula was imposed as a result of the RVF outbreak in Saudi Arabia in 2001/2002 (Admassu, 2009; Davis, 2006). After significant efforts by local, regional, and global organizations were successful in establishing the necessary capacity for livestock movement, including the essential safeguards against recognized trans-boundary animal diseases (Yehia, 2009).

The CBPP was formerly prevalent all over the world, but by the mid-twentieth century, it had been wiped from most continents. By the 1970s, it was likewise on the decline throughout Africa. The disease resurfaced towards the end of 1980s and early 1990s due to economic and financial challenges that hampered governments' capacity to effectively finance Veterinary Services (Tambi, 2006; Rovid, 2008). Over the last few years, major CBPP infections have occurred in Eastern, Southern, and West Africa. It presently affects 27 African countries at a cost of US $ 2 billion each year (Otte *et al*., 2004).

The FMD is a disease that affects nearly every country on the planet and is caused by a variety of viruses. Outbreaks were detected in Algeria in 1990 and Tunisia in 1989, and the disease was later reported in 21 nations across the region. Vaccination is used to control disease in the majority of these nations, even though suggested control programs call for stamping out, systematic vaccination, or a mix of the two (FAO and OIE, 2011). In Kenya and other parts of the world, FMD is one of the most important endemic TAD. Despite significant progress in controlling FMD in several places, including Europe and South America, outbreaks were reported in Greece, Argentina, Brazil, Korea, and Japan in 2000. (FAO, 2004).

Blue tongue (BT) has a wide geographical distribution, and virological and serological testing have revealed that the virus can be found throughout Africa, portions of Middle East and Asia. The BT virus originated in Africa, with Cyprus experiencing its first outbreak outside the continent in 1943. Since then, reports of BT have been made in Israel, Syria, and Turkey (USAHA, 1992). African horse sickness is a severely fatal viscera-tropic viral disease that infects horses and mules, with subclinical disease affecting other equidae. With outbreaks in north African nations along the Nile Valley and on the continent's west coast, the illness is native to tropical central Africa. There have been notable outbreaks outside of Africa; one of the most prominent took place in the Near and Middle East between 1959 and 1963. Morocco was the site of the most recent outbreak (Geering, 1984).

2.9.3 Distribution of major TADs in Kenya

There are various records in Kenya indicating the occurrence of significant TADs. Notwithstanding the eradication of rinderpest and the control of many other endemic illnesses, important TADs like PPR, CCPP, LSD, CBPP, FMD, NCD, and AHS continue to hinder livestock production and international trade (OIE, 2008). Diseases like PPR, Gumboro, Marek's disease and Maedi-visna, which were uncommon in the country until around 15 years ago, are now widespread among the native cattle and poultry population (FAO/OIE, 2004).

Kenyan livestock are severely affected by CBPP, a highly contagious cow illness that is common in pastoral areas throughout Africa. By impacting animal health, animal food production, accessibility, and quality, transboundary animal diseases like CBPP impose restrictions on the country's livestock industry and have a negative impact on livelihoods. The export of cattle and animal products to foreign markets has long been impeded by CBPP, one of Kenya's major diseases. Pastoral areas produce a substantial percentage of Kenya's cattle and beef meat exports. This area, however, has been affected as a whole for a long time and is an endemic area (Afework, 2000). The CBPP is the most common disease among cattle (Rufael, 2008).

Despite the fact that rinderpest has been eradicated in Kenya, the CBPP continues to stifle trade prospects. Such diseases affect both poor and wealthy livestock farmers by excluding them from higher-priced cattle markets and limiting their ability to engage in value-added trade (FAO, 2002).

Since small ruminants play such an essential role in food security and livelihood resilience, FAO and other development organizations are particularly interested in PPR. Small ruminants give a wide range of products and services to their owners. Throughout the year, they can provide milk, meat, skins, and wool. Peste des petits ruminants (PPR) is a viral disease that is highly contagious and infectious in domestic animals. In 1977, PPR was suspected of being present in goat herds in the Afar region of Eastern Ethiopia based on clinical evidence. The existence of the virus in lymph nodes and spleen tissues collected from an epidemic in a holding land near Addis Ababa was only confirmed in 1991 with a cDNA probe (Pegram *et al.,* 1981). The illness was most likely brought into

Kenya in 1989 in the Southern Omo River basin, from where it spread eastward to the Borena region, then northward along the Rift Valley to Awash (Roeder *et al*., 1994).

The LSD is a new viral illness that is wreaking havoc on the cattle industry. The LSD is endemic in the majority of African nations, and has lately extended to the Middle East. The disease is one of the most serious viral diseases of cattle, causing loss of condition in infected animals and permanent damage to hides. The LSD is a pox disease of cattle that is characterized by fever and nodules on the skin. It was originally discovered in Kenya in 1983 in the country's northwestern region (southwest of Lake Tana). The illness has now spread to practically all of the country's provinces and agro-ecological zones. Because of the disease's extensive prevalence and the size and structure of Kenya's cattle herd, LSD is anticipated to be one of the animal diseases of most economic importance (Gari *et al.,* 2011).

The Food and Agricultural Organization and World Reference Laboratory (FAO/WRL) were the first to report FMD outbreaks in Kenya, indicating that FMD serotypes O, A, and C were responsible for outbreaks between 1957 and 1979. The incidence of FMD outbreaks has increased by 1.3-1.5 times since 1990 (GOK, 2015)**.** The increased occurrence of the disease in recent years has been attributed to extensive cattle movement, a high rate of animal contact at commercial markets, community grazing areas, and watering stations, among other factors. FMD is endemic in Kenya and is well-known for its extensive distribution, however its frequency radically differs among the nation's diverse agricultural systems and ecological zones. The disease is widespread, and it used to be common in the country's pastoral herds. The widespread mobility of livestock, as well as the high rate of animal contact at commercial marketplaces, communal grazing areas, and watering sites, are unquestionably the main reasons of FMD transmission in Kenya (Sahle *et al.,* 2003).

2.9.4 Trade and economic impacts of TADs

There is no question that extensive livestock movement, high animal contact rates at commercial markets, in shared grazing areas, and at watering spots are contributing factors for the spread of FMD in Kenya (Sahle *et al.,* 2003). FMD caused more than USD 500 million in lost feed sales in Asia in 1996; chronic CBPP and ASF continue to inflict significant economic damage to livestock producers in Sub-Saharan Africa. TADs have different effects based on the severity of the disease, the number of animals in danger, the reliance on livestock for a living, and the method of control (Otte *et al*., 2004).

PPR's socioeconomic relevance is influenced by significant production-level losses as well as market effects across the value chain. It is estimated that trade and public expenditure account for 10% of the disease's total impact, while herd productivity accounts for 90% (DFID, 2001-2002). A 1979 outbreak in Nigeria resulted in the death of 10–20% of the nation's small ruminant herd, which was worth $75 million (Wakhusama et al., 2011). Based on an average of 143 small ruminants per flock (a loss of more than US$ 2 per animal), the FAO projected that PPR losses in Kenya were US$ 375 per flock per year (Wakhusama et al., 2011). They lessen output on a clinical and subclinical level. They cause production losses such as lower weight gains, stunted growth, decreased output of milk and meat, higher veterinary costs, and mortalities, especially among younger animals (Swai et al., 2009).

Kenya's animal and animal products export trade with nations in the Middle East and North Africa (MENA) is a significant source of revenues. Rinderpest was mostly found in pastoral areas of Africa, where livestock value chains are distributed over wide distances and a plethora of informal sector actors and market transactions exist. The consequence is that rinderpest's market effects are likely to be complex and nuanced, affecting a wide range of tiny, low-income informal service providers. The prevalence of Rift Valley fever in neighboring nations, as well as the broad development of FMD in the country, are posing a threat to trade. A prohibition on the importation of livestock from the Horn of Africa into the entire Arabian Peninsula was imposed as a result of the RVF outbreak in Saudi Arabia in 2001/2002 (Admassu, 2009; Davis, 2006). Later, significant efforts by local, regional, and global organizations were successful in establishing the necessary capacity for livestock movement, including the essential safeguards against recognized trans-boundary animal diseases (Yehia, 2009).

2.9.5 Approaches on prevention and control of TADs

Livestock diseases that cross borders pose a severe threat to world livestock production and nutritional security, as well as international trade. Significant TAD outbreaks including FMD, Classical swine fever, Rinderpest, PPR, and RVF have devastated economies throughout the world. The World Organization for Animal Health (OIE, Office Internationale des Epizooties) and the Food and Agricultural Organization (FAO) have come up with programmes and actions aimed at addressing the management and control of TADs and other emerging animal diseases. WHO is an important partner in the GF-TADs program, and will collaborate with FAO and OIE to build a shared disease information system to keep the worldwide community informed about the threat of infectious disease outbreaks. The success of the implementation of epidemic disease control programs is dependent on the success of regional organizations. Disease reporting is required by the OIE for all member nations (Domenech *et al*., 2006).

The entire goal of veterinary services is to safeguard livestock against diseases so that the livestock resource's health and production levels are dependably preserved, and the social and economic losses they cause is successfully lowered. The ultimate goal of any disease control program should be specified from the start for every disease that exists in a nation. Eradication has long been the aim of all disease management programs, it is often not possible to achieve in a fair period or at a reasonable cost. Eradication may not be economically or physically viable for some illnesses, particularly TADs, and strategies for long-term disease mitigation may be required (Leslie and McLeod, 2000).

The basic goals of any TADs control program are to determine the 'ideal' degree of disease incidence to achieve a nation's objectives, and then to determine the most affordable means to accomplish that desired degree of containment. A policy on disease free status, for example, is a high threshold that might come at a considerable cost to a country. The 'ideal' level of control varies by country and depends on the findings of the investigation, and it changes over time as production methods and control alternatives evolve. Both the originating and the receipient nations bear main responsibility for preventing the spread of animal disease. Both are burdened by complex quarantine procedures, alongside the threat of decreased productivity and more serious if introductions happen. When a human activity, like trade or travel, or natural transmission, can bring an organism into a location that had not previously been affected, the bulk of control methods are directed at averting its admission and/or proliferation (Leslie and McLeod, 2000).

When and wherever possible, prevention is considered the greatest method for stopping the spread of disease. Some diseases, however, are difficult to prevent because their route of spread is unclear or impossible to regulate. Despite the fact that there seems to be some control and checking for International Veterinary Certificates and International Sanitary Certificates at international borders to prevent the spread of exotic diseases, the potential for illegal entry of animals and animal products across the country's extensive borders remains high. Ideally for the time being, border surveillance for TADs is lacking in this big, mountainous country (Domenech et al., 2006).

When animal movement control is utilized as one of the pillars of an efficient TAD management strategy, it ought to be used with extreme caution and rigor (Calkins and Scasta, 2020). For the foreseeable future, the mainstay of disease prevention and control in Kenya will be implementing quarantine procedures any time a TAD of domestic or foreign origin occurs, as well as ring vaccination backed by other sanitary and bio-security initiatives. This implies the need for emergency preparation and readiness to deal with such situations. As a result, Kenya Veterinary Vaccines Production Institute (KEVEVAPI) is in charge of generating the majority of animal disease vaccines required in an emergency and for regular local use, as well as having the capacity to produce surplus for export.

Prophylaxis is still the most common method of disease prevention in Kenya, but chemoprophylaxis and chemotherapy play a larger role. While the National Government plans and coordinates control programmes for certain diseases with the assistance and backing of Regional Veterinary Investigation Laboratories (VILs), the majority of livestock diseases along with other veterinary issues management are carried out by the County Governments with disease control activities that are locally planned and executed (Gulima, 2010).

2.9.6 Regional and international organizations and the prevention and control of TADs

Disease control programs are the most effective means of reducing the prevalence and incidence of diseases, as well as eradicating them. The regional strategy to animal disease control can be broken down into two primary steps: The creation of veterinary system capacities including a quarantine-based defensive system, swift lab diagnosis, epidemio surveillance as well as data systems as a whole, and emergency preparation and readiness that can mobilize resources quickly and effectively. The second is the Control programs that affect one or more sub-regions and include one or more diseases. According to the information contained in the various national reports, the region can be regarded as one of the world's most vulnerable locations in terms of animal health. In addition, the regional method combats diseases in clusters of nations with similar geographic, epidemiological, economic, social, and political characteristics. The Regional Strategy for Animal Disease Control (RESCAD) is an example of a regional approach to preventing, controlling, and/or eradicating major infectious and epizootic diseases, and various other veterinary diseases that have significant economic effect in the Near and Middle East Region (NEMER) countries (Domenech et al., 2006). The animal health and livestock network of the South African Development Community (SADC), the Mediterranean Animal Health Network, the Caribbean Animal Health Network, the African Union-InterAfrican Bureau of Animal Resources (AU-IBAR), and others are regional networks that take a unique approach to TAD control and livestock development in their respective regions (FAO, 2011).

The OIE was established in 1924, long before the United Nations was established. One of the primary goals of both the OIE and the FAO is to prevent the transmission of livestock illnesses and zoonotic diseases through international movements. The OIE aims to achieve this through defining international standards and guidelines targeted at limiting the import of infections which are harmful to livestock and people and by monitoring, notifying, and controlling disease outbreaks. The OIE and FAO in 2004 launched a project, the Global Framework for the Progressive Control of TADs (GF-TADs), centred on an international approach to the control of veterinary diseases (FAO/OIE, 2004), to improve the control of highly contagious diseases.

FAO carries out an international mission in animal production and health, particularly in the management of TADs like FMD and rinderpest eradication. In addition, the FAO also assumed leadership in influenza field initiatives, granting emergency money for the control of HPAI in afflicted countries. Under the GF-TADs, FAO and OIE formed a formal partnership to combat significant trans-boundary animal diseases. The OIE is also responsible for establishing standards and norms, providing expertise, and promoting international cooperation in the fight against animal diseases. It also collaborates with the Codex Alimentarius committee to ensure animal production food safety. The World Health Organization (WHO) is a key collaborator in designing and implementation of disease control policies to protect both public health and the animal industry (FAO/OIE, 2004).

2.9.7 Policy and institutional framework for prevention and control of TADs

The GF-TADs is a collaborative OIE and FAO program that brings together the strengths of both organizations to accomplish more than could be accomplished through individual initiatives. GF-TADs serves as a facilitation mechanism designed to help nations and clusters of countries battle TADs by providing building capacity and assisting in the development of programs for the targeted management of specific TADs based on regional priorities. The GF-TADs will rely on strong international, regional, and national institutional relationships to enable the essential action, which will be facilitated by Regional Support Units (RSU) in relevant authorities. The OIE is the world's animal health observatory. The FAO is on board with this mission. Its primary goal is to keep county’s veterinary agencies and international organizations notified about the emergence and progression of epizootics wherever they occur. The approach is based on official veterinary reports that Member Countries' Animal Health Agencies are required to submit to the OIE (OIE, 2008).

The OIE creates guidelines for its Member States to adopt in order to prevent disease outbreaks caused by trade in animals and animal products whilst eliminating unjustifiable sanitary obstacles. Experts from OIE network and member nations establish these standards. Member countries' veterinary services are required to provide reports to the OIE. The adoption of standardized reporting templates guarantees that the relevant data is entered into the system in a consistent fashion (OIE, 2008).

According to the FAO/OIE (2004), Kenya's animal health and food safety rules and regulations are obsolete. The introduction and spread of TADs in the country, such as Marke's, Maedi-Visna, and others, highlights the need for new and revised rules to protect the country's livestock resources from exotic diseases. Kenyan legislation must also be aligned with international norms and take into account existing levels of disease prevention, control, and eradication. Harmonization of laws and regulations will help the country's negotiating leverage and reduce trade obstacles. The Veterinary Services Directorate is working to update and enact Kenyan animal health rules and regulations so as to stimulate the export of livestock and livestock products.

If the main goal is to enhance livestock exports, the utility of further investments in the management of TADs is disputed. However, despite a significant rise in exports, there was no significant change in the management of other TADs including FMD, which remains prevalent in Kenya. This suggests that Kenya's key trading partners have tolerated the illness risk posed by live animal and meat exports so far. If this is the case, an economic study is required to demonstrate the increased value that improved TADs management could provide. The review must also evaluate Kenya's competitiveness and the extent to which, even with tighter TADs controls, the country will be able to maintain access to new markets (Scoones and Wolmer, 2008).

2.9.8 Surveillance and monitoring of TADs

Surveillance of livestock diseases is an essential strategy in the control of animal diseases. Disease surveillance, as previously said, is one of the crucial facets of public health. In most nations, pastoralists' natural reaction to an infectious disease is to remove apparently healthy animals from affected regions and secure them elsewhere. The ultimate goal of livestock disease surveillance is intended to assist a country's disease control plan in order to preserve livestock, the economy, the environment, and the country's public health. The primary goal of livestock disease surveillance is to improve the likelihood of detecting significant changes in cattle health early (Christopher *et al*., 2002; Peninah *et al.*, 2010).

A robust surveillance is required to assist member states to meet their commitments to the OIE for the timely provision of up-to-date status of animal health. Any of the following events must be reported to the OIE within 24 hours through the World Animal Health Information System (WAHIS): The initial case of a listed disease in a nation, the reoccurrence of a listed disease in a nation after a report declared the outbreak to be over, a sudden and unforeseen rise in the distribution, incidence, morbidity, or mortality of a listed disease common in a nation, a new disease with substantial morbidity or mortality, or zoonotic potential, and evidence of change in the epidemiology of a listed disease (including host range, pathogenicity, and strain) in particular (OIE, 2011).

The development and maintenance of an appropriate quarantine and border security system, which is the first line of defense for keeping exotic and emerging diseases out, requires the formation of an effective and efficient surveillance system. In Kenya, several actors are active in animal health surveillance. The Epidemiology and Disease Control Unit of the Directorate of Veterinary Services (DVS), as well as the Kenya Tsetse and Trypanosomiasis Eradication Campaign (KENTTEC), are the major actors at the national level. Regional veterinary investigation laboratories (RVIL) are the main actors in surveillance activities at the regional level, and they are charged with collecting, collating, and reporting information on their activities and the state of animal health to the DVS, County Directorate of Veterinary Services (CDVS), and others who require this information. RVIL are also charged with conducting surveillance and diagnostic activities in their respective regions.

2.9.9 FMD prevention and control

In Africa, Asia, and portions of South America, FMD is a highly infectious TAD that affects livestock and wildlife. In Kenya and other parts of the world, it is among the most important endemic TAD with both social and economic implications. It has resulted in significant financial losses in the production of susceptible cloven-hoofed animals. The FMD virus (FMDV) has seven serotypes: O, A, C, SAT1, SAT 2, SAT 3, and Asia 1. FMD outbreaks in these disease-endemic regions continue to pose a threat to cattle sectors in countries where the disease is not present (with or without vaccination). FMD, a disease on the OIE list A, is a major impediment to international trade in live livestock and livestock products. Two-thirds of OIE member states have reported the disease. Millions of animals in Europe, Asia, and Africa (for instance, the United Kingdom, Taiwan, South Africa, as well as Zimbabwe) were afflicted by recent FMD outbreaks (2000–2003). (Vosloo *et al*., 2002).

FMD is very common in Africa. Many African countries, on the other hand, give FMD a low priority, resulting in underreporting of outbreaks to the OIE. Six of the seven FMD virus serotypes are found in Africa, with three of them (SAT 1, 2, and 3) being unique to the continent. They are mostly present in southern Africa and are linked to the African buffalo (*Syncerus caffer*), which serves as an infection host for domestic animals (Sutmoller *et al*., 2000).

FMD is very common and used to occur regularly in pastoral herds, endangering the livelihood of these communities that rely on their animals for survival. FMD virus transmission is most typically transmitted through direct physical contact between acutely infected and vulnerable animals, which generally occurs after animals are moved. The respiratory route is thought to be the predominant route of infection in ruminants. In FMD-endemic nations, however, both the respiratory and oral pathways play a significant role. Small ruminants are primarily infected silently or clinically undetectable, and they play a crucial role in the epidemiology and spread of FMD to cattle, as seen in Greece in 1994, South East Asia in 1999, Turkey in 2001, and the United Kingdom and Ireland in 2001. (Uppal, 2006).

Aside from live animals, FMD viral transmission could be aided by the export of untreated meat and meat products, milk, and sperm from infected animals. The virus lives for several weeks in contaminated hay or straw, which is the most common indirect transmission pathway. FMD can potentially spread through the air under certain climatic and epidemiological conditions. The aerial pathway is favored by high relative humidity, low temperature, large clinical cases, and wind. Despite the broad prevalence of FMD, clinical and analytical investigations on the virus's characteristics have never been comprehensive. Over the last ten years, four of the six serotypes established in Sub-Saharan Africa (A, O, C, and SAT 2) have been found in Kenya (Sahle, 2003).

Many countries have successfully managed this disease by implementing tactics such as forced vaccination of susceptible animals and the slaughter of afflicted animals. However, because of the virus's extremely contagious nature and the increased international traffic of livestock and livestock products, no country has been declared safe. FMD is important not just for the home market, but also for international agricultural trade, due to its ease of transmission between animals. Infected countries are frequently subjected to stringent sanctions imposed by their business partners: Importing countries frequently impose trade restrictions, like import bans, on any nation with outbreak of diseases to reduce the danger of bringing the disease into their domestic herds. These approaches are backed up by the OIE international control and eradication regulations and procedures (Sahle, 2003).

2.9.10 Challenges for prevention and control TADs

TADs-fighting techniques have a number of obstacles. Inadequate or non-existent vaccines obstruct disease control programs, as does the lack of cost-effective intervention or disease control measures. Many farmers are completely unaware of the new diseases that have emerged. Inadequate harmonization of control programs, political instability in some bordering countries, insufficient human, physical, and financial resources, low public knowledge, and poor participation of livestock owners in disease control are all problems in the prevention and control of TADs (Hitchcock *et al*., 2007; FAO, 2008).

The control of rinderpest in the 1940s was severely hampered by a number of limitations, many of which are listed below: Farmers and pastoralists understood a lot about the disease, but they didn't know much about the usefulness of vaccination in controlling and eventually eradicating it. They thought the immunization caused cattle to have abortions, have lower milk yields, become unwell, and die. In Ethiopia, people had the view that the sickness was brought on by an evil spirit known as Zara, and that if cattle were vaccinated, Zara would become enraged and slaughter all of their livestock. As a result, livestock owners used to leave at home healthy animals and bring only the malnourished ones, believing that even if they died, it would not be a big deal. The second problem is that vaccination teams couldn't finish their work in a timely manner, primarily because there were no modern information and communication technologies or skills available at the time to inform, agitate, and raise awareness among livestock farmers so as to influence their opinions and misconceptions about the value of the vaccination campaign (Wondwosen, 2003).

Controlling trans-boundary animal diseases (TADs) like PPR presents a number of issues that must be tackled in a methodical manner. Small ruminant production is one of the most difficult aspects of PPR control. Sheep and goats are frequently common underserved vast production systems and by persons with limited access to services, such as women and pastoralists. Small ruminants are frequently the most valuable item for these folks. Small ruminant lobbies often lack political will or resources at the national level, limiting the attention allocated to PPR. Another problem in sheep and goats production is shorter reproductive cycle, which causes farmers to resist investing in animal health or vaccines because there appears to be no major return on such an investment when compared to large ruminants (FAO, 2012).

2.10 Livestock pests and diseases in the dry lands of Northern Kenya

Spread of veterinary diseases is among the factors that impedes pastoral livelihood development after droughts. The occurrence of droughts and floods in this area further exacerbates the situation (Lelenguyah *et al.,* 2014). Proliferation of livestock diseases especially the emerging ones is therefore complicated by the changing climatic patterns resulting from climate change. Livestock that goes through the drought season are usually emaciated, weakened and poorly prepared for the challenges that come with the rainy seasons that follows droughts.

In Samburu, like in other Counties in Northern Kenya, important diseases of the cattle are prevalent. For instance, FMD which occurs during dry spell, ECF occurring during the wet periods and Trypanosomosis that occurs throughout the year (CDVS, 2015). For sheep and goats, PPR is one of the most prevalent diseases besides Foot rot and Heartwater, Helminthesis. LSD, CCPP, Mange, Bluetongue, CCPP and Enterotoxaemia are other most important diseases (CDVS, 2015). Camels on the other hand are affected by Surra, mange and Orf in both pastoral and agro-pastoral areas of Samburu County.

Pests and diseases mentioned above occur in different seasons of the year and greatly increases mortality, morbidity, and reduces productivity of the affected population. As a consequence, some diseases like RVF and FMD affects off-take of livestock and livestock products because of closure of markets, movement of animals is restricted during such periods through veterinary quarantine measures which restricts movement of animals.

The disease environment in ASALs should be considered in the context of increasing livestock productivity to make investing in its sustainability worthwhile. Whereas the use of indigenous traditional knowledge to control disease needs to be encouraged, strategic mass vaccinations against common livestock diseases and use of anti-helminthics would greatly increase survival rates for these animals. Benefits from vaccinations is usually enormous considering that most vaccines protects the animals against the targeted diseases for between 3 to 6 months, however animal health workers (disease reporters) should be encouraged to report any suspected cases of outbreaks (Catley *et al.*, 2005). Routine vaccinations and deworming should also include regular cost-effective animal health programmes for early detection and treatment of livestock diseases.

2.11 Effects of climate variability on livestock diseases

Livestock disease incidences and their spatial and temporal distribution is closely interrelated with climate variability and change. Worst of the effects of climatic change will be on spread of diseases and is expected to occur at temperature extremes that favor the survival of pathogens and lies between 14-18 ^{o}C and 35 ^{o}C - 40 ^{o}C for lower and upper limits respectively (Githeko *et al.*, 2000). Apart from the effects of variation of temperatures on the biology and ecology of disease causing and transmitting agents, variable precipitation patterns will affect vectors habitats both in the shorter and longer time intervals. Increasing rainfall trends as a result of climate change will affect breeding habitats for vectors such as tsetse flies, ticks and mosquitoes while at the same time impacting on vegetation that are used as resting sites by most of these vectors (Githeko *et al*., 2000; Nguku *et al*., 2010). Temperature is known to affect both the distribution and the rate at which pathogens could be transmitted by disease vector (Hunter, 2003). Gubler *et al.* (2001) outlined the various ways where temperature as well as precipitation changes can affect the spread of diseases transmitted by vectors (Table 2.2).

Table 2.2: Effects of temperature and precipitation on disease vectors

Impacts of Temperature	Impacts of Rainfall
i. Increasing or decreasing vectors survivability. ii. Alterations in dietary habits. iii. Alterations in the pace of expansion of the vector population. iv. Changes in the vector's susceptibility to infections. v. Alteration in pathogens incubating period. vi. Alteration in patterns of vectors activities.	i. Increasing breeding sites as a result of flooding. ii. Reduced rainfall slows flow of river further increasing breeding. iii. Increased rain enhances vegetation growth encouraging in-migration of vertebrate host. iv. Flooding can also cause destruction of habitats for both vectors and hosts. v. Flooding can lead to vertebrate hosts coming close to people further increasing infections.

Source: Gubler *et al.* (2001)

The Kenya veterinary policy (GOK, 2015) indicates that droughts and floods disasters leads to displacement of people and further exacerbates the spread of human and animal diseases caused by vectors, as well as notifiable diseases like FMD, RVF, Bluetongue and LSD. The erosions brought about by droughts and floods further causes environmental instability of the rangeland environments.

2.12 Effects of Herd Mobility on Livestock diseases

Many factors contributes to spreading, persistence and spatio-temporal distribution of livestock diseases as well as zoonotic diseases, and the potential of the pathogens to circulate and further infect other animals is increased by herd mobility and trade channels for livestock and livestock products (Calkins and Scasta, 2020).

The potential of livestock diseases spreading is strongly correlated to increasing mobility of livestock, inadequate disease surveillance, treatment and management and conflict status of the affected area. Risk levels are also closely related to the distribution of disease zones within a County or the Country in general. The herd mobility exposes livestock to new infections from the animals that are encountered during this process (Bouslikhane, 2015). At the same time, these livestock may be carrying other pathogens from other areas thus causing new infections. This creates a vicious cycle of infections. This means that all the pastoralists and their herds have a role to play in the spread of livestock diseases during droughts when they all meet in the same grazing fields from various Counties despite the differences in the epidemiological status of these Counties.
TADs are defined as "highly contagious epidemic diseases that can spread extremely rapidly, irrespective of national borders, and may have serious socio-economic and public health consequences" (FAO, 2019). There are also heavy economic losses resulting from livestock deaths and infections and the costs incurred in the control of these diseases. Outbreaks of most of these diseases raise concerns and in their case herd mobility has to be restricted through quarantines. For large livestock, these include FMD, CBPP, and RVF (Calkins and Scasta, 2020).

The Veterinary Services often have to contend with its own challenges including inadequate human capital, financial challenges and ineffective regulations that are required to promote disease control interventions. These challenges have negatively affected livestock disease surveillance, detection and results dissemination performance, livestock vaccination coverage for all the affected areas and sanitary controls at the border points for livestock, livestock products and quarantine (Bayissa et al., 2009).

These challenges have been further complicated by non-involvement of the private sector in disease control efforts. This is despite the fact that a lot of reforms have been put in place to improve the situation. There is also very little participation by the pastoralists in disease control efforts through sharing of the cost of livestock vaccination activities (Bayissa et al., 2009).

At the regional front, governments are also supposed to be blamed for their lack of support and commitments to regional approach to control of livestock diseases. There's total lack of participation by governments in the joint, harmonised and synchronised control strategies for livestock diseases (Bayissa et al., 2009). For example, CBPP vaccination has usually been offered free of charge in Kenya and Tanzania, but in Uganda, the government meets half the cost and the other cost is met by livestock owners.

Finally, it is important to note that during herd mobility, the rough terrain and the inadequate livestock disease control infrastructure (drug outlets, crushes, dips, veterinary clinics, etc.) makes pastoralists to start using herbal or ethno veterinary treatments whose effectiveness cannot be assured. Further complicating the situation is the use of cheap counterfeit drugs for the control of diseases which might lead to disease resistance and this worsens the situation.

2.13 Small stock Diseases and Herd Mobility in Kenya Rangelands

Sheep and goats comprise a great component of livestock assets in pastoral communities residing in arid and semiarid parts of Samburu County. This asset is crucial in supporting pastoral livelihoods and contributes greatly to food security among pastoral and agro-pastoral communities within Samburu County. However, given the extensive production system practiced in the rangelands characterized by extensive livestock migration, coupled with weak disease control initiatives, this critical asset is under threat from a myriad of TADs such as CCPP, SGP, PPR among others. Specifically, PPR is a prevalent, deadly disease that affects sheep and goats. Considering the socio-economic effect the disease has on livelihoods and food security, PPR and CCPP are thus considered as the most damaging of all sheep and goat diseases in Samburu county as well as other Counties (Bett el al 2008; Chengula et al., 2013). Both state and non-state actors recognize the need to protect this key asset through sustained disease control initiatives both in the short term and the long term. Towards achieving this end, a global strategy for eradication of PPR has been developed. However, the advent of devolution of veterinary services has resulted in different strategies in the control of livestock diseases resulting in different outcomes.

2.13.1 Contagious caprine pleuropneumonia (CCPP)

The CCPP affects goats and causes serious economic losses to the pastoralists in African Countries (Chengula *et al*., 2013). It especially affects Countries north of the Equator in Kenya and Sudan. It is caused by mycoplasma strain F38 (Bett *et al*., 2008). Treatment of this disease is mainly done with tylosin or oxytetracycline which either alleviates the condition or to some extend effects a complete cure. The disease develops rapidly and therefore any intervention must be done early enough to curb the development of the massive lung lesions.

2.13.2 Peste des petits ruminants (PPR)

PPR is a viral disease that can either be acute or sub-acute. It mainly affects goats and sheep and its characteristics includes fever, stomatitis and gastro-enteritis and pneumonia. PPR has been identified as the most destructive viral disease among the small stock with the youngest animals being the most vulnerable. It is also a major obstacle towards the production of small ruminant among the pastoral communities. Its effects can be more devastating especially when the small stock are affected by a combination of other diseases and disorders. It is estimated that the 2008 PPR outbreak in Kenya cost the government approximately 4.8 million Euro through vaccination carried out against the disease (AU-IBAR, 2009). According to Government of Kenya departmental reports, the existing and emerging diseases that destroys the Country's livestock assets requires to be contained to allow livestock production to prosper. If this is achieved, livestock can be used as a means for poverty alleviation and enhancement of food security. PPR is widespread in Kenya and affects Lamu, Taita Taveta, Garissa, Kitui, Machakos, Mwingi, Tharaka Nithi, Meru, Narok, Laikipia, Tana River, Kajiado, Trans Nzoia, Makueni, Elgeyo Marakwet, and Isiolo Counties (GOK, 2010). PPR is among the livestock diseases that is spread through herd mobility and cross-border trade in small ruminants between Counties and Countries. The transmission of the disease is through direct contact between the animals involving secretions or excretions from the infected animal to the surrounding healthy animals. Since PPR vaccination is very effective, then we can conclude that proper targeting of vaccination against this disease can lead to its eradication throughout the World, just the same way rinderpest was eradicated.

2.14 Access to Veterinary Services in the Dry lands of Kenya

Studies in pastoral and agro-pastoral areas have shown that the delivery of livestock health services for instance de-worming, antibiotics, multi-vitamins and vaccinations enhances the survival of animals for longer durations from the impacts of droughts and cushion pastoralists against major livestock losses resulting from reduction of pasture and water availability (Aklilu and Wekesa, 2001). The Actual situation on the ground, is however different resulting from inadequate or lack of livestock health services in the pastoral and agro-pastoral areas of East Africa. Most of the animal health services in this region are located and can only be accessed in towns, shopping centres and in some major livestock markets and do not reach the rural farmers. Such unavailability of animal health services has led pastoralists to depend mainly on herbal medicine whose effectiveness has in treatment cannot be guaranteed. For livestock treatment cases, pastoralists mostly consult fellow herders on what drugs to use. Limited animal health services also affected the adoption of emerging technologies by the pastoralists and more often led to massive losses of livestock during major droughts or outbreaks of livestock diseases. The existing situation demands a review of the approach used for disease control in order to ensure that pastoralists' livelihoods are safeguarded against climatic variability and livestock disease epidemics.

Currently, self-diagnoses and self-medication are available in Kenya (Lamuka et al. 2017), along with veterinarians, livestock health assistants (paraprofessionals), retailers and vendors in the market, ethnoveterinary professionals, and herbalists (Heffernan and Misturelli 2002). Stores, mostly agrovet stores but sometimes regular shops, sell a variety of agricultural items and are mostly privately owned (Higham *et al.,* 2016). For a number of years, Community Animal Health Workers (CAHWs) and animal health assistants (AHAs) had the opportunity to offer private services (Rubyogo *et al.,* 2005). Despite research findings from the second half of the 1990s suggesting that privatized network of AHAs associated with CAHWs were the most commercially viable strategy for delivering viable first-line clinical services in Kenya (Okwiri *et al.,* 2001), CAHWs were dismantled in 2012. Government regulatory bodies claimed that CAHWs could not be incorporated into the prevailing technical, legal, and policy arrangement (Mugunieri *et al.,* 2004).

Livestock diseases remain the most significant productivity limitation in Kenya's pastoral areas (Onono *et al*., 2013), and the privatization of livestock health has left a void that hasn’t been filled. Given their remoteness, few qualified veterinarians are prepared to serve in pastoral areas with high animal populations (Lamuka *et al.,* 2017). Additionally, barriers like the transhumant or nomadic lifestyle of pastoralists (which causes variations in time and space in demand), the monetary unviability of the private industry's offering of livestock health products and services as a result of the significant travel expenses associated with serving pastoral animals owners, as well as poor infrastructure that results in high delivery costs (Ilukor 2014; Lamuka et al. 2017) discourage individuals from investing in the offering of livestock health supplies and services among pastoralists. Self-diagnosing and treatments have thus become commonplace, potentially leading to improper drug usage (Lamuka et al. 2017) and, as a result, antimicrobial resistance issues in other situations high antimicrobial use, low levels of professional consultation, and absence of withdrawal, all of which may affect resistance (Caudell *et al*. 2017).

Innovative approaches are required to promote pastoralists' access to and usage of livestock health services due to the fact that this practice increases household economic prosperity (Marsh et al. 2016). In order to ascertain whether lucrative private animal health services might be established in ASALs and to identify the circumstances (rules or regulations) that would increase its sustainability, mobile veterinarian clinics were initially tested in three ASAL counties in Kenya. In order to establish routine and scheduled clinical veterinary visits through areas with a high concentration of livestock, such as markets, watering holes, and grazing areas (taking livestock migration into consideration), veterinarians who provide animal health products and services partnered with private sector agrovets. This test case remains a gap as no results have been reported.

2.15 Impacts of Climate Change on Pastoral and Agro-pastoral Livelihoods

Climate variability and change, by negatively impacting on the key economic areas including the agricultural sector, water, energy and healthcare, presents overwhelming challenges to efforts aimed at poverty reduction and achievement of the Millenium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) in Kenya and the region at large. Therefore, there's need to understand the inter-connection between climate change and various livelihood systems. As a first step towards this, the relationship between climate variability and change and livestock production systems, particularly among the pastoralists needs first to be established.

The people who are worst affected by the impacts of climate change in Kenya are those that mainly rely on crop production as their livelihood source. In 1990, approximately 7 million people in Kenya were said to living in food poverty (Downing, 1992). The figure has over the recent past gone up to approximately 50% of the Country's total population in Kenya. This is expected to continue rising as long as the population keeps on rising while the economic growth rate remains at less than 10%. The continued change in climate will further complicate the situation, and lead to increased socio-economic issues in Kenya.

According to Downing (1992), climate change would result in a decrease in both farmed and appropriate regions, which would greatly increase the population of people lacking access to enough food. This is considered to be the most probable situation for Kenya, especially in the outlying regions. The seven users-groups listed below are those that Downing (1992) determined are most likely to suffer adverse effects from climatic changes in Kenya:

i) Nomadic pastoralists who don't practice crop production - 85% food risk;
ii) Agro-pastoralist who grow few crops - 33% food risk;
iii) Migrant farmers who have permanent farmlands and keep livestock - 55% food risk;
iv) Landless people – farmers who have little or no land at all and are perpetually food-insecure (85% food risk);
v) Squatters who occupy large lands with no legal claim to the land - 33% food risk;
vi) Smallholders (those that own less than 20 hectares), accounting for 50% of the farming population in each County - 29% food risk; and
vii) Urban-poor – those who live in major towns and only depend on casual labour - 40% food risk.

The projected shortening of the growing season for crops will lead to increased number of vulnerable people due to a general reduction of the capacity to produce enough food quantities and varieties. Land suitability for different crop regimes will also be affected by climate change thereby leading to a reduction in agricultural productivity hence reducing the availability of food. For example, certain Counties in Western, Rift Valley and Central regions which currently supports production of major food crops including maize and beans may end up changing to cash crops. This significant change might jeopardize the nation's food security. Nevertheless, the magnitude of such changes in production and the scale of its impacts will also be dependent on other factors other than climate change.

2.16 Strategies and Policies affecting Pastoralism

Kenya's National Climate Change Response Strategy (NCCRS) was introduced in 2010 (GoK, 2010). The implications of climate change on national development were not fully documented in Kenya's Vision 2030. The NCCRS recognizes the threat that climate change poses to long-term development and promotes for the incorporation of climate change data into government policies at the national level. Kenya's first climate change action plan, the National Climate Change Action Plan (NCCAP), was launched in 2013 (and was to run until 2017). It was created with the intention of implementing the NCCRS. Its goal is to help Kenya lower its vulnerability to climate change and strengthen the country's ability to capitalize on the opportunities presented by climate change. Agroforestry, conservation tillage, the limited use of fire in agricultural regions, the growth of drought-tolerant crops, water collection, and integrated soil fertility management are some of the noteworthy farming practices highlighted in the Action Plan. Climate change-related information, index-based insurance schemes, agricultural consulting services, and capacity development all play a crucial role in ensuring that choices for tackling climate change are broadly understood, according to the Action Plan. The goal is to construct a low-carbon, climate-resilient development path that contributes to Vision 2030, which seeks to convert Kenya into a newly industrializing, middle-income country that provides a good quality of living to all of its residents in a clean and secure environment. The Ministry of Environment and Natural Resources (MENR) is in charge of ministerial-level climate change coordination as the coordinating ministry for all environmental matters. To improve this function and monitor the technical development and implementation of the NCCRS and NCCAP, the ministry has formed a Climate Change Secretariat.

Kenya ratified both the UN Convention on Biological Diversity (CBD) and the UN Convention to Combat Desertification (CCD), for which it developed a Biological Diversity National Strategy and a National Plan of Action to Combat Desertification. Kenya has also ratified the United Nations Framework Convention on Climate Change (UNFCCC) as well as the Kyoto Protocol. The Paris Deal was signed in April 2016 and ratified in December 2016, with the agreement going into force in January 2017. The country has been a regular attendee at the Conferences of the Parties (COP) and in 2010 joined the Copenhagen Accord. It filed its Initial National Communication to the UNFCCC in 2002, and as part of the Initial National Communication, it completed its Greenhouse Gas (GHG) inventory. For agriculture, water, aquatic and marine resources, energy, health, and the social economic backdrop in general, the Initial National Communication outlined mitigation alternatives as well as important sector vulnerability and adaptation issues. In 2015, a second national communication was submitted, which contained an update to its GHG inventory and highlighted the potential for emissions reduction through agroforestry and forest restoration.

Kenya is one of only nine countries to submit a National Adaptation Plan (NAP) (GoK, 2016) to the United Nations Framework Convention on Climate Change (UNFCCC). The NAP builds on the NCCRS and NCCAP foundations and serves as the framework for Kenya's adaptation component of its Nationally Determined Contribution (NDC). To improve long-term resilience and adaptable capability, the NAP consolidates the country's vision on adaptation, which is backed by macro-level adaptation measures that correspond to economic sectors and county-level vulnerabilities. It recommends macro-level adaptation actions and sub-actions in 20 planning sectors, dividing them into three time frames: short, medium, and long. The NAP identifies gaps in each sector, assesses the costs of macro-level actions anticipated to 2030, and identifies key institutions needed to accomplish them. The third Medium Term Plan is planned to include prioritized measures that have not yet been mainstreamed into Kenya's development objectives (2017-2022). Kenya has filed a Nationally Appropriate Mitigation Action (NAMA) to the UNFCCC to encourage private investment in geothermal energy development by channeling targeted international climate money and technical assistance.

Appropriate policies are a critical component in stabilizing pastoral systems' livelihoods, particularly those focused toward climate change mitigation. Policies that are well-crafted and adaptable to the needs of pastoral communities, incorporating indigenous knowledge and acknowledging the role of customary institutions, will foster a robust business environment that supports businesses and investments in pastoral systems, resulting in communities that are better prepared to deal with climate change. Kenya's policy environment is strong, with new climate change laws and institutional frameworks in place to help communities and individuals build economic, social, and environmental resilience to climate change shocks. However, the policy frameworks lack a strong pastoralist agenda, leaving pastoralists and their staple cattle economic system vulnerable, resulting in poor resilience solutions. Pastoralists do not have strong representation (backed up by evidence) in national and county-level climate strategies and finacing platforms in the following areas: The National Climate Change Response Strategy, which was published in 2010. Kenya is a signatory to the UN Framework Convention on Climate Change (UNFCCC), hence the strategy is a commitment to the UNFCCC. Its main goal is to make sure that adaptation and mitigation actions are factored into all government planning, budgeting, and development goals. The pastoralists' concerns are not adequately addressed in the text, and participation in its revision is required. Others are Climate Smart Agricultural Framework, the National Livestock Policy, County Integrated Development Plans (CIDPs), climate change legislation in the Counties, the Counties' livestock policies, Water policies and strategic strategies, Range management and pastoralism strategy (2021-2031) and the Community land Act (2016).

The civil society's involvement in the aforementioned financial structures and policy environments will create legal opportunities for economic, political, social, and ecological concerns impacting pastoralist communities' susceptibility to climate change to be tackled extensively from a point of information and in an organized way.

Whereas vision 2030 document proposes the establishment of four disease free zones in Kenya (GoK, 2007), this seems to be receiving very little attention. If this was to be implemented, more resources would have been allocated towards the control of livestock diseases and the disease burden among pastoralists' herds would have reduced dramatically. The 23rd session of the African Union assembly in Malabo, Equatorial Guinea on 26th - 27th June 2014, the heads of state and governments committed to ensuring that 30% of pastoral households are resilient to climate and weather related risks (African Union, 2014). Goal 13 of the Sustainable Development Goals urges governments to take urgent action towards combating climate change and its effects by building resilience and enhancing adaptive capacity to climatic hazards (United Nations, 2015). Policy framework for pastoralism in Africa (African Union, 2010) strategy 1.3 (ii) advocates for equitable access to services including animal health to pastoralists. Various other policy documents including the Kenya veterinary policy (GoK, 2015), the National livestock policy (GoK, 2008), the National climate change response strategy (NCCRS) for Kenya (GoK, 2010), Sessional Paper No. 8 of 2012 on National Policy for the Sustainable Development of Northern Kenya and other Arid Lands (GoK, 2012) and the Samburu County integrated development plan 2018 - 2022 (SCG, 2018) recognises animal health services as being necessary in preventing, controlling and eradicating diseases that negatively affect the market value and acceptability of livestock and livestock products. These policy documents emphasizes on notifiable and TADs being given more attention.

2.17 Knowledge gaps arising from Literature Review

The literature review provided above gives proof regarding climate variability, change, and its present and future effects. The primary implications of climatic variability and change on pastoralists were determined to be animal diseases, the impacts of flooding, and severe droughts, amongst other. While herd mobility is meant to support the kind of life lead by the pastoralists during hash climatic conditions, it is also a major contributor of disease outbreaks and spread and also a constraint to their control. The impact of herd mobility especially on the distribution and prevalence of livestock diseases, and with closer regard to TADs, and on trade in livestock and livestock products can clearly be seen and thus should be prioritized by all levels of governments and the relevant international donor agencies and regulatory bodies.

The requirements for the control or prevention of livestock diseases cannot be separated from that of removing the challenges of herd mobility. Any proposed strategy must take an approach that is globally, complex and focused to provide a lasting solution to the problem. It should also respect and maintain the cultural values and customs and promote sustainable development of pastoralism by leading to improved epidemiology and reduced threats of livestock diseases. This approach can only be achieved through the support of the national government and collaboration between County governments in the control of livestock diseases and its management during herd mobility. One of the strategies that can be an area of collaboration is synchronized vaccination between neighbouring Counties.

Most studies have focused on climate variability and coping strategies, however no study has focused on the interactions of climate variability and herd mobility in creating livestock disease hotspots to inform targeted disease control in ASALs. Since little information on the effects of these two variables had previously been gathered in the focus area with respect to animals' disease management, it was of utmost significance to gather this information. Additionally, nearly all the data gathered had evaluated the effects of climate variability and change with regards to livelihoods including pastoralism, whereas pastoral susceptibility and the effects of the aforementioned factors vary considerably across distinct regions depending upon the variety of livelihood resources and the geological and geographical setting of the region in question. Therefore, it was important that data be collected on climate variability, herd mobility and their effects on livestock disease control.

CHAPTER THREE

3.0 GENERAL METHODOLOGY

3.1 The Study Area

The study was conducted in Samburu County, Kenya (Figure 3.1). It covered six study sites (sub locations) that included Longewan (Samburu Central), Arsim and Lonyangaten (Samburu North), Swari, Lpus and Ngutuk Engiron (Samburu East).

3.1.1 Location

The size of Samburu County is 21,022 km^2. It is an arid rangeland with an average elevation of 900 meters above sea level that is located between latitudes 00^o30'N and 2^o45'N and longitudes 36^o15'E and 38^o10'E (Samburu County Government, 2018). The County borders Laikipia, Marsabit, Baringo, Turkana and Isiolo Counties. The following main units represent physiographic divisions of the County: Based on a report prepared by the Samburu County Government and the World Food Program (SCG & WFP, 2015), the Mathews ranges have elevations between 1,500 and 2500 meters, the Nyiru and Ndoto mountains reach heights of over 2000 meters, and the Leroghi plateau extends to above 2000 meters. Also present are the plains, which range in elevation from 1000 to 1350 meters and have slopes that lead to Lake Turkana, Isiolo, and Marsabit on the eastern border of the vast Rift Valley. The County's climate conditions change with change in altitude. According to SCG & WFP (2015), the annual rainfall ranges from less than 400 mm in the lowlands to more than 1250 mm in the highlands. With sufficient moisture to sustain viable agriculture, 8% of the County is considered to have heavy rainfall. The remainder of the County is categorized as rangeland. This study was carried out in six sub-locations of Samburu County.

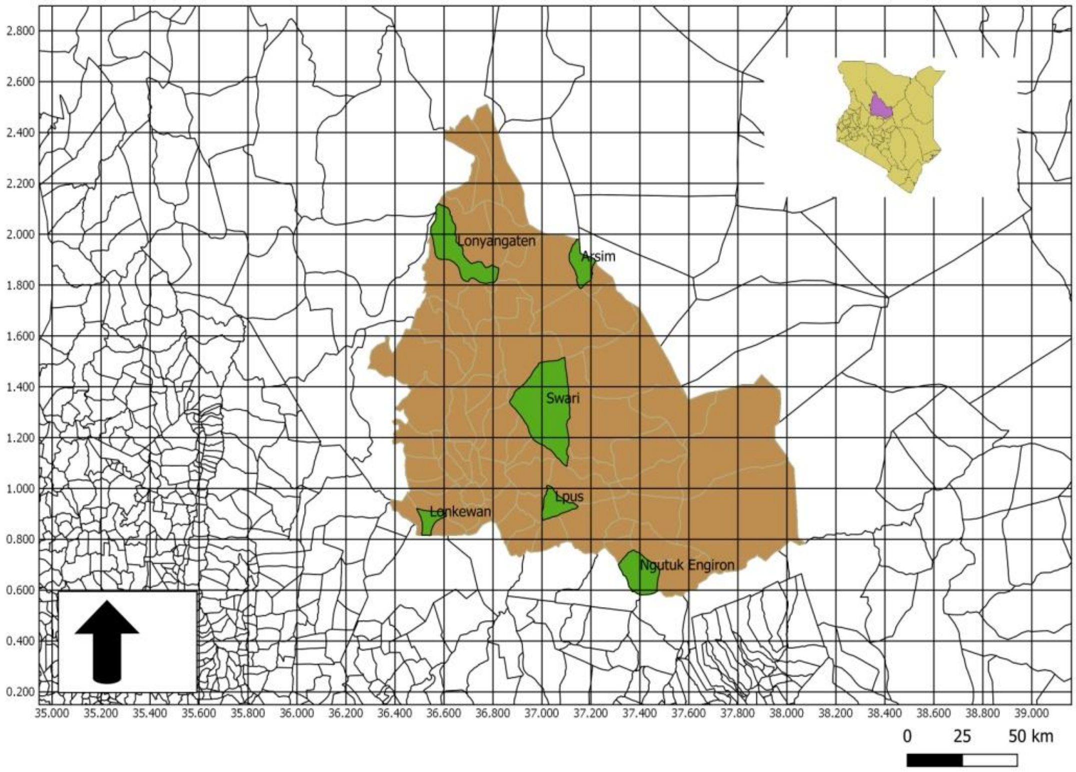


Figure 3.1: Map showing study sites (Source: Geoffrey Lelenguyah)

3.1.2 Climate

The climate of the County can be described as dry lowland equatorial climate. Rainfall patterns follow a very unpredictable pattern which can vary very significantly in time and space. The driest months are January to March. The long rain season occurs between November/December but some rains are experienced during other months especially in May/June. Potential annual evaporation in the County is a function of altitude and it ranges from 500mm to 1200 mm per annum (SCG & WFP, 2015). Temperature ranges from 24^{o} c to 36^{o} C.

3.1.3 Samburu County ecological zones

This County can be categorized into the following Ecological zones: lower highlands zone, upper midland, lower midlands zone, intermediate lowlands and indistinct zones/transitional zones (SCG & WFP, 2015; SCG, 2013; SCG, 2018).

3.1.4 Vegetation and wildlife

Evergreen forests, evergreen bushes, dry semi-deciduous bushes/thickets, and grasslands defines the county's vegetation. The main vegetation species include: Trees; *Acacia tortilis, Acacia Senegalia, Boscia angustifolia,* Shrubs: *Salvadora persica, Cordia sinensis, Croton dichogamus, Psiadia punctulata,* Grasses: *Themeda Triandra, Cenchrus ciliaris, Eragrostis superba.* Wild animals; *Panthera leo* (lion), Warthog, *Crocuta crocuta* (Hyena), *Loxodonta africana* (Elephant), *Gazella spp.* (gazelles), *Antilopinae spp*. (antelops), *Equus spp.* (zebras) and various *Avian spp.* (birds) including Swallows, House Crows (*Corvus Splendens*) Pigeons, Glossy Starlings, Tinker birds, warblers (SCG, 2013; SCG, 2018).

3.1.5 Drainage

Samburu County typically has little water resources. It has few regular rivers including Kurungu, South Horr Rivers and Ewaso Nyiro River. Most water utilized in the County is harnessed from rain. The County falls within Kenya drainage areas of Kerio Valley and Ewaso Nyiro North (SCG, 2013; SCG, 2018). The County's primary sources of water are groundwater and surface waters. The four state forest blocks, namely Leroghi, Mathews Ranges, Ndoto and Nyiro have several permanent water springs and hence are important water towers particularly in the perspective of the local community.

3.1.6 Ethnic composition

The Samburu tribe makes up the majority ethnic group in the County. There are however other tribes such as Turkana, Pokot and the small populations of hunter gatherers (Ndorobo) who are undoubtedly the oldest inhabitants of the County. The urban centres and towns such as Maralal, Wamba, Ngurunit, Archers Post and Baragoi are fairly cosmopolitan made up of several other ethnic groups who consist of the main traders in town and who include Kikuyu, Meru, Rendile, Kalenjin and Somali.

The Samburu people are predominantly semi-nomadic pastoralists and move with their livestock to seek grazing although the people living adjacent to the urban areas and to the western part of the County have adopted sedentary lifestyles

3.2 Conceptual Framework for the Study

Any pastoralist community can be affected by the impacts of climate variability and change through exposure. These exposures especially in relation to lack of or inadequate rainfall more often triggers herd mobility to other areas seeking for water and pastures. Climate variability and such mobility tend to interact and create disease hotspots since livestock from all over concentrate in one area increasing the rate of spread or transmission of diseases. An understanding of climate variability, livestock mobility patterns and the disease hotspots is important in the control and treatment of livestock diseases. Such knowledge can be used to designate strategic areas to be used for seasonal targeting of livestock disease control, thus making veterinary interventions more effective (Figure 3.1).

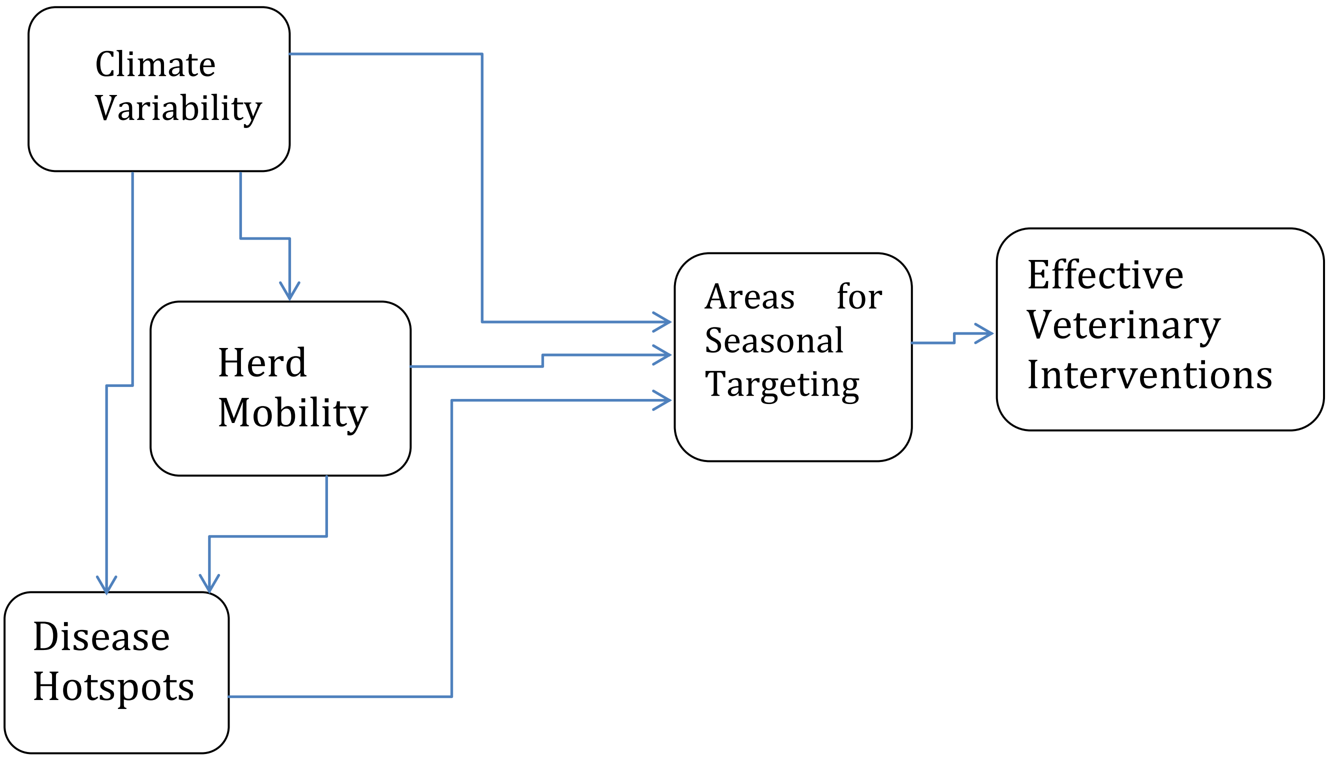


Figure 3.2: Conceptual framework for seasonal targeting of veterinary interventions.

3.3 General Study Design

This research utilized an explanatory multiple-case study design. The case study approach was utilised in order to understand interrelationships between climate variability, livestock mobility and veterinary disease incidences in the day to day life of a pastoralist (Yin, 1994; Zainal, 2007; Yin, 2014). The pastoral communities of Ngutuk Engiron, Lpus, Swari, Lonyangaten and Arsim, and the agro-pastoral community of Longewan (Figure 4.1) were the case studies for purposes of this research. The Sub-locations were selected based on criteria of:

i. Representativeness of livelihood zones
ii. Areas prone to drought shocks hence affected by herd mobility
iii. Neighbouring other Counties hence allowing cross-border herd mobility

The above sublocations were selected from the 5 Wards (Suguta Marmar, Wamba West, Waso, Wamba North, Ndoto and Elbarta) in Samburu County, all of which borders other Counties hence allowing cross-border herd mobility. Therefore, Samburu County in this case acted as an epicentre for herd mobility and the study analysed how such mobility resulted to disease hotspots in the 4 Counties of Samburu, Isiolo, Laikipia and Marsabit. Table 3.1 presents the profile of the study sub-locations.

Table 3.1: The profile of the study sub-locations

Subcounty	Ward	Location	Sublocation	Male	Female	Total	HH	Area (Km2)
Samburu Central	Suguta Marmar	Amaiya	Longewan	1522	1510	3032	513	76.90
Samburu East	Wamba West	Londungokwe	Lpus	609	625	1234	263	96.20
Samburu East	Wamba West	Waso West	Ngutuk Engiron	827	709	1536	234	81.10
Samburu East	Wamba North	Naimirimo	Swari	2332	2297	2639	898	396.70
Samburu North	Ndoto	Arism	Arism	743	768	1511	358	211.40
Samburu North	Elbarta	Kawop	Lonyang'aten	2058	2110	4168	661	34.80

Source: Kenya National Bureau of Statistics, 2019

CHAPTER FOUR

4.0 LOCAL PERCEPTIONS ON CLIMATE VARIABILITY TRENDS, ITS IMPACTS ON LIVESTOCK PRODUCTION AND STRATEGIES USED BY COMMUNITIES TO COPE WITH THE STRESS IN THE RANGELANDS OF NORTHERN KENYA

Manuscript published in the International Journal of Climate Change: Impacts and Responses on 3rd May 2023

Lelenguyah, G., Nyangito, M., Wasonga, O., & Bett, R. (2023). Herders' Perspectives on Climate Variability and Livestock Diseases Trends in the Semiarid Rangelands of Northern Kenya. *The International Journal of Climate Change: Impacts and Responses*, *15*(2), 69.

Abstract

Arid and semi-arid lands occupy at least one-third of the planet's land area, while in Africa, they comprise about two-thirds of the continent. These ecosystems are subject to diverse drivers including rainfall variability, to fire, and grazing and browsing and that end up creating a dynamic and patchy rangeland landscape that is inherently unpredictable in space and time. This has necessitated the pastoralists, who are the primary resource users to adopt adaptive resource use strategies such as mobility/migrations, herding different species of livestock and herd splitting to cope with ecosystem risks and uncertainties. In Northern Kenya, livelihood risks occasioned by conflicts and disease outbreaks are closely interrelated with climate variability and change. The objective of this study was to analyze local perceptions on climate variability and pastoralists coping strategies in Samburu County. The study utilized an explanatory multiple-case study design. A total of 347 respondents (163 males, 184 females) were selected through simple random sampling from six study sites (Longewan, Lonyangaten, Arsim, Swari, Lpus and Ngutuk Engiron). Drought was perceived to be more severe while rains have been decreasing. A statistically significant association was noted on the perception on the trend of rainfall and the study sub-locations ($\chi2= 19.438$, df= 1, p= 0.000), temperature ($\chi2= 15.215$, df= 1, p= 0.000), floods ($\chi2= 18.301$, df= 1, p= 0.000) and drought ($\chi2= 22.016$, df= 1, p= 0.000). Pestes des Petits Ruminants (PPR), Contagious Caprine PleuroPneumonia (CCPP) and Foot and Mouth Disease (FMD) were said to have been increasing by 57.3% (n=199), 66.0% (n=229) and 54.6% (n=189) of the respondents respectively. Pasture availability was found to be the most important factor when it comes to decision-making on where pastoralists will move their animals as mentioned by 100% of the respondents. This was followed by water availability (97.4%), conflicts (79.4%), type of livestock kept (79.1%) and emergence of livestock diseases (72.8%). Pastoralists coping strategies included migration, eating wild fruits, reducing the herd size as well as herd splitting. In conclusion, there has been general change in rainfall and temperature variability which have had negative impacts on the pastoralists and their livelihoods. This calls for improvement of veterinary services delivery system, infrastructure development and enhancing information dissemination mechanism to suit the pastoral areas.

Keywords: Pastoralists perception, Livestock diseases, Climate variability, Livelihoods, Coping strategies, Northern Kenya

4.1. Introduction

For pastoralists and disadvantaged segments of the population like women and children, livestock is a positive factor in domestic food and nutritional security (Government of Kenya (GoK) 2021; Lesorogol, 2008; GoK, 2008; GoK, 2018; Aklilu and Wekesa 2001). Socially, economically and culturally livestock are used as a source of food through provision of milk, meat, ghee, eggs, fat; as a source of revenue by way of the sales of animals and animal products. It is also used as a means for cultural exchange in paying for the bride prices, penalties, and presents to visitors and relatives; as security and insurance against natural disasters; for status and satisfaction. Additionally, livestock is slaughtered over special ceremonial events including wedding parties, anniversaries, funerals, and circumcision; as a foundation for young people and newlywed men to embark on entrepreneurial activities (Catley *et al.*, 2005).

Livestock production in Samburu County is based on two main production systems namely pastoralism and agro-pastoralism (Lesorogol, 2008; Mulianga, 2009; CGS, 2018). The former is the key production system practiced mainly in Samburu North and Samburu East sub-counties and in the lowlands of Samburu Central Sub-county (Lesorogol, 2008; CGS, 2018). To obtain sustenance, pastoralists rely on the sale of their livestock and livestock products. They move around as nomads, following a seasonal cycle of available grazing resources. Agro-pastoralists are settled pastoralists who also practice crop production (maize, beans, cowpeas, potatoes and vegetables and also grow cash crops such as wheat and barley) but still value livestock as a source of livelihood. This type of production system is practiced in the highlands of Samburu central sub-county, mainly in Poro, Maralal, Suguta Marmar, Loosuk and parts of Lodokejek wards (CGS, 2018). Other alternative livelihoods include beekeeping, poultry and fish production.

There are key strategic challenges constraining the two livestock production systems in the county. The key one is vulnerability to climatic shocks, especially droughts that lead to inadequate water and pasture, which have over the years wiped off large numbers of livestock during severe droughts (CGS, 2018). This is exacerbated by cattle rustling and conflicts over grazing resources which are common phenomenon in the county. The conflicts have created very negative and severe impacts on the two main communities - the Samburu and Turkana. Conflicts typically result in losses of lives and assets, the forced migration of a significant portion of the population, and the interruption of livelihood and socio-economic activity. The other challenge is outbreak of endemic livestock diseases which include FMD, CCPP, SGP, PPR, RVF, Blue tongue, LSD and Hemorrhagic Septicaemia (HS) and Severe Respiratory Syndrome (SRS) in camels (CDVS, 2015). Livestock diseases prevention is crucial to enhance livestock resilience to drought. However, there is need for a fully functional cold chain facility with well stocked vaccines in time. Lesorogol (2008) and Mulianga (2009) note that the pastoralists also struggle with poor capital investment in their businesses, gender inequity and poor service delivery, high illiteracy rates, and unfavorable land tenure issues. Failure to establish effective co-management models with Livestock Marketing Associations (LMAs), distance to markets, inadequate information about markets, poor product quality, and the absence of value-adding initiatives are all contributing factors to marketing constraints.

Climatic variability and change is going to affect various populations across the globe at different levels or magnitudes, and most of the populations have already been affected and are already considered very vulnerable to any further impacts (WISP, 2008, GoK, 2021; Ayanda, 2013; Davies and Nori, 2008). The pastoral and agro-pastoral areas of Eastern Africa, including the Northern Kenya such as Samburu and the neighbouring Counties of Turkana, Marsabit, Isiolo, Baringo and Laikipia are also at risk of the negative impacts of climate change (Bailey, 2012; Belay *et al.*, 2005). While the effects of climate change are becoming increasingly apparent across all continents, little is known about how different populations, including those in pastoral areas, perceive the most significant changes and effects, vulnerabilities, as well as capacity for adaptation (Davies and Nori, 2008). Additionally, based upon the resources readily accessible for sustaining livelihoods, geography, and the geographical location of the place, pastoral vulnerability and the effects of climate change vary greatly across distinct regions. Many factors play a role in the transmission of livestock diseases. The risk of pathogen transmission and occurrence in a livestock population is increased by herd mobility and trade channels for livestock and livestock products (Bett *et al.*, 2008). Herd mobility on the other hand is increased by climate variability. There is a strong relationship between the occurrence of epizootic infections and the increase in the frequency of herd mobility, the inadequacy of animal health surveillance and response systems and the various conflict situations that arise in these areas. The degree of risk also has a direct relationship with the distribution of diseases within a County or the Country in general (Moenga *et al*., 2016). Herd mobility exposes livestock to new infections. Such animals could also be carrying other pathogens to their new grazing areas hence creating a vicious circle. Based on insights gathered from the pastoral and agro-pastoral populations, this paper makes a contribution to filling these gaps. In this context, this research explores how local populations perceive climatic variability and change relying on the accounts of pastoral communities in Northern Kenya, as well as its effects and coping mechanisms. It stresses on the need for a thorough examination of pastoralists coping strategies with a view of informing their modeling to enhance adaptive capacity.

4.2. Materials and Methods

This study was carried out in Samburu County, Kenya. It covered six study sites (sub locations) that included Longewan (Samburu Central), Arsim and Lonyangaten (Samburu North), Swari, Lpus and Ngutuk Engiron (Samburu East).

This research utilized an explanatory multiple-case study design in order to understand interrelationships between climatic variability, livestock mobility and animal diseases. The pastoral communities of Ngutuk Engiron, Lpus, Swari, Lonyangaten and Arsim, and the agro-pastoral community of Longewan (Figure 3.1) were the case studies for purposes of this research. The Sub-locations were selected based on criteria of representativeness of livelihood zones; areas prone to drought shocks hence experience herd mobility; and neighboring other Counties hence allowing cross-border herd mobility.

The sub-locations were selected from the 6 Wards namely; Suguta Marmar, Wamba West, Waso, Wamba North, Ndoto and Elbarta in Samburu County, all of which border other Counties hence allowing inter-county herd mobility. The study also analysed how such mobility results to disease hotspots in the 5 Counties of Samburu, Isiolo, Baringo, Laikipia and Marsabit.

The Cochran formula was used in determining the sample size. The formula allows to calculate an ideal sample size given a desired level of precision, desired confidence level and the estimated proportion of the attribute present in the population (Cochran, 1977).

Cochran’s formula is considered especially appropriate in situations with large populations. A sample of any given size provides more information about a smaller population than a larger one. The Cochran formula is:

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where:

- n_o represents the sample size
- e represents the desired precision level,
- p represents the estimated population proportion with the attribute in question,
- q equals to 1 – p.

The z-value can be found in the Z table.

Cochran's Formula Example

If p = 0.5 and at 95% confidence, and at least 5 percent—plus or minus—precision. A 95 % confidence level gives Z value of 1.96, therefore, this gives a sample size of;

$((1.96)^2 (0.5) (0.5)) / (0.05)^2 = 385.$

Therefore, a random sample of 385 households in the target population should be enough to give the confidence levels needed.

Modified Cochran Formula for Sample Size Calculation in Smaller Populations

If the population being studied is small, the sample size calculated in the above formula can modified by using this equation:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

Here n_0 is Cochran's sample size recommendation, N is the population size, and n is the new, adjusted sample size. This study had a total of 2692 households according to the lists obtained from the local leaders (chiefs and village administrators) being for Longewan (392), Lpus (370), Ngutuk Engiron (264), Swari (573), Arsim (392), and Lonyangaten (701), and therefore the sample was calculated as follows:

385 / (1+(384 / 2692)) = 357

So from 2692 households, 357 were selected for this study. The number of households for every study site was calculated as described in table 4.1:

Table 4.1: Site specific sample size calculation

Study site	Sample size calculation	Determined sample size
Longewan	(392/2692)*357 = 51.99	52
Lpus	(370/2692)*357 = 49.07	49
Ngutuk Engiron	(264/2692)*357 = 35.01	35
Swari	(573/2692)*357 = 75.99	76
Arism	(392/2692)*357 = 51.99	52
Lonyang'aten	(701/2692)*357 = 92.96	93
Total sample size (No. of households) for the study		**357**

4.2.1 Household interviews

Data from the six sub-locations' household interviews was collected from household representatives' using semi-structured questionnaires that included closed-ended as well as open-ended questions (Appendix 10.1). Simple random sampling was used to choose the houses that would take part in the study. First, the village administration or the area assistant chiefs were contacted for lists of households in the sub-locations that included the names of the heads of households. After that, numbers were assigned to each list's names. Using online-based Stat Trek's random number generator, 52, 49, 35, 76, 52 and 93 random numbers were generated for Longewan, Lpus, Ngutuk Engiron, Swari, Arsim and Lonyangaten sub-locations respectively.

The household head from the selected household was individually interviewed with regard to climate variability, seasonal herd mobility, seasonal rainfall and grazing patterns and areas for seasonal targeting for disease control by the County government and other stakeholders. The various factors that determine the movement in and out of each location were investigated and ranked. The household questionnaire was administered with the assistance of trained enumerators in the study sites. Out of the targeted 357 households, 347 were interviewed while 10 households could not be reached as they had either moved out of the study sites or were away during data collection period.

4.2.2 Data analysis

Data was entered and analyzed in International Business Machines Corporation (IBM) Statistical Package for the Social Sciences (SPSS) statistics version 20. A number of analyses related to pastoral livelihoods were done including frequencies/ percentages of respondents for category of responses; correlation and regression analysis to show the interrelationship between the responses and characteristics of households; chi-square to test the relationship or significant associations across different categories of variables, and; thematic analysis to identify themes and sub-themes in the qualitative data.

4.3. Results

4.3.1 Characteristics of sampled households

A total of 347 questionnaire responses were obtained from the selected households in six study sites. The actual numbers of households responses obtained in Longewan, Lpus, Ngutuk Engiron, Swari, Arsim and Lonyangaten sub-locations were 50, 48, 34, 75, 50 and 90 respectively (Figure 4.2). The selection of the households was through simple random sampling procedure.

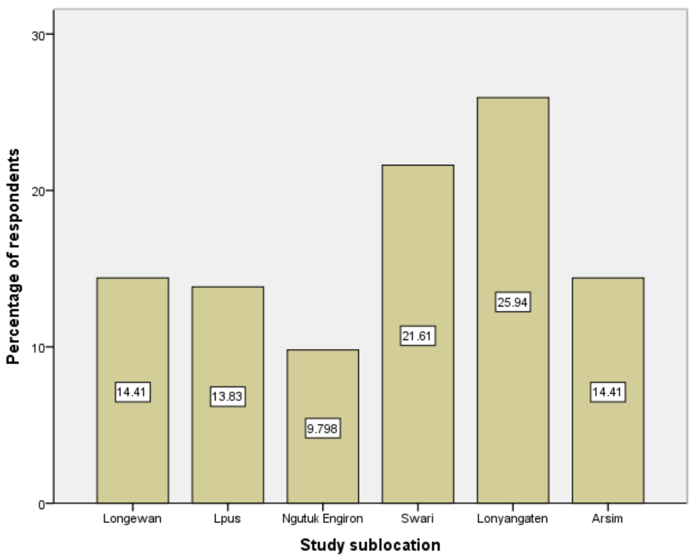


Figure 4.1: Respondents distribution by Sublocation

In all six study sites, there was no statistically significant association between respondents' ages. The results of the chi-square test were x^2=1.269, df=1, and p=0.260. The respondents' ages were divided into three groups: 18–35, 36–59, and above 60 (Figure 4.3). The pattern of the distribution of ages shows a wide spectrum of younger, middle-aged, and elderly respondents.

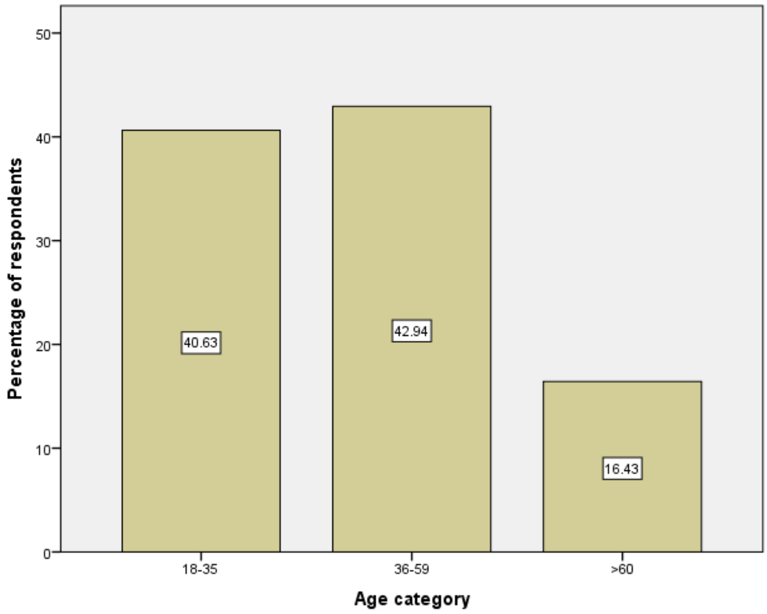


Figure 4.2: Respondents distribution by age

In total, 163 males and 184 females made up the sample of respondents who took part in this investigation. The sex of the respondents in the six study sub-locations showed no statistically significant association (X^2= 2.596, df= 1, and p= 0.107). The study did not specifically target any one sex, as both the man and the woman were interviewed in the chosen houses.

Figure 4.4 shows that 83.29% (n=289) of study participants had no formal education, while only 2% (n=7) had higher education. According to the results of the chi-square test, there was no statistically significant correlation between respondents' education levels across the six study sites (X^2= 0.397, df= 1, and p= 0.529).

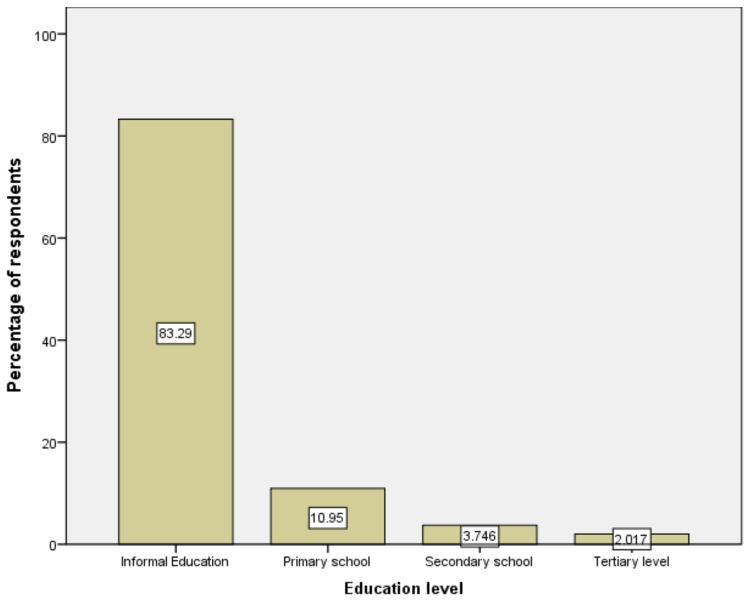


Figure 4.3: Respondents distribution by education level

At the household level, males headed 83.6% (n=290) of the households, while females headed the other 16.4% (n=57) of households. Across the 6 study locations, there was a statistically significant association on the gender of the household head (χ^2= 6.384, df= 1, p= 0.012). Ngutuk Engiron had the highest number of households headed by females at 44% (n=15). This was followed by Arsim and Swari at 36% (n=18) and 13.3% (n=10) respectively.

Most of the respondents (64.27%) mentioned livestock keeping as their major occupation. While only 1.44% depended on formal employment as a major occupation (Figure 4.5). Although also practicing livestock keeping, most of the respondents (80%) from Longewan study site were mainly mixed farmers (agro-pastoralists).

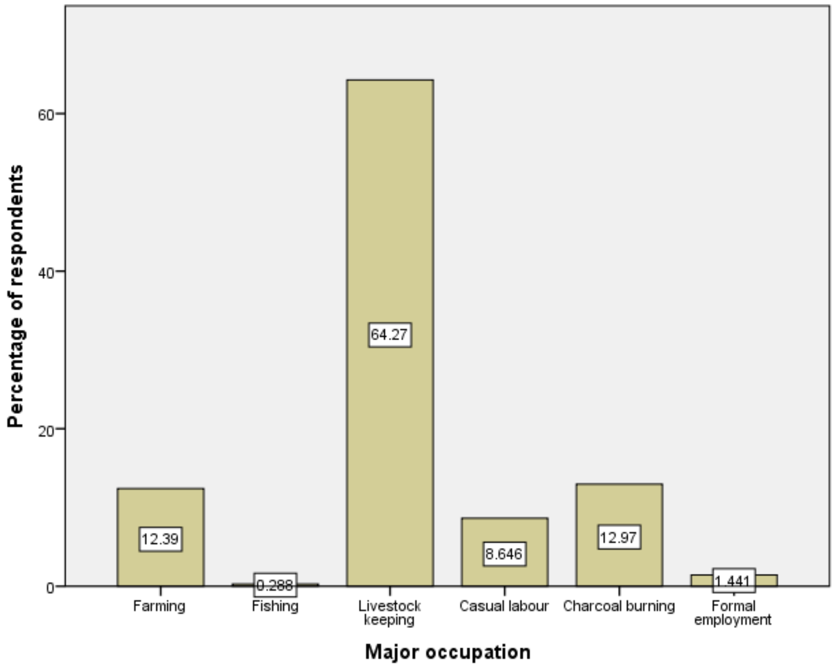
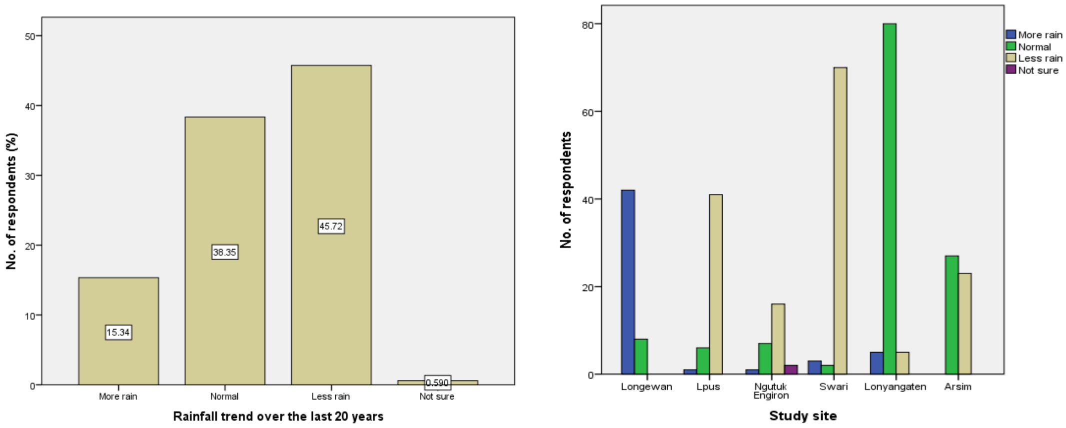


Figure 4.4: Respondents distribution by major occupation

4.3.2 Perceived climatic and environmental trends over the study period

Specifically between the six study sites, various respondents interpreted shifts in climatic and ecological variables differently (Figure 4.6).

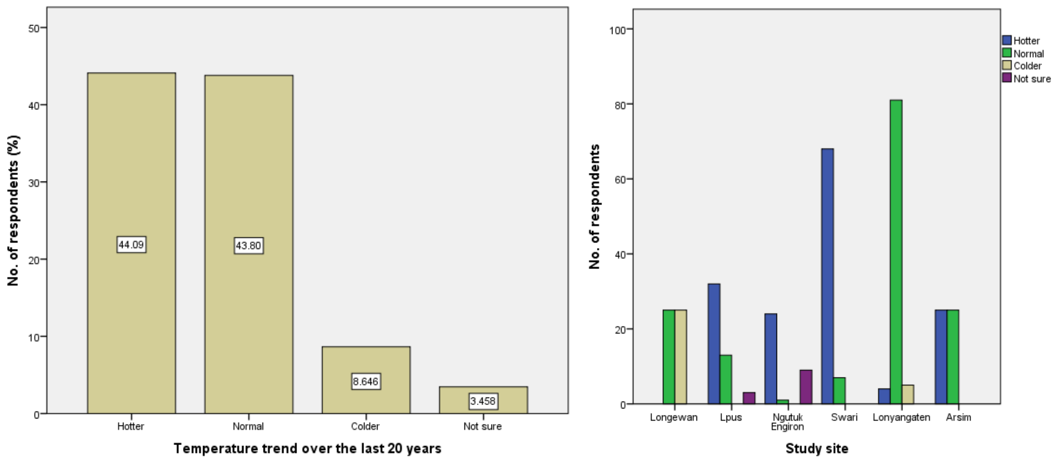
About 15.3% (n=52) of those interviewed believed that the trend in rainfall was increasing. Consequently, a small percentage of respondents assert that the study area is experiencing more rainfall than in previous years. On the other hand, 38.3% (n=130) of the respondents claimed that the trend in rainfall was normal; 45.7% (n=155) said that it had decreased; and 0.6% (n=2) were not sure.A statistically significant association was noted on the perception towards the trend of rainfall over the last 20 years between the 6 study sites (χ^2= 19.438, df= 1, p= 0.000).



(a) **(b)**

Figure 4.5: Perceived trend of rainfall over the last 20 years

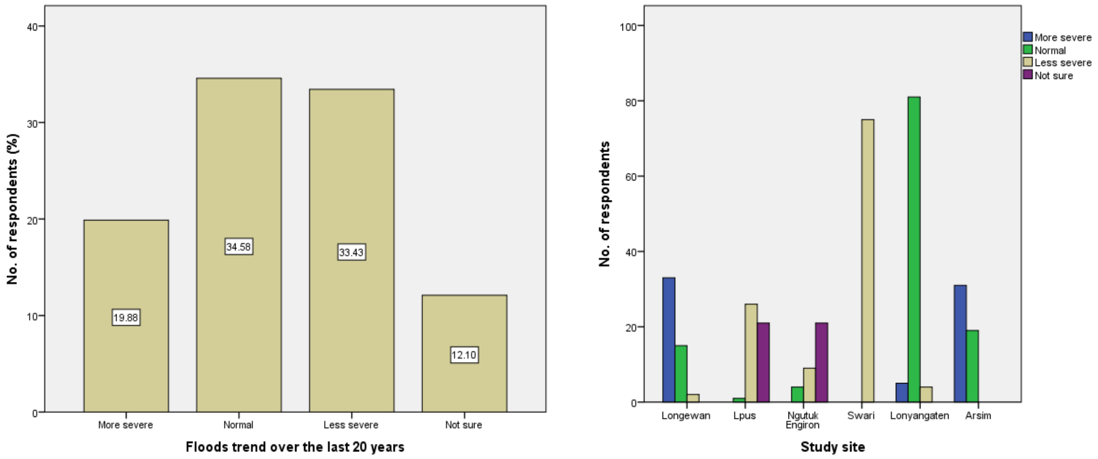
About 44.1% (n=153) of the respondents indicated the temperature was hotter, followed by 43.8% (n=152) who said it was normal, and 8.6% (n=30) who claimed it was colder (Figure 4.7). In addition, 3.5% (n=12) of the those who responded, were unsure of the temperature trend. A statistically significant association was also noted on the perception towards the trend of temperature over the last 20 years between the 6 study sites (χ^2= 15.215, df= 1, p= 0.000).



(a) **(b)**

Figure 4.6: Perceived trend of temperature over the last 20 years

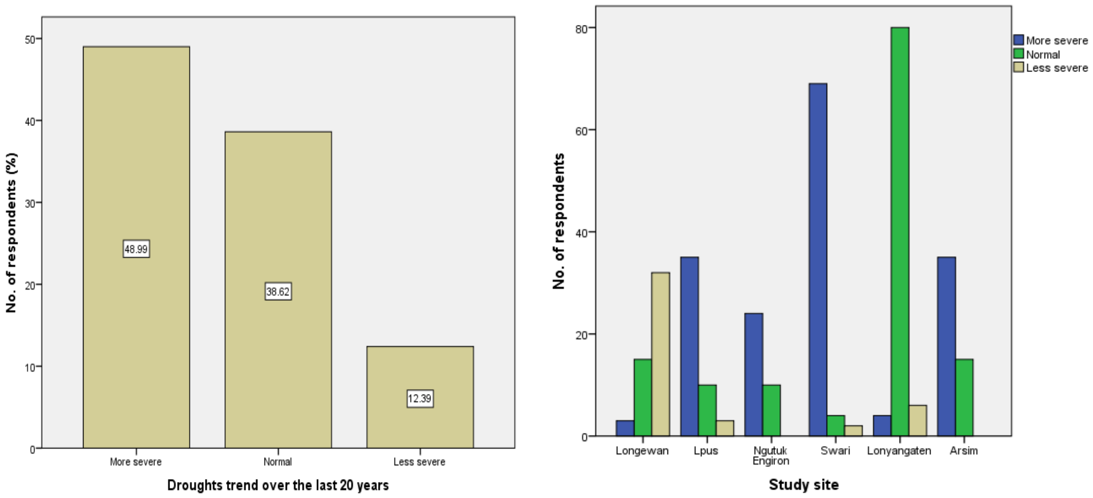
Floods were said to have become more severe by only 19.9% (n=69) of the people who were surveyed. However, 34.6% (n=120) believed it to be normal, 33.4% (n=116) to be less severe and 12.1% (n=42) were unsure about the trend. There was a strong statistically significant association on the perception towards the trend of floods over the last 20 years between the 6 study sites (χ^2= 18.301, df= 1, p= 0.000). However, it is worth noting that more severe floods were reported in Arsim and Longewan areas of Samburu North and Central Subcounties respectively (Figure 4.8).



(a) **(b)**

Figure 4.7: Perceived trend of floods over the last 20 years

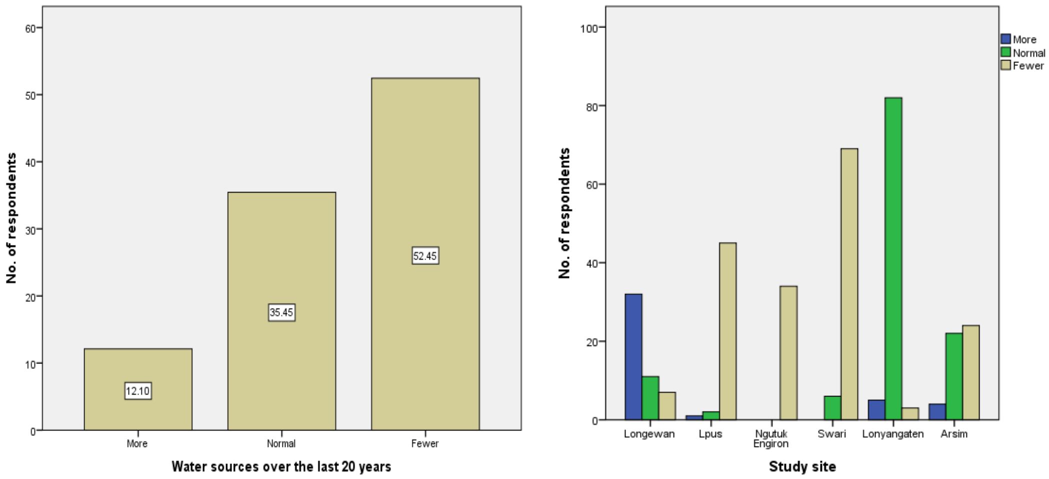
Drought severity was reported to have increased by 49% (n=170) of respondents, remained largely unchanged by 38.6% (n=134), and decreased by 12.4% (n=43) of respondents (Figure 4.9). There was a strong statistically significant association on the perception towards the trend of droughts over the last 20 years between the 6 study sites (χ^2= 22.016, df= 1, p= 0.000).



(a) **(b)**

Figure 4.8: Perceived trend of droughts over the last 20 years

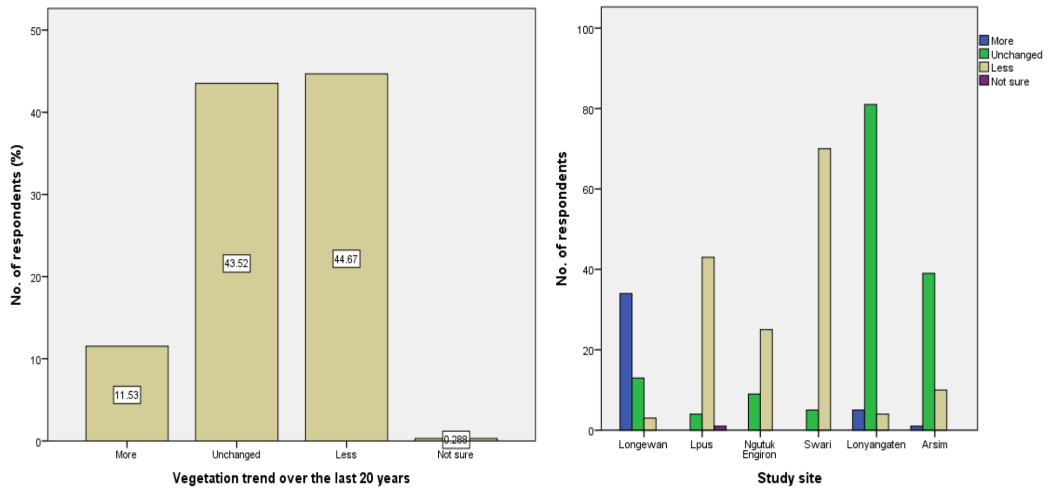
About 52.4% (n=182) of the respondents claimed that there are now fewer water sources than there were previously. Nevertheless, 35.4% (n = 123) and 12.1% (n = 42) thought it was normal and more respectively (Figure 4.10). There was no statistically significant association on the perception towards the trend of water sources over the last 20 years between the 6 study sites (χ^2= 1.634, df= 1, p= 0.201).



(a) **(b)**

Figure 4.9: Perceived trend of water sources over the last 20 years

The opinions of the respondents regarding the trend of vegetation cover over the study period were diverse (Figure 4.11). However, 11.5% (n=40), 43.5% (n=151), and 44.7% (n=155) of the respondents, respectively, thought that the trend in vegetation cover over the research period was more, unchanged, and less. But 0.3% (n=1) of people were not certain. There was no statistically significant association on the perception towards the trend of vegetation cover over the last 20 years between the 6 study sites (χ^2= 1.478, df= 1, p= 0.224).



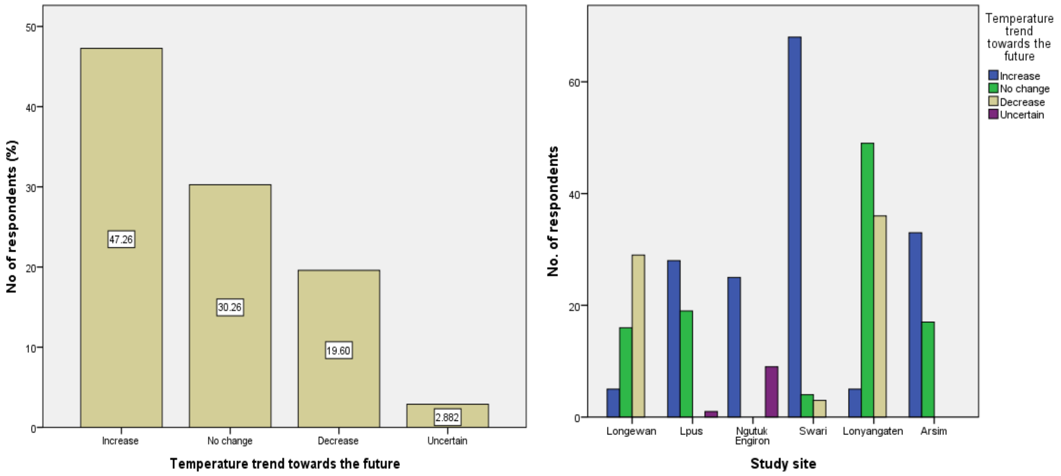
(a) **(b)**

Figure 4.10: Perceived trend of vegetation cover over the last 20 years

4.3.3 Perceived future scenarios of climatic and environmental trends

The majority of respondents (47.3%, n=164) think temperatures will rise in the future. Additionally, 52.5% (n=181), 44.1% (n=153), and 59.2% (n=205) of the respondents, respectively, projected that floods, droughts, and diseases would all worsen in the future. However, rainfall trend was predicted to be decreasing towards the future by 40.6% (n=140) of the respondents (Figure 4.12).

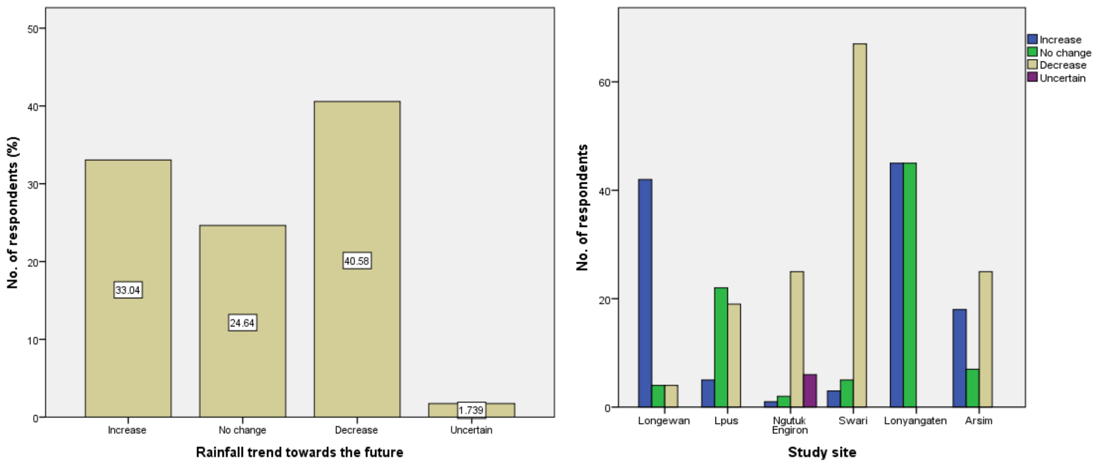
The trend of temperature was perceived to be increasing towards the future by 47.3% (n=164), no change by 43.8% (n=105), decrease by 8.6% (n=68) and uncertain by 2.9% (n=10) of the surveyed households. There was a statistically significant association on the perception on the trend of temperature towards the future between the 6 study sites (χ^2= 6.590, df= 1, p= 0.010).



(a) **(b)**

Figure 4.11: Perceived trend of temperature towards the future

The trend of rainfall was said to be decreasing towards the future by 40.6% (n=140), increase by 33.0% (n=114) and no change by 24.6% (n=85) of the surveyed households. On the other side, 1.7% (n=6) of the respondents were uncertain on the rainfall trend (Figure 4.13). There was no statistically significant association on the perception towards the trend of rainfall towards the future between the 6 study sites (χ^2= 1.087, df= 1, p= 0.297).

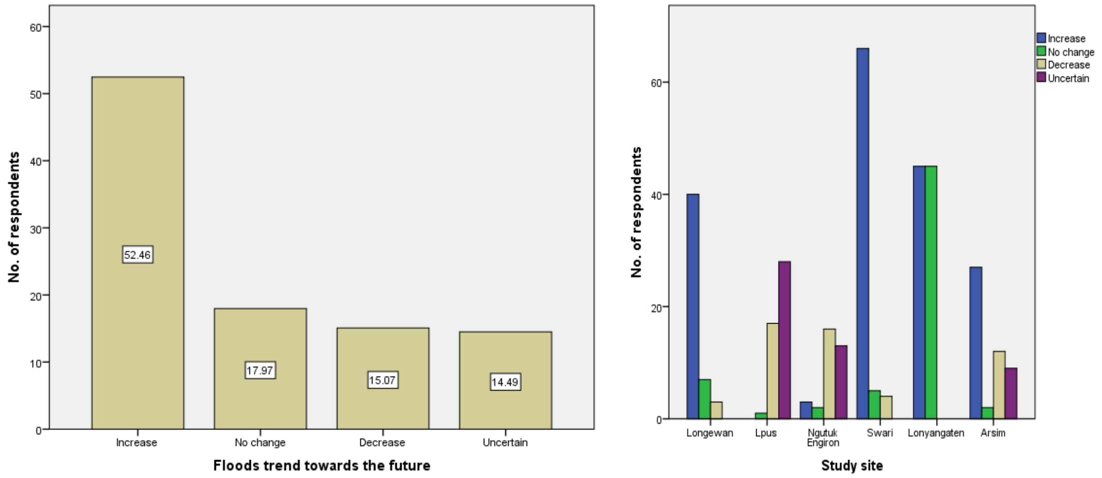


(a) **(b)**

Figure 4.12: Perceived trend of rainfall amount towards the future

The frequency of floods were said to be increasing towards the future by 52.5% (n=181) no change by 18.0% (n=62) and decrease by 15.1% (n=52) of those interviewed. But

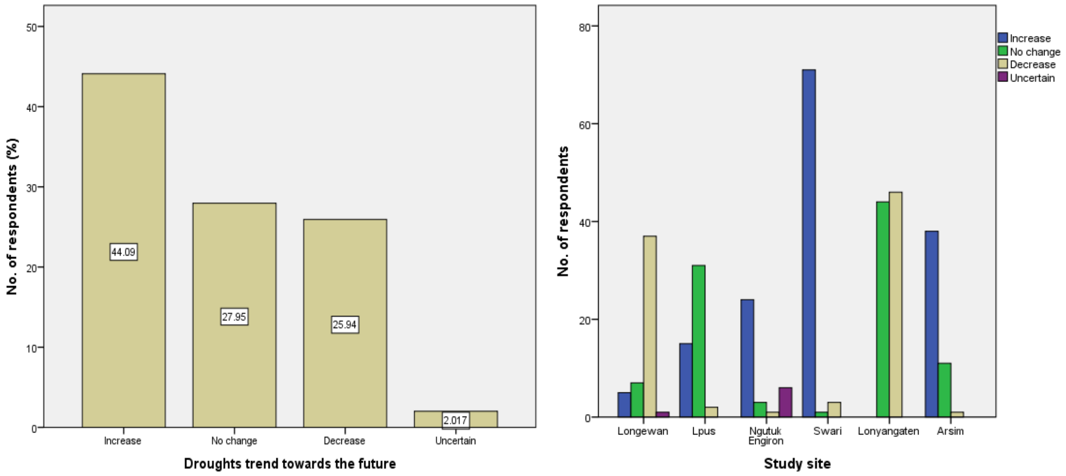
14.5% (n=50) of the respondents were also not certain on the trend of floods towards the future (Figure 4.14). A statistically significant association was also noted on the perception towards the trend of floods towards the future between the 6 study sites (χ^2= 12.331, df= 1, p= 0.000).



(a) **(b)**

Figure 4.13: Perceived trend of floods frequency towards the future

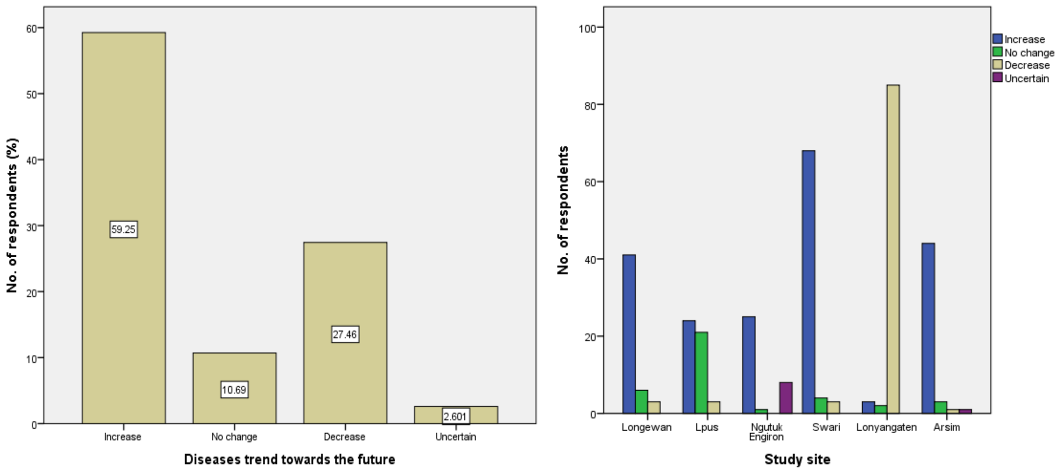
The frequency of droughts were also said to be increasing towards the future by 44.1% (n=153), no change by 28.0% (n=97) and decrease by 25.9% (n=90) of those interviewed. In addition, 2.0% (n=7) of those interviewed were not certain on the temperature trend towards the future (Figure 4.15). A statistically significant association was also noted on the perception towards the trend of temperature towards the future between the 6 study sites (χ^2= 15.531, df= 1, p= 0.000).



(a) **(b)**

Figure 4.14: Perceived trend of drought frequency towards the future

Disease incidences were also said to be increasing towards the future by 59.2% (n=205) no change by 10.7% (n=37) and decrease by 27.5% (n=95) of those interviewed. On the other hand, 2.6% (n=9) of those interviewed were not certain on the disease incidences trend towards the future (Figure 4.16). A statistically significant association was also noted on the perception towards the trend of disease incidences towards the future between the 6 study sites (χ^2= 23.329, df= 1, p= 0.000).



(a) **(b)**

Figure 4.15: Perceived trend of disease incidences towards the future

4.3.4 Perceived trend of various disease vectors over the study period

As reported by those surveyed (figures 4.17, 4.18, 4.19 and 4.20), the trend of mosquitoes and ticks has been an upward one as indicated by 49.1% (n=166) and 51.3% (n=176) respectively. However, the trend of tsetse flies was said to have been constant (41.9%, n=138) while that of other biting flies to have been decreasing (62.6%, n=119). There was a statistically significant association between the respondents' views in the six study sites on the trend of mosquitoes (χ^2= 6.149, df= 1, p= 0.013) and ticks (χ^2= 11.513, df= 1, p= 0.001). However, there was no statistically significant association between the perception of the respondents on the trend of tsetse flies (χ^2= 2.047, df= 1, p= 0.152) and other biting flies (χ^2= 1.169, df= 1, p= 0.280).

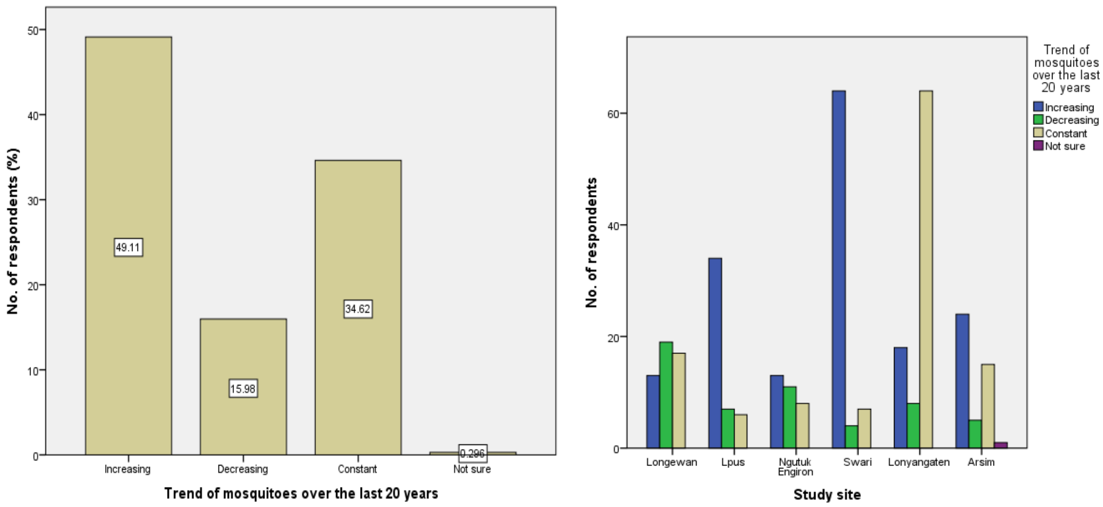


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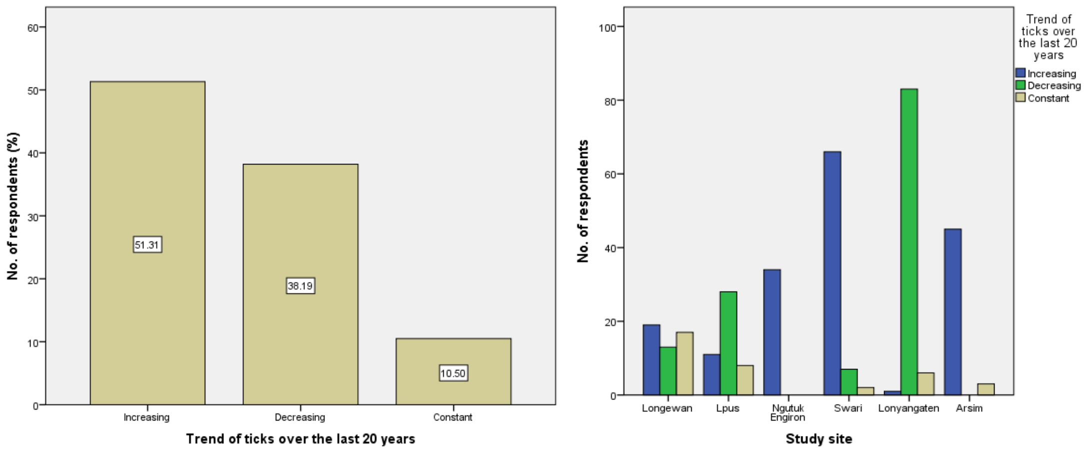
Figure 4.16: Perceived trend of mosquitoes over the last 20 years



(a) **(b)**

Figure 4.17: Perceived trend of ticks over the last 20 years

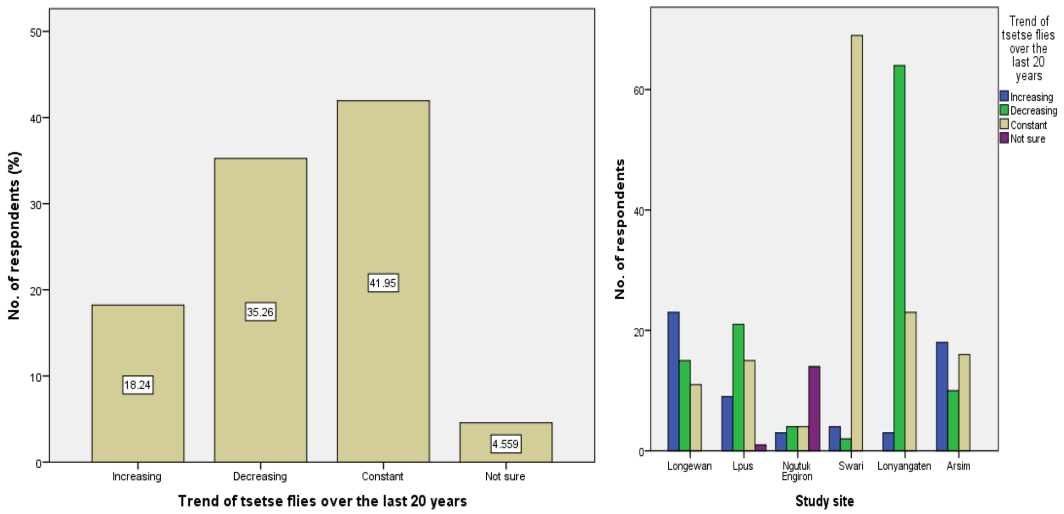


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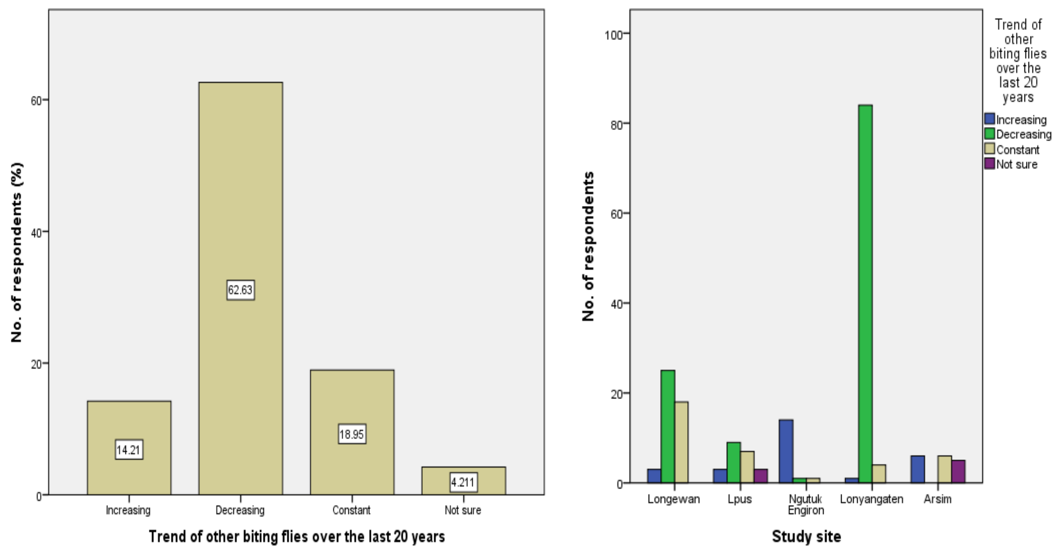
Figure 4.18: Perceived trend of tsetse flies over the last 20 years

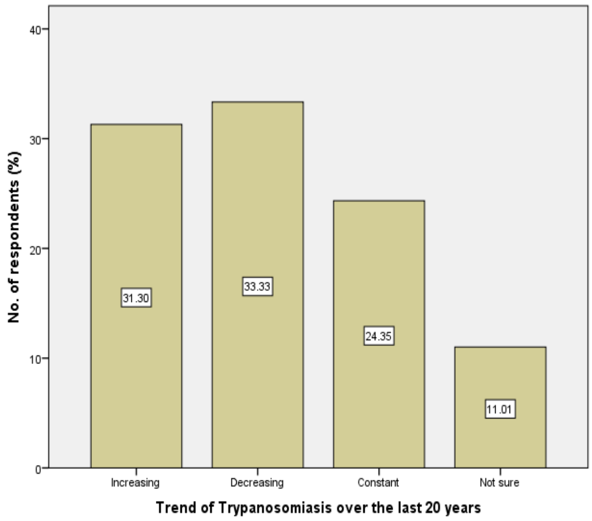


(a) **(b)**

Figure 4.19: Perceived trend of other biting flies over the last 20 years

4.3.5 Trend of various veterinary diseases over the study period

Out of the five diseases that were under investigation, PPR, CCPP and FMD were said to have been increasing over the last 20 years by 57.3% (n=199), 66.0% (n=229) and 54.6% (n=189) respectively while Trypanosomiasis and Camel pox were perceived to have been on the decline by 33.3% (n=115) and 36.8% (n=107) respectively (Figure 4.21, 4.22 and 4.23). Chi-square test for independence showed a statistically significant association in the responses between the six study sites on the trend of Trypanosomiasis (χ^2= 31.829, df= 1, p= 0.000), CCPP (χ^2= 5.469, df= 1, p= 0.019) PPR (χ^2= 4.365, df= 1, p= 0.037) and Camel pox (χ^2= 7.754, df= 1, p= 0.005) while the responses with regard to the trend of FMD showed no statistical associations (χ^2= 3.210, df= 1, p= 0.073).



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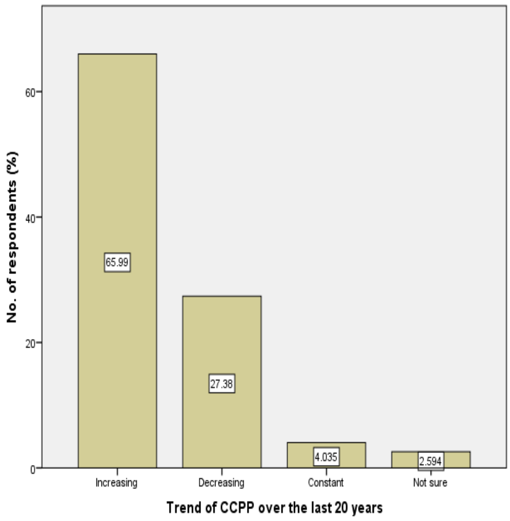

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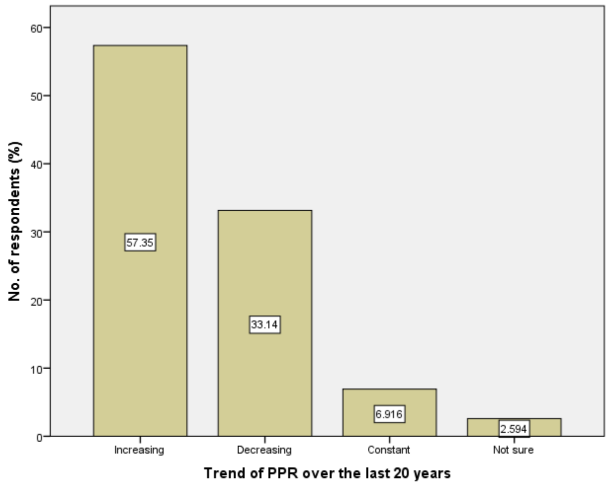

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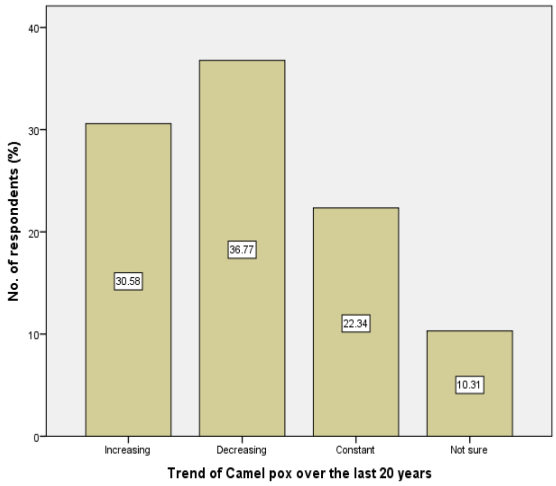


(d)

Figure 4.20: Perceived general trend of various veterinary diseases over the study period

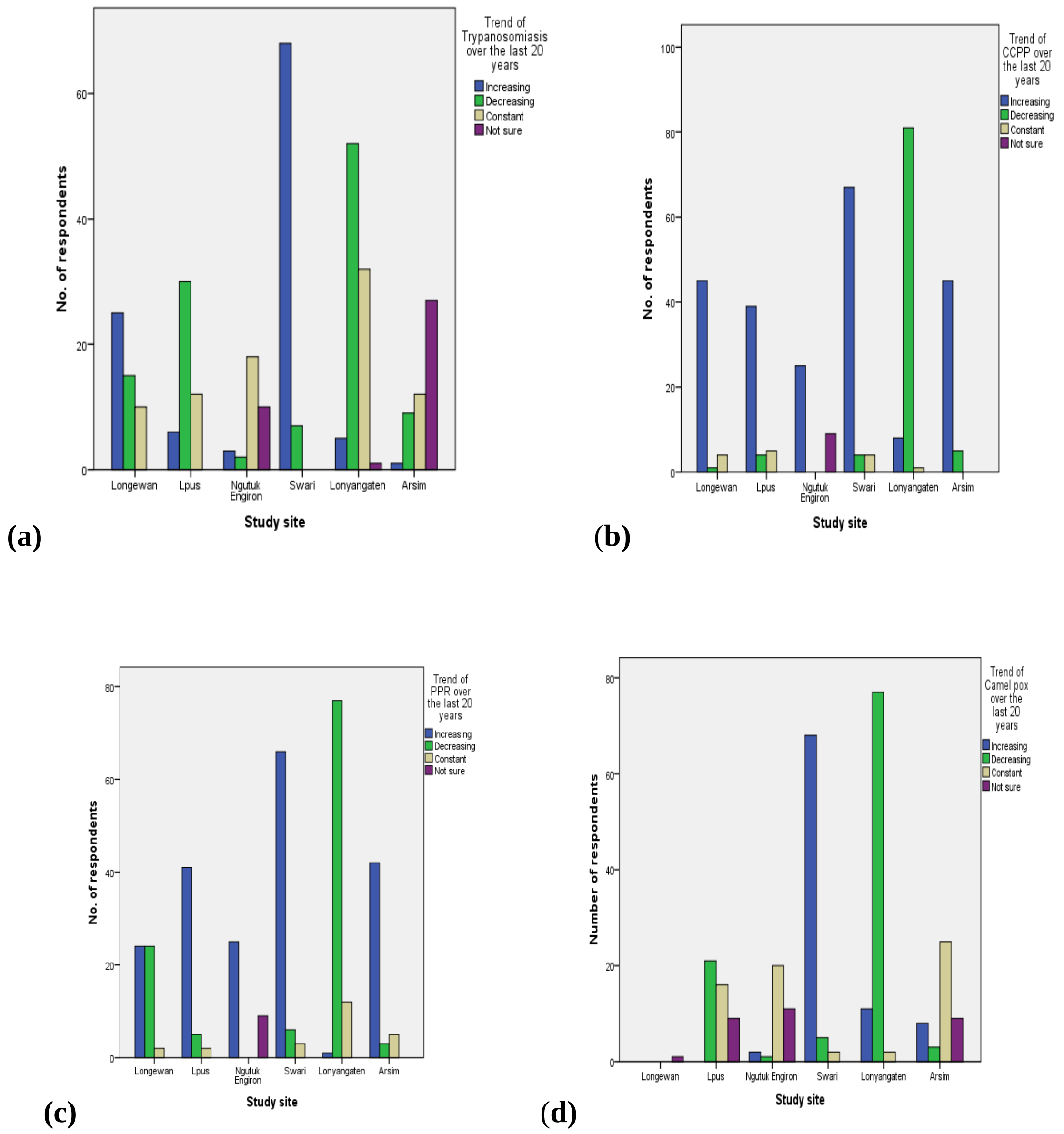
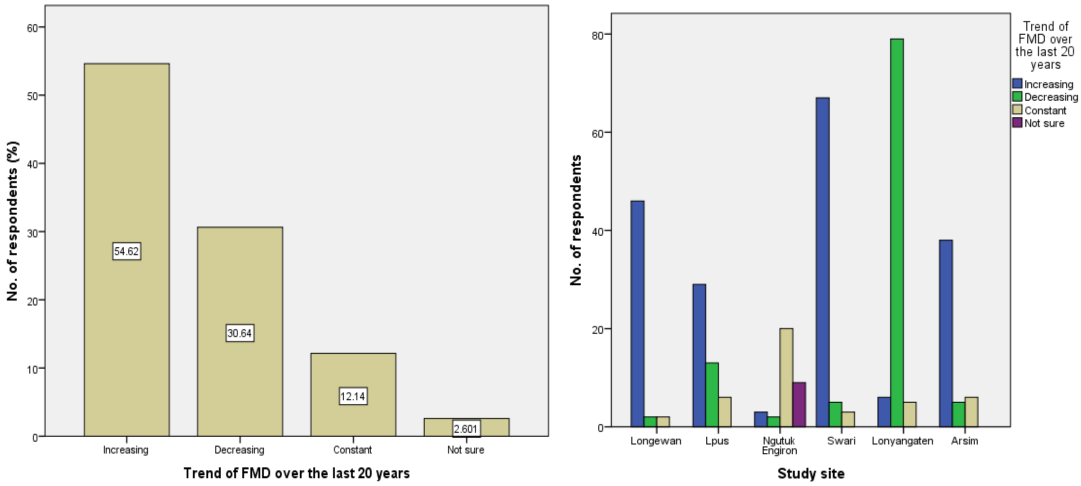


Figure 4.21: Perceived area-specific trends of various veterinary diseases over the study period



(a) **(b)**

Figure 4.22: Trend of FMD over the last 20 years

4.3.6 Effects of the climatic and environmental changes on the respondents

The effects of the climatic and environmental changes mentioned by the respondents can be categorized with reference to the variables under investigation. The household respondents mentioned a number of effects of the changes that are described in table 4.2 below:

Table 4.2: Effects of the climatic and environmental changes on the respondents

Variable	Related effects
Drought	Drought resulted to death of livestock. The year 2000 drought was said to have caused massive deaths of livestock. The long dry seasons of 2007 to 2008 also caused death of many livestock while the 2000, 2004, 2007, 2009 and 2017 droughts led to shortage of pasture, reduced livestock productivity, poor health, death of livestock, shortage of food, increased prices for cereals (maize and beans), conflicts and destitution of many families.
Floods	The 2012 and 2018 floods in Arsim area led to destruction of properties, livestock deaths and loss of human lives as well as erosion of the grazing areas
Diseases	Recurrence of diseases like FMD and CCPP made animals weaker and less productive. Respondents also reported increased CCPP cases, emergence of new livestock diseases like Hemorrhagic Septicaemia in camels and increase in tick infestation
Vegetation	The current trend of reduction in vegetation cover resulted to increased migration of livestock and increased incidences of flash floods.
Rainfall	Extreme rainfall and floods of 2018 resulted to the death of many animals, destruction of properties and loss of human life. In 2011 high rainfall was experienced that caused floods resulting to death of animals and increased cases of CCPP and SGP. Less rain resulted to droughts of 2014 and 2017 leading to the death of animals.
Temperature	In 2014 temperatures were higher than normal and resulted to drought. Higher temperatures were also said to have increased demand for water.
Reduction in water sources	Reduced water sources in the lowlands of Samburu has increased herd mobility to other areas. Fewer water sources has caused people to move away, increased trekking distance and increased poverty levels.

4.3.7 Households' coping & adaptation strategies to climatic and environmental changes

The respondents reported diverse ways of coping with the mentioned climatic and environmental changes. These included migration, reducing the herd size and livelihood diversification. Table 4.3 presents the pastoralists coping strategies for climatic and environmental changes:

Table 4.3: Households' coping & adaptation strategies to climatic and environmental changes

Coping and adaptation strategies	Description
Migration	Moving livestock from one area to another in search of pasture and water in long dry seasons, migration to higher grounds during rain seasons.
Traditional resource management strategy	These included digging of wells for water, controlled grazing, controlling deforestation and settlement planning to enhance vegetation cover. Others are proper land management, management of water sources, peace meetings between warring communities and measures put towards protection of Kirisia forest reserve.
Exploitation of nature	Collecting honey and wild fruits from the forest, using herbal treatment.
Seeking external assistance	Relief food from the National and County government and borrowing from relatives and friends
Reducing the herd size	Selling livestock to buy food, slaughtering livestock, keeping a manageable number of livestock that can be sustained during drought
Livelihood diversification	Venturing into alternative livelihoods including poultry production, other businesses, fishing and crop farming.
Alternative livestock feeding strategy	Getting green leaves and pods from trees to feed the livestock, purchasing hay and supplementary livestock feeds.
Taking care of sick animals	Includes de-worming of livestock, treatment of the sick and vaccination of livestock.

4.3.8 Factors that inform the decision of the pastoralists on where or when to move their animals

Pasture availability was reported to be the most important factor influencing decision-making on where pastoralists will move their animals as mentioned by all (100%) of the respondents. This was followed by water availability (97.4%), conflicts (82.9%), availability of salt licks (79.4%), type of livestock kept (79.1%), and emergence of livestock diseases (72.8%). The results of the responses are described in table 4.4 below:.

Table 4.4: Analysis of factors that inform the decision of the pastoralists to move their animals

Factor	Yes	No
Water availability	336 (97.4%)	11 (2.6%)
Physical barriers	185 (53.6%)	160 (46.4%)
Type of livestock kept	273 (79.1%)	72 (20.9%)
Household labour	143 (41.4%)	202 (58.6%)
Pasture availability	345 (100%)	0
Emergency of livestock diseases	251 (72.8%)	94 (27.2%)
External Interventions	136 (39.4%)	209 (60.6%)
Conflicts	286 (82.9%)	59 (27.1%)
Availability of salt licks	274 (79.4%)	71 (20.6%)

4.3.9 Livestock diseases during herd mobility

A total of 96.25% of the respondents admitted that livestock diseases are a challenge during herd mobility (Figure 4.24). There was no statistically significant association on the responses towards the challenge of livestock diseases during mobility between the 6 study sites (χ^2= 0.078, df= 1, p= 0.780).

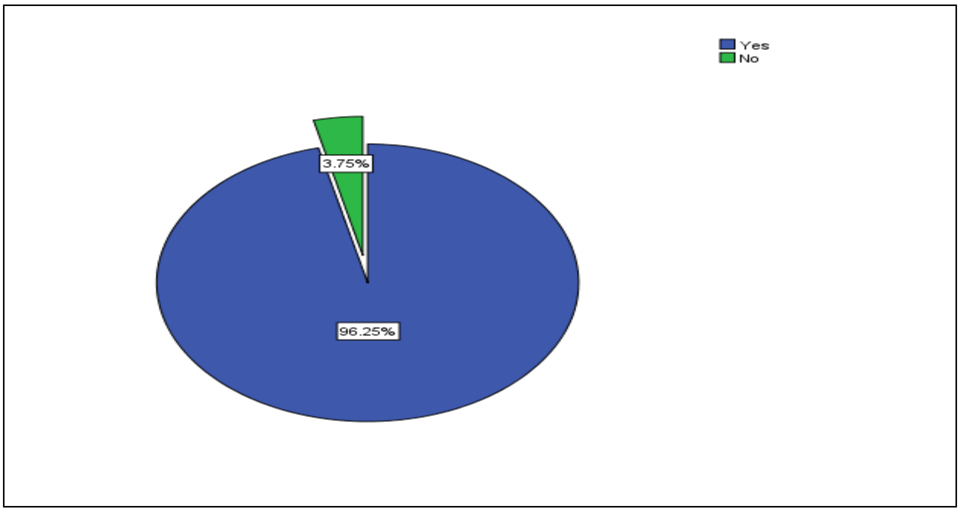


Figure 4.23: Perception of respondents on disease challenge during mobility

Diseases that were mentioned by the respondents to be a challenge during herd mobility included Heartwater, Foot rot, 3-days fever, Worms, Anaplasmosis, Enterotoxaemia and FMD. Additionally, the respondents also mentioned PPR, Trypanosomiasis (Nagana), Camel pox, Red water (Babesiosis), ECF and LSD. The diseases also included Diarrhoea, Black quarter, Anaemia and Sheep and Goat pox.

4.3.10 Effects of diseases on the household and the animals during mobility

The reported effects of diseases were categorized into two and summarized on a table (Table 4.5). The effects at the household level mainly impacted on the nutrition and food security while the effects on the animal was mainly on its health and reproduction.

Table 4.5: Effects of diseases on the household and the animals during mobility

Effect of diseases on the household	Effect of diseases on the animal
Reduction in food availability and food security	Poor health and death of animals
Restricted mobility	Infertility of the affected livestock
Reduced number of livestock	Loss of market weight
Poor quality and quantity livestock products (milk, meat)	Low reproduction rate
Transmission of diseases to humans	Poor quality of livestock products

4.3.11 Coping strategies to reduce the effects of livestock diseases

A number of coping strategies to reduce the effects of livestock diseases were mentioned by the respondents including buying of drugs to treat sick animals, moving the animals to areas not affected by diseases, calling veterinarians to treat the sick and reporting disease outbreaks. Other coping strategies included controlled movements, herbal treatment, isolation of the sick animals, quarantining the sick animals and restricting livestock movement. In addition, the respondents have been coping through seeking assistance from government and other partners, selling some animals to buy drugs, slaughtering the affected animals and throwing away dead carcass to prevent spread of diseases.

4.3.12 Control and treatment of livestock diseases during mobility

The responses here were classified based on the actor or the person responsible for taking the action to control or treat the livestock disease in question. The following are the categories:

a) Pastoralist-dependent roles - Avoid interaction between livestock and wildlife, avoiding areas prone to diseases, avoiding taking animals to rocky areas like Terter in Baragoi, deworming and spraying and keeping drought resistant breeds. Others included early treatment, herbal treatment, independent herd grazing, isolating sick animals, moving to areas not affected by the disease, timely reporting of disease outbreaks and community elders control movement of livestock to control spread of diseases.

b) County government or partner-dependent roles - Construction of disease control facilities i.e. cattle dips and crushes, early disease detection and communication, increasing veterinary personnel for efficient response, setting aside strategic areas for disease control and timely information on upcoming disease control programmes. Others are training herders to carry out vaccinations and treatment of diseases, treating animals prior to mobility, using dry season grazing areas as disease control zones, carrying out mass treatments, vaccinating livestock, passing reliable information in advance, quarantine and training community members on disease control and treatment.

4.3.13 Constraints in accessing veterinary services

The respondents mentioned a number of factors constraining the access to veterinary services in the rangelands of Samburu County. The constraints were categorized into 4 based on information, vaccine-delivery,infrastructure and human-induced constraints Table 4.6 presents the constraints to access of veterinary services mentioned by the respondents.

Table 4.6: Constraints mentioned by the respondents to be affecting access to the veterinary services

Information-based constraints	Vaccine delivery constraints
▪ Improper communication channels ▪ Inadequate communication on upcoming veterinary services ▪ Non-reporting of disease outbreaks ▪ Lack of proper mobilization and scheduling ▪ Lack of knowledge on how to identify and treat diseases	▪ Overcrowding during vaccinations ▪ Few veterinary officers ▪ Some diseases cannot be identified without carrying out tests ▪ Irregular vaccinations ▪ No identified location/site for regular vaccination ▪ Vaccines unavailable or inadequate ▪ Slow pace during vaccinations
Infrastructure-based constraints	**Human-induced constraints**
▪ Poor road network ▪ Inaccessible veterinary offices to report cases of diseases ▪ Inaccessibility of some areas during vaccinations ▪ Inadequate or unavailability of disease control facilities e.g. dips and crushes	▪ Non-reporting of disease outbreaks ▪ Over-dosage - under-dosage due to absence of veterinary personnel ▪ Non-involvement of community members in disease control activities ▪ Scattered settlements making it hard to vaccinate animals in one location ▪ Insecurity and resource-based conflicts

4.3.14 Ways to improve access and delivery of veterinary services

The respondents suggested a number of ways to improve delivery of veterinary services to the pastoralists (table 4.7). Key among them is the importance of proper communication, improvement of vaccine delivery and enhancement of knowledge and skills in livestock disease detection, treatment and control among the pastoral communities.

Table 4.7: Ways to improve access and delivery of veterinary services

Solutions to improve delivery of veterinary services	Description
Proper communication	Proper community mobilization, sharing of information and efficient communication on the upcoming veterinary services and establishing a livestock disease reporting office or information centre or hotline. In addition, timely reporting of disease outbreaks as well as working closely with identified key community contact members.
Improvement of veterinary vaccine delivery	Timely vaccinations, creating strategic locations for vaccinations, increase the number of veterinary personnel, allocate more resources towards disease control,provide enough vaccines and introducing village-level vaccinations and treatments.
Infrastructure development	Improve communication infrastructure, improve road networks, enhance accessibility to drugs, construct new strategic cattle dips and rehabilitate old ones for pest control and construction of crushes.
Knowledge and skills improvement	Sensitization and training community members on disease identification, control and treatment, training some herders to assist in vaccination and financial support to herders.
Animal diseases preventive measures	Regular de-worming, let herders treat their livestock where veterinarians are not accessible, mass treatments to be done twice a year, regular disease surveillance, sensitization on disease control and bring veterinary services closer to the people.

4.3.15 Information channels for disease outbreaks and upcoming veterinary services

There are a number of ways that the respondents reported for getting information about diseases outbreaks and upcoming veterinary services. They include local leaders (area chief and village administrator), nyumba kumi, local forums (public barazas, village or community meetings), community members (neighbours, villagers), community disease reporter and community mobilization meetings done by veterinary department. Other ways mentioned by the respondents were through County government, drought monitors, relatives (from husband, own children), from Monthly NDMA Bulletins and public notices (posters from veterinary department).

4.3.16 Reporting channels for disease outbreaks

When asked on to who they report disease outbreaks, the respondents mentioned that they give information to local leaders (area chief, village administrators, village council), area disease reporter and County government through veterinary department or individual veterinary officers. Other recipients of the information included drought monitors, relatives, traditional herbal specialists and villagers.

4.3.17 Prevention and control measures for livestock diseases by the community

Respondents gave a number of ways that they use to prevent or control livestock diseases in their herds which are listed in table 4.8. Disease control measures include isolation of sick animals and changing grazing area while disease preventive measures included spraying animals to get rid of ticks and vaccinating all animals. However, a number of respondents also said that they do not use any prevention and control methods for livestock diseases, while some simply prayed to God to take away the diseases from their animals.

Table 4.8: Prevention and control measures for livestock diseases by the community

Disease preventive measures	Disease control measures
Spraying animals to get rid of ticks	Changing grazing area
Vaccinating all animals	Changing watering points
De-worming	Keeping animals away from affected animals
Treatment using prophylactic drugs	Treatment of sick animals using veterinary drugs
	Restriction of movement though quarantine
	Slaughtering and disposal of the affected livestock
	Isolation of sick animals

4.3.18 Constraints for prevention and control measures taken by the community

Prevention and control measures taken by the respondents were reported to have been constrained by various factors that are described in table 4.9. Some of the factors include inaccessibility of vaccination centres, convergence of animals in common grazing areas and water points where diseases are transmitted and lack of drugs and vaccines for the animals and when available they are expensive and herders cannot afford to buy.

Table 4.9: Constraints for prevention and control measures taken by the community

Constraints	Description
Infrastructure-based solutions	Inaccessibility of vaccination centres,
Traditional institution-based constraints	Uncontrolled grazing, lack of knowledge on how to vaccinate and what drugs to use for treatment, increased herd mobility makes it difficult to target any specific area
Regulator-based constraints	Lack of drugs and vaccines for the animals and when available they are expensive and herders cannot afford to buy, inadequate enforcement of quarantine measures, unavailability of veterinary personnel in the area, lack of skilled personnel at community level, poor communication and poor timing of vaccinations
Administrative constraints	Insecurity and lack of financial support to herders
Pastoralist-based constraints	Convergence of animals in common grazing areas and water points where diseases are transmitted, untimely reporting of disease outbreaks and high illiteracy levels
Emerging factors	Unpredictable disease outbreaks, changing disease distribution patterns and new emerging diseases

4.3.19 Possible solutions to improve prevention and control of livestock diseases

The possible solutions proposed by the respondents were categorized into 5 including infrastructure-based, traditional institution-based, regulator-based, community-based and administration-based. More detailed description of these categories are presented in table 4.10:

Table 4.10: Solutions to improve prevention and control of livestock diseases

Solutions to improve prevention and control of diseases	**Description**
Infrastructure-based solutions	Construction of cattle dips and vaccination crushes
Traditional institution-based solutions	Controlled grazing, regulate herd mobility and grazing patterns
Regulator-based solutions	Enforce quarantine during outbreaks, proper timing of vaccinations, provide disease control facilities, recruit veterinary personnel and deployment to the ward level, regular disease surveillance, supervision of veterinary officers to improve efficiency, training and sensitizing livestock keepers on how to control, treat and prevent livestock diseases, enhance accessibility to veterinary drugs and vaccines in the area, identification and training of selected herders as community livestock health workers, improving communication, veterinary department should consider distances from villages when designing vaccination sites and working closely with local people for easy monitoring of disease outbreaks.
Administrative solutions	Improve security and provide financial support to herders
Pastoralist-based solutions	Use proper personal protective equipments (PPEs), timely reporting of disease outbreaks.

5.0 Discussion

The perception on climate variability trends generally varied across the study locations but with a universal agreement that rainfall has been on the decline. All other climate factors, excluding rainfall, such as temperature, floods, and droughts, were said to have increased over the study period. Additionally, only rainfall was predicted to decrease in the future among the climatic factors, while respondents predicted that temperature, drought, and floods could increase in the future. This is in agreement with global projections that temperature will increase within a range of 1.0^{o}C and 3.5^{o}C by 2100 (Githeko *et al*., 2000). This is consistent with the observation that the trend in rainfall has been declining. The UNDP's climate change assessment for Kenya indicates that instances of heavy rainfall are gradually increasing without a statistically significant trend (McSweeny *et al.*, 2010). The report goes on to elaborate on the findings by highlighting that there has been no statistically significant association between rainfall records since 1960.

According to the responses from the Arsim area, the region has continued to experience major rainfall occurrences since 2011, when it was severely flooded. A household investigation revealed that the main cause of the displacement of populations in Arsim was floods. Most of the affected households in Arsim sub-location are said to have settled next to the rivers that flows from Ndoto Mountains, and flood particularly during the heavy rainfall events (Lelenguyah *et al*., 2021). It is known that whenever there are floods in the affected areas, people are displaced, there are casualties and property losses, as well as emergence of diseases.

Most of the respondents perceived temperature to have been increasing while droughts to be more severe in the study locations over the study period. On the other hand, environmental variables that included water sources and vegetation were said to have been on the decline. The diminishing trends in water sources and vegetation cover can be attributed to the declining trend of rainfall received in most of the arid and semi arid areas. The changes and variability in climate is being experienced in most of the pastoral areas of the African continent (Ayanda, 2013; Abroulaye *et al*., 2015).

The pastoralists had varied opinion on the trend of the vectors of livestock diseases. While they perceived the trend of ticks and mosquitoes to be an upward one, those of other biting flies as well as tsetse flies were said to be declining and/or constant respectively.

This is a confirmation of what was observed by key informants in a study carried out by Lelenguyah *et al.* (2021). According to other findings (Githeko *et al.,* 2000; Kshirsagar *et al.,* 2013; Lelenguyah *et al.,* 2014; and Nguku *et al.,* 2010), precipitation, temperature, and humidity fluctuations have an impact on the ecology and biology of vectors, which can lead to an increase or decrease in the population of those vectors. Key informants in these locations, however, assert that the change in land use may also be responsible for the decrease in the number of biting flies (Lelenguyah *et al.,* 2021). According to the community and organizations leaders in Samburu County, there has been increased bush management and land use changes activities over the recent past in Ngutuk Engiron, Lonyangaten and Longewan in order to pave way for crops and pasture production, and in some instances the changes brought about by charcoal production activities. The cultivation and bush clearing and management activities typically results in the destruction of the habitat for livestock disease vectors and causes a decline in their populations (Yatich, 1987; Lelenguyah *et al.,* 2014).

Analysis of the perception on the trend of veterinary diseases under investigation revealed that only trypanosomiasis and camel pox declined over the study period. The rest including FMD, CCPP and PPR were considered to be on the rise. Githeko *et al.* (2000) suggested that changes in the ecology and physiology of disease vectors increase the probability of disease transmission, which may be a major factor in the rising trend of diseases over the period under study. Climate and weather variations also contributes to the increasing or decreasing trends of disease outbreaks because such changes are known to affect both the spatial and temporal distribution and the intensity of the outbreaks (Githeko *et al.,* 2000; Kshirsagar *et al*., 2013; Lelenguyah *et al.,* 2014; Nguku *et al*. 2010). This affects most of the diseases including CCPP which commonly occurs during colder seasons (Lelenguyah *et al*., 2021).

Generally, the observed changes have had negative impacts on the pastoralists' livelihoods including livestock deaths resulting to poverty and destitution, reduction in pasture and water availability as well as reduction of livestock productivity and market value. Other effects included human deaths as well as livestock migrations. These impacts seem to cut across rangelands in most ASALs (Ayanda, 2013; Bailey, 2012; Catley *et al.,* 2005; Egeru, 2016; Onono *et al.,* 2010). As a coping strategy, pastoralists resorted to migration, resource-use planning, exploitation of natural resources, reducing herd size as well as livelihood diversification. While migration to other areas allows pastoralists to utilize available resources in a rotational manner, reducing the size of the herd though taking some to family members who stays in areas not affected by drought reduces the risk of losing the whole herd (Belay *et al.*, 2015; Opiyo *et al*., 2015). When the effects of climate variability persisted, the pastoralists had to seek external assistance as well as alternative livestock feeding strategies which included hiring of private pasturelands, purchasing hay and lopping of trees to feed livestock.

According to the respondents, pasture availability was a key factor considered by the pastoralists in coming up with a decision on where and when to move their livestock. This was followed by proximity to watering points, vulnerability to conflicts, species of livestock kept and outbreak of livestock diseases respectively. While this observation is also shared by the key informants in the area (Lelenguyah *et al*., 2021), coincidentally, pasture scarcity also becomes a factor of insecurity and conflicts (Abroulaye *et al*., 2015). Water availability and availability of transhumance routes are other factors that can result to conflicts according to Abroulaye *et al*., (2015).

Managing livestock diseases is difficult during herd mobility. Heartwater, ECF, Redwater (babesiosis), Anaplasmosis, and Trypanosomiasis (nagana) were some of the vector-borne diseases cited by the respondents as being a challenge during herd mobility. The productivity of animals is severely hampered by livestock diseases (Belay *et al.*, 2015). Therefore, raising livestock as a source of livelihood for pastoralists becomes a nearly impossible endeavor as it becomes increasingly harder to control such diseases during herd mobility. The impact of diseases on animals and the household during mobility were various according to the respondents. The effects included a negative impact on household food availability and food security, animal health problems and deaths, movement restrictions, infertility in the afflicted livestock, and weight loss. The spread of zoonotic diseases to humans, weak and unhealthy animals, low reproduction, poor quality products, a reduction in the number of livestock, and poor quality and quantity of livestock products (meat, milk) were additional effects of diseases on livestock during mobility. Livestock diseases can not only pose a great challenge to food security situation of the pastoralists but also a health risk as some of the pastoralists feed on the dead animals (Chengula *et al.*, 2013; Montavon *et al*., 2013). Therefore, it is imperative that the County and National governments take measures to curb the spread of these diseases and reduce its effects on the pastoralists.

The respondents listed a number of coping mechanisms to lessen the effects of livestock diseases, including purchasing medications to treat sick animals, moving the animals to locations free of disease, putting sick animals to death to prevent disease spread, and reporting disease outbreaks. Other coping mechanisms included restricted movement, herbal treatment, and quarantining sick animals. In addition, the respondents have been coping through seeking assistance from other places, selling some animals to buy drugs. These coping strategies has been in use by the pastoralists for a long time (Lamuka et al. 2017; Chengula *et al.,* 2013; Kshirsagar *et al*., 2013; Aklilu and Wekesa, 2001).

The veterinary staff were not readily available in most of the pastoral areas to provide treatment to livestock when need arises. This observation confirms what was observed by Chengula *et al*. (2013). This forces the pastoralists to use readily available options including using herbal treatments and, in some instances using already expired drugs. Despite the fact that pastoralists strived to cope with the effect of livestock diseases through putting in place their own traditional coping mechanisms, they were constrained due to limited knowledge on livestock diseases, poor infrastructure, lack of drugs and vaccines, insecurity and lack of disease control facilities. The respondents complained of poor communication on upcoming veterinary services, non-involvement of local community members and inaccessibility of some of the sites identified for disease control. The best ways to handle livestock diseases challenge in the pastoral areas is to sensitize the pastoralists so that they are able to report emergence of diseases while at the same time using the community animal health workers to control such diseases (Chengula *et al.,* 2013; Kshirsagar *et al*., 2013).

6.0 Conclusions and recommendations

Pastoralists' perception indicates that there has been general decline in rainfall and an increase in temperature and drought and floods incidences in Samburu County. The observed changes have had negative impacts on the pastoralists and their livelihoods. This calls for concerted efforts to ensure that the pastoralists and their livelihoods are secured against climatic shocks. The measures include improvement of veterinary services, infrastructure development and enhancing information dissemination mechanism to suit the pastoral areas.

Livestock diseases were perceived to be among the major challenges affecting pastoralists and their livelihoods. To improve veterinary services, it is very important to streamline communication channels, conduct timely and regular vaccinations, improve infrastructure and enhance knowledge and skills of pastoralists/herders on disease control as well as streamlining animal diseases preventive measures. The relevant agencies need to identify the most appropriate channel of communication that is convenient for most of the community members. For instance, the use of community disease reporters (CDRs) in collaboration with local administrators can be very appropriate. There is need for a policy change in order to use of paravets in disease control since as they are now, they are not recognized by Kenya Veterinary Board.

Critical livestock facilities that support livestock production include water points, livestock markets, crushes and cattle-dips. These facilities are few and unable to serve the huge livestock populations in the county. There is need to develop more livestock markets, strategic water sources and vaccination crushes while mapping the existing structures.

CHAPTER FIVE

5.0 KEY INFORMANTS PERCEPTIONS ON CLIMATE VARIABILITY, LIVESTOCK DISEASES, AND HERD MOBILITY AND THE ADAPTATION STRATEGIES OF PASTORALISTS IN SAMBURU COUNTY

Manuscript published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-1, December 2021, pp.273-279, URL: https://www.ijtsrd.com/papers/ijtsrd47777.pdf

Lelenguyah, G. L., Nyangito, M. M., Wasonga, O. V., & Bett, R. C. (2021). Perception of Key Informants on Climate Variability, Livestock Diseases, Herd Mobility and the Adaptation Strategies of Local Pastoralists in Samburu County, Kenya. *IJTSRD*, *6*(1).

5.1 Abstract

The continued rise in global temperature, increasing rainfall intensity and frequency of droughts would have a severe impact on pastoralists' livelihoods. Planning for sustainable responses and management of disasters resulting from these changes requires an awareness of how the major stakeholders perceive the changes and assessing their contributions towards mitigations of impacts. The pastoralist communities manage resources variability through regular herd movement and dividing their grazing areas for utilization into dry and wet season. However, little attention has been paid to the information on which pastoralists base their methods for managing resources and how they view the major problems that affect herd mobility. This study aimed to examine how key informants perceived climate variability and livestock diseases effects on pastoralists' livelihoods, their coping strategies and the institutional support systems available. Interviews with the key informants were used in this investigation. A total of twenty-two (22) key informants selected purposively were interviewed; these included veterinary officers, livestock officers, veterinary drugs outlets and other key stakeholders from each of the three Sub-counties of Samburu County. Themes and sub-themes were developed through the qualitative analysis of key informant data. The respondents observed that there have been climate variations that has continued to affect the pastoralists. The effects of the changes stated included the death of animals, a rise in disease occurrences, and more frequent migrations. The study suggests controlled herd mobility and grazing management, and continuous vaccination of livestock to reduce disease recurrence. The development of grazing management committees, drug provision, additional livestock treatment sites, and vaccination of animals before entry into disease infested areas are hereby recommended.

Keywords: climate change adaptation, herd mobility, key informant interviews, livestock diseases, pastoralists

5.2 Background

The rangelands that the pastoralists relied on for thousands of years have continued to be affected by climate variability and change in terms of pasture and water availability (GoK, 2017; Wasonga *et al*., 2011; Fer *et al*., 2017; Mcsweeney *et al*., 2010; Lelenguyah et al., 2014). Because of this, pastoralists and their herds have been moving about regularly in pursuit of these rare supplies (Adriansen, 1999; Ellis and Galvin, 1994). Pastoralists from many ethnic groups have always found themselves converging and vying for the same resources since the availability of these resources determines their migration patterns (Lengoiboni, 2011; Mulianga, 2009).

Pastoralism is reliant on the intricate interplay of the environment's resources, thriving community structures for administration, and livestock that has become adapted to it. Environmental resources, local institutions, and livestock are the three primary pillars of pastoralism; all three are greatly influenced by seasonal patterns, whose functionality is continually disrupted by climatic change.

Pastoral communities divide their land into dry and wet grazing zones to manage it (Lengoiboni, 2011; Lesorogol, 2008). During the rainy season, they graze in drier portions of the rangeland, then shift to wetter areas during drought, when there is no more grass or water available (Meza-Morales, 2010). For generations, this nomadic movement has maintained pastoral life, but today their livelihood is in jeopardy as climate change takes front stage. Floodstorms and cyclical droughts are two examples of how climate change presents itself in dryland regions damaging livelihoods by causing high livestock mortality, compromising people' adaptive capacity and resilience in Kenya's drylands.

In Kenya, regular mobility usually occurs mainly as the dry season sets in. There are two such seasons in the ASAL areas of this country and they occur in the months of July to September and January to March (Mutai & Ward, 2000). During these periods, pastoralists maintain their seasonal routes dictated by pasture and water availability. As the pastoralists move, they come across various challenges such as competition for resources leading to resource-based conflicts, livestock diseases and predation from wild cats (Blench, 2000; Moenga et al., 2016). Livestock disease cases are usually presumably higher due to the fact that veterinary services in the dry season grazing areas are limited or not available at all. At the same time, livestock from all over the various pastoral communities converge in such areas, hence the risk of spread of diseases also rise.

Despite the recurrent epidemics and loss of animals, little attention has been paid to finding solutions to pastoralism-related livestock disease outbreaks and their control. A disease-specific control strategy has not been developed for these harsh pastoral environments. Particularly, the relationship between climate variability and herd mobility, and the resulting disease incidences has not been examined.

In order to control livestock diseases resulting from herd mobility and to adapt pastoralists to the changing climate, this study sought to get information from key informants who are mainly professionals working in various organizations in the three sub-counties of Samburu County. The information obtained was on the various changes in climate and disease patterns, its effects on pastoralists, their coping strategies and the assistance provided by these organizations. The study then suggested disease control strategies and interventions for pastoralists in northern Kenya to ensure that climate variability and herd mobility do not constrain livestock disease control.

5.3. Methodology

5.3.1 Study area

The study area is as described in Chapter 3 (Figure 3.1).

5.3.2 Research design and sampling procedure

The study utilized a non-probability sampling technique. Purposive sampling was used to determine the sample size for the institutional survey. The investigator might choose representative units using expert judgment based on non-probability sampling technique. A total of twenty-two (22) key informants from the public and private sectors were interviewed for this study at the county and sub-county levels between March and June 2021. Veterinary (3), livestock (3), Agriculture (3), National Drought Management Authority (NDMA) (1), Special Programs (3), County Livestock Marketing Council (CLMC) (1), Food and Agricultural Organization (FAO) (1), CARITAS (1), Veterinary drug outlets (3), and Sub-County administration (3) were the organizations chosen for key informant interviews. The selection of the institutions and the key informants, however, was purposive and primarily based on the significance of the institution and the key informant's position in the community under investigation. The results of this study was used to triangulate information that had already been collected from the local pastoralists. The respondents from the selected organization were asked questions with regard to climate variability trends, trends of livestock diseases, coping strategies for the local pastoralists and support provided by the organization to the community to assist them cope with the changes and towards disease control. The interviews were administered with the assistance of trained enumerators.

5.3.3 Statistical methods and analysis

Themes and sub-themes were used to qualitatively analyze key informant data, according to Maguire and Delahunt (2017). Every interview was transcribed. In a qualitative analysis of the transcriptions, keywords and themes were found, allocated to a specific coding subject (such as decreasing rainfall), and then tallied to assess how frequently respondents made remarks about that theme. The transcribed interviews were analyzed using an inductive coding method to identify patterns in behavior and thought (Bernard 2002).

5.4 Results

The results of this study have been presented in form of themes and sub-themes as described by Maguire and Delahunt (2017). The presented results have focused on each of the key informant interviews questions that was asked during the research process. The summary of results of this investigation are as described in table 5.1.

Table 5.1: Key informant responses on the trend of various variables over the last 20 years (2000 - 2020)

Selected Sub-themes	Key informant responses (N = 22)
Decreasing rainfall amount	86.4%
Increasing temperature	77.3%
Normal trend of floods	59.1%
More severe droughts	77.3%
Fewer water sources	54.5%
Less vegetation cover	59.1%
Increasing trend of mosquitoes	63.6%
Increasing trend of ticks	68.2%
Constant trend of tsetse flies	54.5%
Increasing cases of PPR	77.3%
Increasing cases of CCPP	81.8%
Increasing cases of FMD	72.7%
Declining cases of Trypanosomiasis	59.1%
Declining cases of Camel pox	54.5%

5.4.1 Changes experienced in the trend of the climatic variables over the study period

5.4.1.1 Temperature

The respondents noted that there have been a lot of changes. Temperatures are becoming warmer. More heat is being experienced now during the day time and very few cold nights compared to before. The year 2016 was said to have been the hottest year. Temperature was also said to have become very high during dry season and fall below normal in wet season. Very high temperatures were also observed in 2002 and 2007 according to one of the respondents. This has been fluctuating where the normally perceived hot seasons of the year becoming hotter while the cold seasons become colder. Some of the respondents noted an increased diurnal range i.e. high temperatures during the day and very low at night. Highland areas like Maralal was said to have been very cold but warmer now.

5.4.1.2 Rainfall

The rains were said to have become quite erratic with a major shift in time of onset of rains from March being observed from early 2000. Frequency has also reduced with a lot of inconsistencies and little amounts attributed to climate changes. Unexpected above normal rains have often occurred and sometimes a total failure of rains. Some respondents observed that the highest was received in 2019, 2010 and 2013. It was observed that rainfall patterns have changed, they are no longer predictable thus causing problems to pastoralists. The rains have been unpredictable and either inadequate or sometimes in excess. Rainfall was said to have been declining between 1999 and 2019. It was noted that, it no longer follows the historical patterns of March-April-May and October-November-December.

5.4.1.3 Drought

Increased recurrence of drought was noted by the respondents with some saying that droughts are experienced approximately every 1-2 years. There was a general observation among the respondents that the periods between droughts have narrowed down to 1-2 years unlike previously where it occurred once in ten years. It was observed that severe droughts were experienced in 2002 and 2007 due to lack of enough rains. Other years that droughts were observed included 1999/2000; 2005/2006, 2008/2009; 2016/2017 and inadequate rains in between. What was referred to as a mini drought was also said to have occurred in 2013/2014. Generally, drought frequency has been on an increase over time and cases of prolonged droughts caused by failure of two consecutive rainfall seasons leading to serious drought.

5.4.1.4 Floods

Floods were said to have increased because of land degradation. Respondents mentioned flash floods have occurred causing property and livestock losses mostly experienced during El nino and extended long rains. Although floods were said to be uncommon in Samburu County, it was reported being experienced in 2010, 2013 and 2016 in some parts of the County. The frequency of floods was noted to have increased drastically and exacerbated by land degradation. Floods was only said to be affecting only a few pockets of Samburu County and mainly occurs along major rivers including Ewaso Nyiro, Seyia, Nagor-Oworu, Barsilinga and Lengusaka.

5.4.2 Effects of the changes on the livelihoods of the pastoralists

The key informants mentioned increased incidences of diseases, poverty levels and vulnerability as some of the effects of the changes.

> *"Recurrence of conflicts has increased over pasture due to reduced grazing land and pasture. Conflicts have increased as people compete for limited resources, the animals are forced to trek for longer distances resulting to increased pests and diseases. Poor harvests and losses due to untimely rain seasons leading to food insecurity. Loss of life of livestock, crops and properties as a result of floods".* **Sub-County Agriculture Officer (Samburu Central, Kenya)**

Livestock losses during droughts lead to increase in poverty levels. Above normal rains was said to have led to diseases like Rift Valley fever and Blue tongue hence exacerbating further loss of animals. There has been increased migrations of animals from one place to another in search of pasture and water. Pastoralists livelihoods system was also noted to have changed since most of the times they are constantly on the move looking for pastures and water for their animals, which has also affected them economically and socially. Loss of vegetation cover was said to have led to land degradation through soil erosion resulting into bare land.

Loss of human lives and properties every rainy season as a result of floods as well as loss of livestock during periods of drought and disease outbreaks was said to have led to pastoral drop outs which results to poverty at the household level. Many households were reported to have dropped from pastoralism to new trades including employments, petty trade and charcoal burning. Increased land degradation was blamed for poor regeneration of pastures resulting to less feed availability for livestock. The observed changes were also blamed for reduced purchasing power leading to reduction in number of meals consumed in a day, engagement in alternative livelihoods such as charcoal burning, increased dependency and increased school dropout rates. The old and children suffer most through malnutrition. Pasture and browse have reduced causing resource use conflicts leading to loss of livestock and human lives. Increased drought incidences have also led to depletion of natural resources (water and pastures) resulting to low livestock productivity and at times livestock mortalities due to frequent livestock movements.

5.4.3 Major diseases outbreaks over the last 20 years

Respondents gave a number of disease outbreaks that have been experienced over the last 20 years. They included FMD, PPR, ECF, RVF among others. A more comprehensive list is provided in Table 5.2 below.

Table 5.2: A list of the major diseases outbreaks over the last 20 years

Year	Livestock Disease	Year	Livestock Disease
2004	FMD	2009	PPR- Goats
2009	FMD	2010-2011	FMD
2018	PPR	2013	CCPP
2000	East Coast Fever	2017-2019	Foot rot
2013	FMD	2006/2007	PPR
2007	RVF	2016/2017	FMD
2016	SGP	2016/2017	LSD
2018	Blue Tongue	2016/2017	S&G pox
2017	PPR	2018	CCPP
2018	FMD	2019	HS
2019/2020	FMD		

5.4.4 Areas perceived to be infested by the veterinary vectors in Samburu County

Infestation of veterinary vectors in an area means that the affected area is prone to the diseases caused by the vector. The major veterinary vectors includes ticks, tsetse flies, mosquitoes and a variety of biting flies. The respondents mentioned areas infested by these vectors (Table 5.3) and at the same time listing the locations with the highest infestation.

Table 5.3: Areas perceived to be infested by the veterinary vectors in Samburu County

Vector	Location with highest infestation	Other areas infested by these vectors			
		Area 1	Area 2	Area 3	Area 4
Mosquitoes	Samburu East	Archers Post	Sereolipi	Wamba	Lodungokwe
	Archers post	Wamba	Baragoi	Waso	South Horr
	Sereolipi	Wamba	Lodungokwe	Noonkeek	Lerata
	Wamba	Remot	Nangoroworu	Barsaloi	
	Along major rivers	Wamba	Nkaroni	Lkisin	Sereolipi
	Ndoto	Latakweny	Loikumkum	Suiyan	Barsaloi
Ticks	Samburu East	Loosuk	Kirimun	Suguta	Longewan
	Kitenya	Naiborkeju	Angata lerai	Longewan	Lorukoti
	Wamba	Sarara	Lengusaka		
	Mathew ranges	Ngilai	Oromoidei	Nkare narok	Wamba
	Elbarta	Lesirikan	South Horr	Tuum	Marti
Tsetse fly	Ndoto hills				
	Loosuk	Suguta	Logorate	Poro	Lesidai
	Tinga	Nasur	Kao	Amaiya	Baragoi
	Sarara	Reteti			
	Mathew ranges	Wamba	Ngilai		
Other biting flies	Illaut	Ngurunit	Sereolipi	South horr	
	Malaso	Kirisia forest	Tamiyoi	Opiroi	Barsaloi
	Ngilai	Sarara area	Nkare Narok	Murit	Ndonyo Uasin
	Masikita	Suiyan	Sererit	Seren	Ngurunit

5.4.5 Trends of the TADs in Samburu County over the last 20 years

Transboundary animal diseases were mentioned to have affected Samburu County over several decades. The key informants gave the trends of some of the TADs in Samburu County over the last 20 years (Table 5.4). The trend of most of the TADs mentioned was said to be increasing.

Table 5.4: Trends of the TADs in Samburu County over the last 20 years (Jan. 1999 - Dec. 2019).

Livestock diseases	Trend of livestock diseases			
	Increasing	Decreasing	Normal/Constant	Not sure
Trypanosomiasis	+	( )	+	+
CCPP	+++	( )	( )	( )
PPR	( )	+++	( )	( )
FMD	+++	( )	( )	( )
Camel pox	+	( )	+	+

+ indicates 33.3% of the responses; +++ indicates 100% of the responses; ( ) indicates 0% of the responses

5.4.6 Link between livestock disease outbreaks and climate variability

Although most of the livestock diseases were not directly linked to climate variability, frequent migrations of animals were blamed for the occurrence of most of the diseases. This is because these climatic changes lead to livestock movement from one area or Subcounty to other areas, Sub-counties or Counties. FMD is transmitted when animals move from one area to another in search of pasture. PPR was said to be a new disease associated with emerging trends in climate change. Blue tongue and RVF were noted to occur after above normal rains leading to flooding events while CCPP and foot rot were said to mostly occur during the rainy season.

5.4.7 Areas that livestock graze during different seasons in Samburu County.

The key informants, just like the household heads were the major source of information on where livestock grazed during different seasons of the year. The respondents were given an opportunity to mention three key areas that livestock moved to in each of the four seasons experienced in Samburu County. The areas mentioned area captured in Table 5.5.

Table 5.5: Areas that livestock graze during different seasons in Samburu County

Month	Area 1	Area 2	Area 3
Jan. - March	Lorroki	Wamba	Marti
	Lbukoi	Kawap	
	Kirisia forest	Marti	Suguta valley
	Elbarta plains	Kom	Maralal
	Naiborkeju	Sura Adoru	Kirimun
	Maralal	Baragoi	Sarara
	Losesia	Kom	Mathew ranges/sarara
	Naisiicho	Kawap	Mbukoi, Naturkan
	Sarara	Kom	Seketani
	Kirimon	Kirisia Hills	Laikipia
	Mathew ranges	Sarara	Ndonyo wasin
	Suiyan	Naisiicho	Sere olipi
April - June	Around homesteads		
July - September	Lorroki	Laikipia	Longewan
	Elbarta plains	Kom	Maralal
	Nkutoto Arus	Logorate	Amaiya
	Sarara	Reteti	
	Laikipia	Kirisia	Kom
	Laikipia	Marti	Losesia/Kom
	Angata Esikiria	Kawap	Mbukoi, Masikita
	Lorukoti	Lodungokwe	Nkaroni
	Kom	Baragoi	Laikipia
	Marti	Tuum	Laon
October to December	Around homesteads		

5.4.8 Determinants of herd mobility patterns each year

The major determinant of herd mobility was said to be the amount of rains received in a particular area. If, for instance, the wet season has not received sufficient rains around the homesteads then there is increased mobility. According to the key informants, the pastoralists have become accustomed to their own seasonal calendar that they tend to follow. During wet seasons all animals are driven back home while during dry seasons, they move to the dry season grazing areas. The unpredictable weather patterns has resulted in the interruption of the normal rainfall cycle. Generally, herd mobility patterns are dependent on availability of pastures and water

5.4.9 Challenges of livestock diseases during herd mobility

The key informants acknowledged the fact that livestock diseases have become a major challenge during herd mobility. As livestock interact from different localities, they transmit diseases to each other. This is because livestock from different areas converge and thus incidences of diseases increase. There are also incidences of diseases being transmitted between sick herds and healthy herds especially at water points. Despite the increased incidences of livestock diseases during herd mobility, the veterinary drug outlets reported low demand for veterinary drugs during these periods. This could mean that when animals move far away from the homesteads, there's less focus on their health due to decreased purchasing powers at the household level and accessibility of drugs. The disease challenge during herd mobility lowers the productivity of livestock thus affecting their market value. Insecurity also occurs as a result of livestock diseases since avoiding infected areas and moving to other areas increases insecurity due to conflicts between communities. Even as the risk of disease transmission increases in the dry season grazing areas, the key informants from veterinary department observed that controlling diseases during these periods also poses another major challenge. This is especially so due to the vastness of the area as well as lack of accessibility to where livestock graze and also insecurity challenges.

> "*Its a big challenge controlling diseases during herd mobility considering the inter-County nature of migrations. Also some of the areas are hard to reach and veterinary service provision becomes a challenge*". **Sub-County Veterinary officer (Samburu North)**

Major migrations always results to major disease outbreaks periods leading to closure of markets to curb further spread.

Apart from livestock diseases, other challenges that were mentioned by the key informants included animals feeding on crops and pastures in private farms resulting to conflicts with crop farmers, increase in petty theft, and reduction in household income. When the animals were away from home, households were said to be unable to buy farm inputs for crop production and pay for cost of cultivation. Influx of livestock from other areas was also said to have led to low market prices.

5.4.10 Local community coping strategies to diseases and other challenges

The respondents mentioned a number of coping strategies employed by the pastoralists when faced with diseases and other challenges. They included selling of their animals and buying drugs, appealing to the government for support, destocking weak animals and reporting to local leaders for example chiefs or community disease reporters trained by livestock department. In addition, the key respondents also mentioned imposition of quarantine in specific grazing areas and watering points, treatment with drugs from the veterinary outlets, use of ethno-veterinary medicine and vaccinating their livestock before and during outbreaks.

> *"The community cope through self-administration of veterinary drugs without seeking professional services and most cases let these diseases take a natural course".* **Sub-County Special Programs Officer (Samburu East)**

Herd splitting to make them manageable was also said to be a coping strategy during herd mobility. During disease outbreaks, the pastoral community also seeks support from veterinary department. Other coping strategies noted by the key informants included peace dialogues through community barazas, migration to safer areas, fencing off of land, use of acacia pods and deferred movement to grazing areas, controlled grazing patterns and observing weather and climate patterns. Generally, the respondents observed that communities have become resilient to these challenges.

5.4.11 Organizations' interventions during disease outbreaks

The key informants being the representatives of the selected organizations mentioned a number of interventions that they provide during disease outbreaks. Such interventions included provision of logistical support to the veterinary department for instance by providing funds for disease surveillance and mass vaccinations, treatments, quarantines and livestock movement control, advising livestock owners, availing essential drugs to the livestock keepers, organizing outreach services and providing relief food to the communities. The NDMA has also developed an early warning systems used to train pastoralists on risk reduction. The veterinary department has also been doing capacity building on identification of diseases, surveillance and giving treatment at the village level.

> *”Other partners have been facilitating the procurement of vaccines to support veterinary department while others offer logistical support. Veterinary department have also been intervening through ring vaccinations, advising herders on the right drugs to be administered to various diseases, mass vaccinations either supported by county government or by other development partners and also advising farmers through offering extension services".* **County Director of Veterinary Services (Samburu County, Kenya)**

Some of the partners, work in collaboration with livestock department towards the control of livestock diseases through community sensitization, facilitating grazing plans, water provision, facilitating community dialogues and peace meetings, livestock offtake, offering supportive treatments and supplementary feeds during drought periods.

5.4.12 Factors that determine how and when different organizations intervenes in disease control

A number of factors were mentioned by the key informants to be the key determinants of the organizations' interventions. Among them are the length of the dry season, whether or not the situation calls for emergency intervention, availability of funds, partnership with relevant personnel during disease occurrence, size of the organization's budget allocation and procurement delays. Other factors included availability of transport, availability of resources (vaccines, facilitation allowances for the staff, vehicles and fuels, and adequate cold chain facilities), willingness of the farmers to accept their animals to be vaccinated and how well the communities/farmers have been mobilized to increase vaccines uptake and coverage. In addition, accessibility of the area by road, weather patterns (for instance during rainy seasons it is a challenge to do any interventions), migration patterns, incidences of disease outbreaks reported, stage of drought (Normal, alert, alarm or emergency), security status of the area and availability of partners support towards disease control interventions.

5.4.13 Ways that livestock diseases can be controlled/treated during mobility

A number of suggestions were made on how best to control or treat livestock diseases during mobility. These included minimizing migration, development of disease free zones, continuous vaccination to minimize disease recurrence, routine dipping, arrange herders to move in specific direction to minimize conflicts, creating awareness campaigns on disease surveillance during mobility and establishing of grazing management committees.

> *"I strongly advocate for provision of veterinary drugs and creating more livestock treatment stations, vaccination before entry into affected areas or preventive antibiotic therapy, weekly spraying to control ticks, providing prophylaxis drugs during herd mobility, isolating the sick animals from the rest of the herd and through mass vaccinations. This will ensure reaching out to large numbers of livestock".* **Sub-County Veterinary Officer (Samburu East, Kenya)**

Finally, restricting movement of herds by zoning the areas to be grazed, informing authorities in advance about the migrations, regular vaccinations, inter-County cooperation in disease control, understanding the livestock movement patterns and treating/vaccinating them at the specific sites, avoiding concentration of livestock in one area, supportive treatments, encouraging the use of ethno-medicine and ensuring the herders move to accessible areas during disease control were also suggested by the key informants.

5.5 Discussion

All the key informants agreed that there had been sporadic instances of extremely heavy rain with an irregular rainfall trend. This was in agreement with the UNDP's climate change assessment for Kenya, which indicates that instances of heavy rainfall are gradually increasing without a statistically significant trend (McSweeny *et al.,* 2010).

The key informants indicated that since 2011 when the area was subjected to exceptionally significant flooding, heavy rainfall occurrences have persisted in the Arsim area. The respondents observed that among the several circumstances that led to the displacement of the households in Arsim, the effects of floods predominated. Most homes in the Arsim area are located along the rivers that originate in the Ndoto Mountains and flood during periods of significant climate fluctuation, notably during periods of heavy rainfall. Floods inevitably cause population displacement, fatalities, and rising cases of water-borne diseases in the afflicted areas.

According to reports, temperatures and droughts got hotter and worse during the research period. Vegetation cover has also been declining. Nonetheless, only rainfall is anticipated to decrease in the future, but respondents also indicated that temperature rise, frequency of droughts and floods might probably increase. By 2100, it is anticipated that temperatures will have increased globally by 1.0 to 3.5 degrees Celsius (Githeko *et al*., 2000).

Most respondents believed that the trend for ticks and mosquitoes was upward. On the other hand, Tsetse flies were claimed to have a consistent trend, while other biting flies were said to be decreasing. Variations in temperature, precipitation, and humidity have an effect on the ecology and physiology of vectors, which may lead to a rise or reduction in the population of vectors, according to research by Githeko *et al.* (2000).

However, the respondents' perceived that the drop in the prevalence of other biting flies in these areas may have been influenced by changes in land use. They claim that increased bush clearing in Ngutuk Engiron, Lonyangaten, and Longewan for farming, pasture production, or simply for other economic activities like charcoal burning may also have led to change in population of veterinary disease vectors. Their population is reduced by destroying the vectors' habitat through cultivation and bush clearing (Yatich, 1995).

Only trypanosomiasis and camel pox were found to have decreased over the study period among the veterinary diseases under review. All other diseases, such as FMD, CCPP, and PPR, were thought to be getting worse. Githeko *et al*. (2000) postulates that the changes in the biology and ecology of disease-carrying vectors enhance the likelihood of disease transmission, which may be a major reason for the rising trend of diseases over the research period.

When dealing with disease outbreaks, the weather factor also comes into play because it is known that weather conditions impact both the timing and the severity of epidemics (Githeko *et al*., 2000). This is especially true concerning CCPP. According to the respondents, pasture availability was the primary determinant in deciding where pastoralists would move their livestock. Others included water availability, disputes, the kind of livestock kept, and the onset of livestock diseases.

Managing livestock diseases is difficult during herd mobility (Aklilu and Wekesa, 2001). Heartwater, sheep and goat pox, anaemia, black quarter, diarrhoea, LSD, and ECF are some diseases that respondents mentioned as challenging during herd migration. Other diseases were Redwater (Babesiosis), Camel Pox, Trypanosomiasis (Nagana), PPR, FMD, Enterotoxaemia, Anaplasmosis, Worms, 3-Day Fever, and Foot Rot.

Regarding how diseases affect livestock and the household during herd mobility, there are several effects on the herder or the pastoralists, the animal and the animal products (Bayissa *et al*., 2009). The respondents highlighted some implications, including the impact on household food supply and security, limited mobility, the effect on livestock reproduction, and weight loss. They also mentioned the effects on animal health and death. Other effects of infections on livestock during mobility included limited reproduction, reduced number of animals, low-quality and quantity of products (meat, milk), the transmission of diseases to humans, and weak and unhealthy animals.

The respondents listed several coping mechanisms to lessen the effects of livestock diseases, including purchasing medications to treat sick animals, moving the animals to locations free of disease, killing sick animals to prevent disease spread and reporting disease outbreaks. Other coping mechanisms included restricted movement, herbal treatment, quarantining sick animals, and controlling livestock movement. According to Chengula *et al.* (2013), pastoralists have become adapted to the arid and semi-arid rangelands where service provision is deficient and veterinary personnel and services are inaccessible. They, therefore, go to the extent of treating the sick animals themselves, controlling the movements of the herds thereby controlling the spread of livestock diseases.

5.6 Conclusions and recommendations

The key informants' perception indicates a general decline in rainfall and an increase in temperature and drought and flood incidences in Samburu County. The observed changes have had adverse effects on the pastoralists and their livelihoods. The pastoralists and their livelihoods need to be safeguarded against climatic shocks, which needs to be done through a collaborative approach by all the stakeholders. It is critical to improve veterinary services through effective communication channels, regular vaccinations and disease control infrastructure and to enhance the knowledge and skills of the pastoralists on disease control. Critical facilities supporting livestock production and disease control were said to be few and inaccessible. There is a need to develop more of these facilities to ensure effective disease control.

CHAPTER SIX

6.0 DETERMINATION OF THE RELATIONSHIP BETWEEN SEASONAL RAINFALL AND TEMPERATURE VARIABILITY AND HERD MOBILITY PATTERN IN SAMBURU COUNTY, KENYA

Manuscript published in the African Journal of Range and Forage Science in 6th July, 2023 as:

Lelenguyah, G. L., Nyangito, M. M., Wasonga, O. V., & Bett, R. C. (2023). Seasonal distribution of livestock in Samburu county, northern Kenya: a response to variable pasture and water in semi-arid rangelands. *African Journal of Range & Forage Science*, 1-14.

6.1 Abstract

Pastoral herd mobility is a key coping strategy in the arid and semi-arid rangelands where grazing and water resources are highly variable in space and time. The spatial and temporal climate variability dictate herd mobility, and therefore understanding this interrelationship is key to sustainable management of rangelands, especially in the face of the changing climate. This study was undertaken in Samburu County in Kenya, an area characterized by varying climatic conditions, land uses and agro-ecological zones to determine the interrelationship between rainfall and temperature variability and the mobility of herds. To achieve the research objectives, 20-years data for temperature, rainfall, normalized difference vegetation index (NDVI) and geo-referenced data (GIS) together with field data obtained through household interviews and community participatory mapping were utilized. Wet-season and dry-season grazing areas characterize the Samburu pastoral system. Only in Samburu central which is endowed with good rainfall did the pastoralists graze around their homes all year round. Livestock in Samburu east infrequently graze around homesteads due to low rainfall received and degraded pastures. The herds spatial distribution patterns followed pasture availability as shown by vegetation NDVI patterns. Areas with higher NDVIs of over 0.3 attracted herds concentration but with high *in situ* mobility to maximize on grazing of the most nutritious pastures. Because of the irregular rainfall pattern, animals moved around the area in search of grass and water, and grazing patterns were always shifting. This study proposes grazing management embedded in observed herd mobility and grazing resource use patterns as a strategy towards adapting the pastoral communities to the changing climate.

Key words: *Herd mobility; Participatory mapping; Pastoralism; Seasonal grazing patterns*

6.2 Introduction

The practice of livestock keeping by the pastoralists who inhabit at least one half of the earth's surface enables utilization of the World's unfavorable areas characterized by extreme climatic conditions as well as the variability and uncertainty in climatic conditions (ILRI *et al.* 2021; Galaty and Johnson 1990). Pastoralism is the practice of animal production involving mobility of herds in time and space across expansive areas in search of scarce and highly variable grazing and water resources in the rangelands (Macopiyo 2005). In northern Kenya, particularly Samburu County, pastoral mobility has been documented to be the most effective strategy to make use of variable resources and this makes mobile pastoralism to be a highly-valued strategy in the management of grazing areas and exploitation of resource variability (Pas-Schrijver 2019). Rangelands are water limited ecosystems that largely occupy ASAL areas and support more than one-third of those that inhabit the African continent (Adriansen 1999). The rangelands make remarkable contributions to national, regional and world economic development by supporting livestock production opportunities, sustainable development goals (SDGs), carbon sequestration, wildlife conservation, promotion of tourism development and protection of culture (Timpong-Jones *et al.* 2023; Mulianga 2009).

In order to replace nomadic pastoralism and promote settled agriculture in suitable areas, the colonial government established the African Land Development Organization (ALDEV) in 1945. This organization created a private enclosure land system where land ownership was firmly based on family holdings (Kibugi, 2013). An investigation into land consolidation and registration in Kenya was ordered by the government in 1965. The inquiry report, also known as the Lawrence Report, came to the conclusion that group registration of land had greater significance to range areas than individual registration. The Land Adjudication Act and the Land (Group Representatives) Act were subsequently passed by the government in order to establish a legal framework for defining and regulating group ranches (Wayumba 2004; Wayumba 2017). In Samburu, grass predominates on poorly maintained rangelands. Overstocking, unplanned or unregulated grazing, overgrazing, and inadequate grazing management techniques have all contributed to their decline over the years (Pas-Schrijver 2019). Overgrazing and uncontrolled grazing are acknowledged as the two main causes of land degradation that lead to overgrazing and rangeland degradation in general. The degradation of Samburu County's natural grazing lands is primarily the result of shifting land use patterns, including the encroachment of settlements and cultivation into rangelands, partial breakdown of traditional seasonal grazing patterns, less mobility of herds as a result of new settlements, loss of the authority of traditional elders, and an overabundance of livestock (Lesorogol 2008). Additional contributing causes include climatic changes, such as frequent, protracted droughts and unpredictable rainfall linked to climate change. Investments in infrastructure including Lamu Port, South Sudan, Ethiopia Transport (LAPSSET) Corridor has heavily impacted on pastoralism in ways that includes restricting rights to land and other resources, triggering immigrations and increasing security issues (Lind, Okenwa and Scoones, 2020).

Rangelands cover 80, 50 and 40% of Kenya, Tanzania and Uganda respectively and have provided livelihoods for millions of pastoralists in East Africa (Fratkin 2001; Orindi *et al.* 2007; Nyariki *et al.* 2009). Pastoralists in these rangelands have lived harmoniously with their environment and herds. However, with increasing human population pressure, extractive market forces, renewable energy projects, afforestation programmes, land privatization and alienation from the pastoral system have precipitated grazing resource degradation and increasingly, resource-based conflicts in these areas. This situation is exacerbated by emerging diseases and other factors that pose challenges to access to pasture (Moenga *et al.* 2016). Climatic variability and change will increase the fluctuations of feed and fodder availability, further amplifying these risks. Moreover, increasing livestock numbers to meet rising need for animals products in the context of human population pressure, loss of pastoral land to conservation and agriculture have constrained access to enough feeds by pastoral communities (Galvin *et al.* 2001; Mulianga 2009). The major effect of these changes is reduced space that restricts seasonal mobility of their herds to exploit resources that vary spatially and temporally across the landscapes as dictated by both natural and climatic factors of the production system (Adriansen 1999; Mulianga 2009; Lengoiboni 2011). Such mobility could either be regular and limited to short distances or irregular which involves large scale and trans-boundary movements depending upon socio-economic, climatic and environmental factors (Samuels *et al.* 2019; Macopiyo 2005).

On the other hand, environmental and socio-economic factors are exerting negative trends posing a threat to the livelihoods of the pastoral community (Michael 2017). This includes increased variability of rain days and extreme weather events, increase in disease incidences (Kitasho *et al.* 2020). Vulnerability of pastoralists varies between places and changes over time and therefore this calls for development of a set of actions that are aimed towards adapting pastoralists to the changing climate (Eriksen and Marin 2011). The current adaptation practices employed by the pastoralists includes livestock destocking, livestock species diversification, migration, livelihood diversification while some have started growing fodder grass and engaging in petty trade (Kitasho *et al.* 2020; Cuni-Sanchez *et al.* 2019; Berhanu and Beyene 2015). Pastoralists are also exploring alternative livelihoods due to population growth, changes in land use and effects of droughts (Catley et al., 2016).

In Eastern Africa, rangelands experience two rain episodes with the long rains mostly being experienced between April and June and the short rains being received in the months of October, November and December (Galvin *et al.* 2001; Mutai and Ward 2000). In Kenya, mobility usually occurs as the dry seasons sets in. There are two such seasons in the ASAL areas of Kenya and they occur in the months of July to September and January to March (Mutai and Ward 2000). During these periods, pastoralists maintain their seasonal routes dictated by pasture and water availability. While dependent on the method of analysis used, mobility patterns among the pastoralists was seen as both unpredictable yet regular and orderly (McCabe 2010). As the pastoralists move, they face various challenges such as competition over resources leading to resource-based conflicts, livestock diseases and predation from wild cats (Blench 2000; Moenga *et al.* 2016). Livestock disease cases are usually presumably high during the drier months due to the fact that veterinary services in the dry season grazing areas are limited or not available at all (Nkedianye *et al.* 2011; Cowled and Garner 2008; Bayissa *et al.* 2009). At the same time, livestock from all over the various pastoral communities converge in such areas, hence the risk of spread of diseases. Low-potential rangelands which account for 77.5% of total land surface area in Samburu County, are primarily located in the Wamba North, Wamba East, Wamba West, Waso, Nyiro and Ndoto Wards, most of which land is controlled under community group ranch systems. Nomadic pastoralism dominates land use in these rangelands. The County has roughly 140,900 hectares (7%) of medium to prospective agricultural land. This area is located in the Kirisia and Lorroki area, which receive 600-900 mm of precipitation each year. Approximately 6,000 hectares are under cultivation and planted with beans, barley, maize, wheat, and a variety of fruits and vegetables. Nomadic pastoralism dominates the usage of the lowlands, which account for 77.5% of County's total mass. The cultivation activities are increasing while dairy production is becoming more popular (SCG 2018; 2013).

Overgrazing and its associated environmental deterioration are a problem with communal land ownership in the rangelands (Zinsstag *et al.* 2016). As more land is cultivated in the highlands, there is a reduction of vegetation cover and exposure of soils increasing its susceptibility to erosion. Acacia species dominate the vegetation in the Samburu lowlands, which are mostly covered with bushed and forested grasslands. Heavy grazing in the past and an uneven distribution of rain have resulted to bush encroachment making it difficult for cattle to find grazing for most of the year in the area between the Seyia River and Waso Nyiro (Pas-Schrijver 2019). Because it is more difficult for cattle to find grazing in the area, the Samburu have begun to invest in goats and camels, which can use browse plants other than the grass. The aforementioned strategies are designed to deal with climate fluctuation and vegetation changes, however they do not always work, resulting in high animal mortality and starvation among pastoralists during periods of prolonged drought (Nkedienye *et al.* 2011). Droughts were common in the African dry lands long before climate change was a topic of popular discussion. For example, from 1540 to 1800 AD, there were 26 significant droughts and famines recorded, including the Great Famine of 1889–92 (Scoones 1995; Niamir-Fuller 1999). Droughts have been observed in East Africa since the Middle Ages, and at least two major droughts occurred in the Sahel before mid-twentieth century, prior to the well-publicized Sahelian drought in the late 1960s and early 1970s (Scoones 1995).

Pastoralist production requires access to labor (for herding) as well as important pasture and water resources. Because these resources are dispersed in geography and time, pastoralist production relies heavily on livestock mobility. Pastoralists in northern Kenya currently practice semi-nomadic pastoralism, which means that only part of the family, not the entire household, moves the animals to locations with pasture and water.

While drought exerts pressure on the already fragile rangelands, this situation is further exacerbated by floods , resulting in crop failure and livestock death. Epidemics of the late 19th and early 20th centuries, such as rinderpest, resulted in massive cattle (and wildlife) mortality and human suffering (Bizimana 1994). Cropping expansion into pastoral areas is displacing the greatest dry-season pastures in several countries (Lesorogol 2008). Due to the changing climate patterns, some of the pastoralists have turned to farming. This has brought about resource-based conflicts due to land use changes as evidence suggests that the conflicts increases during the wet seasons and concentrated around agricultural lands (McGuirk and Nunn 2020). Also decreasing grass growth are the invasive plants such as *Prosopis* and *Sansevieria* species which are increasingly common. Further access to pastures is frequently hampered by resource use conflicts, disease outbreaks and related trade bans, as well as population expansion and a corresponding fall in the average herd size, i.e., the number of animals per person, to a level below subsistence diminishing income and viability of pastoral production.

Despite these challenges and the continued loss of animals, little or no attention has been directed towards getting solutions to pastoralism-related challenges. Particularly, the nexus between climate variability and herd mobility has not been adequately analyzed in Samburu County to spur resource planning in order to ensure utilization of rangeland resources in a sustainable manner. It is through the understanding of the relationship between temperature and rainfall variability and herd mobility that proper planning and management of rangelands can be achieved. While Sperling (1987) conducted a study in Samburu which describes the labor requirements for herding and during herd mobility, data is lacking on herd mobility trends, herd distribution in space and time, transhumance and the relationship between herd mobility and climate variability. This study intended to investigate the patterns of herd mobility and resource use and its relationship with climate variability through analysis of herds distribution during different seasons of the year. This will inform interventions and strategies for Northern Kenya that will ensure that climate variability and herd mobility does not become a constraint to livestock production.

6.3 Materials and Methods

6.3.1 Study area

The study area is as described in Chapter 3 (Figure 3.1).

The driest months are January to March. The long rain season occurs between November/December but some rains are experienced during other months especially in May/June. Potential annual evaporation in the County is a function of altitude and it ranges from 500 mm to 1200 mm per annum (SCG and WFP 2015). Temperature ranges from 24^{o} c to 36^{o} C. The climate of the County can be described as dry lowland equatorial climate. Rainfall patterns follow a very unpredictable pattern which varies very significantly in time and space.

Samburu County is categorized into upper midland, lower highlands zone, lower midlands zone, intermediate lowlands and indistinct zones/transitional ecological zones (SCG and WFP 2015; SCG 2013; SCG 2018). The vegetation in the study area can be described as grasslands, evergreen bush land, dry semi-deciduous bush land and evergreen forests. The main trees and shrub species include: *Vachellia tortilis, Senegalia senegal, Boscia angustifolia, Salvadora persica, Cordia sinensis, Croton dichogamus, Psiadia punctulata.* Grasses comprise *Themeda triandra, Cenchrus ciliaris, Eragrostis superba.* Wild animals in Samburu include *Panthera leo* (lion), *Phacochoerus africanus* (Warthog), *Crocuta crocuta* (Hyena), *Loxodonta africana* (Elephant), *Gazella* spp. (gazelles), *Antilopinae* spp. (antelops), *Equus* spp. (zebras) and various Avian spp. (birds) (SCG 2013; SCG 2018).

6.3.2 Selection of the study sites

This research utilized an explanatory multiple-case study design. The case study approach was utilized in order to understand interrelationships between climatic variability, livestock mobility and resource use patterns on day to day life of a pastoralist (Yin 1994; Zainal 2007; Yin 2014). The pastoral communities of Ngutuk Engiron, Lpus, Swari, Lonyangaten and Arsim sub-locations, and the agro-pastoral community of Longewan sub-location (Figure 1) were used as case studies in this study. The sub-locations were selected based on: representativeness of livelihood zones; areas prone to drought shocks hence experience herd mobility; and neighbouring other Counties hence allowing cross-border herd mobility

The sub-locations were selected from the six Wards (Suguta Marmar, Wamba West, Waso, Wamba North, Ndoto and Elbarta) in Samburu County, which border other Counties hence allowing cross-border herd mobility. Therefore, Samburu County in this case acted as an epicenter for herd mobility.

Permission was requested from the concerned National and County government offices before embarking on the data collection for this research. As an ethical requirement for any study involving human elements, the researcher and the enumerators sought consent of the targeted participants and let them know the purpose of the research before starting the interviews sessions. This research was licensed by the National Commission for Science, Technology and Innovation in Kenya under license number NACOSTI/P/22/15712.

6.3.3 Data Collection

6.3.3.1 Participatory herd mobility mapping

Participatory mapping was used to investigate the timing and routes used for seasonal migrations by translating the information obtained onto a map. Participatory mapping usually involves the respondents discussing and agreeing about the mobility routes (Lengoiboni 2011), especially with regards to areas where they frequent in search of pasture during droughts and how often they use those routes. This knowledge has been acquired by the pastoralists through the seasons and in a spatial-temporal context. Despite the fact that herd mobility patterns can easily be generated using other GIS-based methods, well informed, comprehensive and reliable patterns demands a lot of inputs from the pastoralists themselves. Participatory mapping is a visualization tool that helps to appreciate key livestock infrastructure, social amenities, stock routes, and livestock disease hotspots/ entry points (Chambers 2006). Probing the maps helped to appreciate the dry season grazing zones, resource-based conflict zones and the association between seasonality, livestock migration, intercommunity conflict and livestock health events.

In order to ensure that the desired data on herd mobility was obtained, a participatory mapping exercise was conducted per study site (composed of all age categories and both male and female) of between 5 to 10 participants (aged between 22 and 70 years) with knowledge and experience in herd mobility selected purposively through the assistance of local leaders. In the course of the discussion, validation of the mobility patterns resulting from literature review and other sources was done. Mapping sessions were conducted with one focus group per study site. During this exercise, the participants drew maps on flip charts with information regarding the study site (roads, towns, forests, surrounding group ranches and private ranches). The drawn maps were then used in the participatory mapping exercise. The participants identified the location of their homesteads (*manyattas)*, topographic features, wet-season and dry-season herding areas and categorize the identified herding areas with respect to the resources that are found there and how they can be accessed. The participants further drew the livestock mobility sequence during the different seasons of the year. The actual livestock mobility patterns were discussed, agreed to and approved by the group members themselves. Further probing was done to confirm any changes between the current herd mobility patterns and the past (up to 20 years ago). In case of any difference, they were captured in these maps and the reasons for the changes probed and noted in the research findings. The information on these maps with the migratory routes areas was then transferred and analyzed in ArcMap 10.8 software.

The spatial distribution of herds was generated from both the participatory mapping exercise and household survey. The respondent from each household was asked to mention where his or her animals grazed during the months of January-March, April-June, July-September and October-December. For this purpose, the livestock from each household were presumed to be one herd and therefore each household questionnaire response with regard to herd mobility referred to a single herd. In the analyzed map, the concentrations of livestock in an area therefore represented animals having moved from the respective households to those areas. The actual location data for the herds was therefore obtained using the household surveys.

6.3.3.2 Household survey

During the study, the pastoralists from the six study sites were interviewed. A total of 347 household interviews were conducted and targeted household heads. The questionnaire covered a number of topics with regard to herd mobility and climate variability including locations moved to during different seasons of the year, rainfall characteristics, factors influencing the decision on where to move the animals, climatic trends and pests; livestock health and services used.

6.3.3.3 Acquisition and analysis of NDVI data

Monthly decadal Normalized Difference Vegetation Index (NDVI) data was acquired from United States Geological Society's (USGS) Early Warning Explorer (EWX) software (https://earlywarning.usgs.gov/fews/ewx/index.html?region=af) for the years 2002 to 2020. The NDVI analysis was conducted to (1) describe the changes in plant phenology caused by spatial and temporal variability of climatic and habitat characteristics , and (2) investigate the association between NDVI values and herd mobility. Seasonal profiles of mean quarterly (3-month) NDVI were analyzed and compared across the 15 Wards of Samburu County. The quarters are January-March, April-June, July-September and October-December. The mean quarterly NDVI values were calculated for the precise region occupied by the herds for every quarter. in order to study the connection between changes in vegetation cover and animal mobility.

6.3.3.4 Precipitation and temperature data

Monthly precipitation and temperature data was acquired from USGS - Early Warning Explorer for the years 2002 to 2020. Monthly temperature and rainfall data was also acquired from Kenya Meteorological Department (KMD) for the period 1981 to 2020 for the six study locations. This data was used to evaluate the climate trends and variability in Samburu County.

6.3.4 Data analysis

Analysis of rainfall and temperature data was done by use of Ms-Excel spreadsheets to determine seasonal and annual variability. Line charts and graphs were used to show rainfall and temperature variability over time showing the trends of annual rainfall over the past 40 years (1981 to 2020).

The availability of pasture in time and space was computed through analyzing the herd mobility patterns and computation of NDVI values. The herd numbers in various areas during different seasons (obtained from household survey and participatory mapping) was recorded in excel spreadsheets with one column indicating the Wards and the other showing the herd numbers. This was then imported into ArcMap 10.8 and overlaid with administrative polygons (Wards). The spatial distribution of livestock was then mapped and the color graduated symbols option used to develop the Ward-level livestock distribution maps during various seasons. Livestock spatial distribution patterns were indicated by use of a cluster of dots depending on the number of households that moved their livestock to those particular locations. NDVI values maps were generated in ArcMap 10.8 and superimposed with the layers of livestock spatial distribution. Quarterly rainfall averages maps were also generated in ArcMap 10.8 and superimposed with the layers of livestock spatial distribution during analysis of the relationship between herd mobility and rainfall patterns. Where the rainfall or NDVI data was missing, the areas were left blank in the maps without any color-shading. These were mainly areas outside Samburu County. Other factors that dictate herd mobility patterns including availability of pasture, water, salt licks and resource-based conflict situations were also assessed.

6.4 Results

6.4.1 Seasonality of rainfall in Samburu County

Quarterly rainfall seasonality analysis (2000 to 2018) revealed that during the 1st quarter (Q1, January-March), all the fifteen Wards of Samburu County received low amount of rainfall (<40mm). During the 2nd quarter (Q2, April-June) most of the Wards received higher amount of rainfall (>100mm). But in the 3rd quarter (Q3, July-September), there was low amounts (7-40mm) of rains especially in the lowlands of Samburu including Wamba East, West and North, Waso, El-Barta, Nachola, Ndoto and Nyiro. On the other hand, Angata Nanyokie, Baawa, Lodokejek, Loosuk, Maralal, Poro and Suguta Marmar received more rains of between 69mm and 142mm. The 4th quarter of the year (Q4) received rainfall which was slightly more in the lowlands of Samburu East (136mm - 160mm) than the highlands areas of Samburu Central (116mm - 137mm). Figure 6.2 provides a detailed analysis of the seasonal trends of rainfall. In the first three quarters of the year, more rainfall is experienced in the highlands of Samburu compared to the lowlands, but in the fourth quarter, the lowlands areas receives more rains than the highlands.

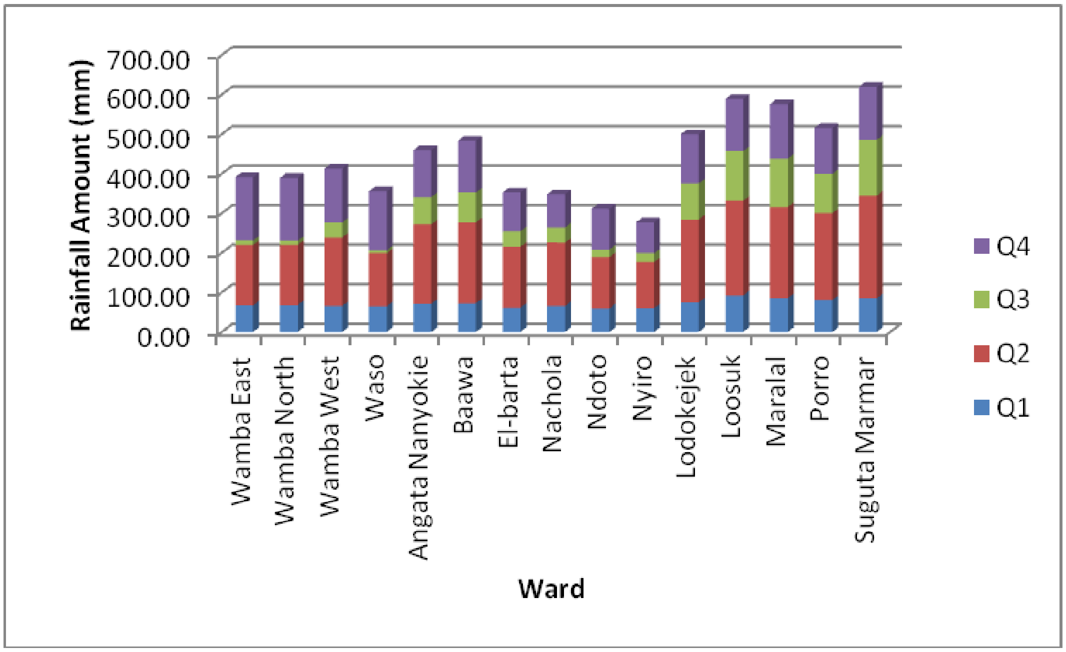


Figure 6.1: Seasonal amounts of rainfall in Samburu Wards (2000 - 2018) in January to March (Q1), April to June (Q2), July to September (Q3) and October to December (Q4)

An analysis of the annual trends of the rainfall between 1981 to 2020 (Figure 6.3) showed a general decline in rainfall amounts in Samburu north (Lonyangaten and Arsim) and a general increase in the rainfall amounts received in Samburu central (Longewan) and Samburu East (Swari, Lpus and Ngutuk Engiron).

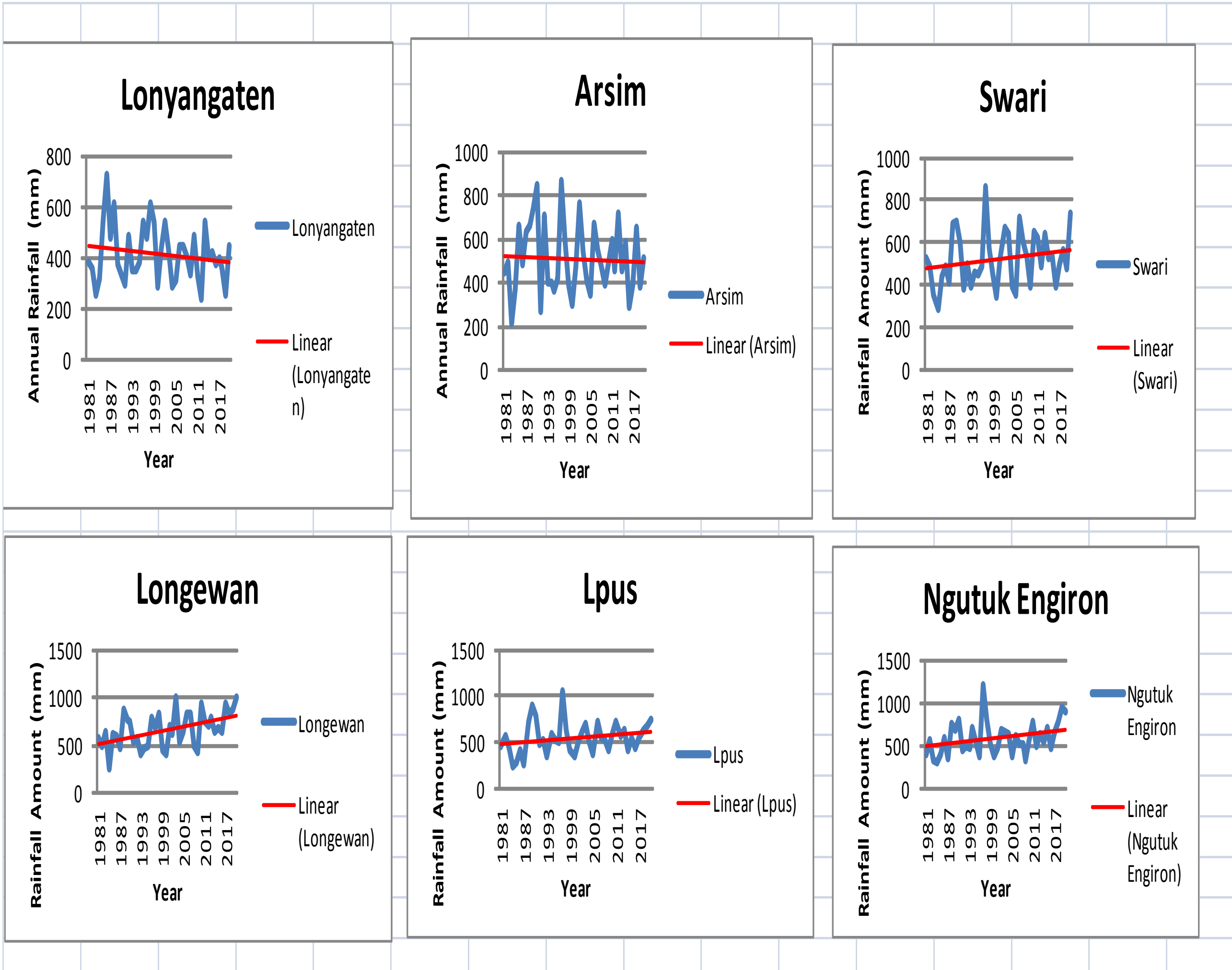


Figure 6.2: Annual trends of rainfall in the six study sub-locations (1981 - 2020)

6.4.2 Factors that determine the direction and time that pastoralists move their animals

Pasture availability was the most important factor that determined when and where the pastoralists moved their herds according to all of the household respondents (100%). Water availability was second (97.4%) followed by vulnerability of the area to resource-based conflicts (82.9%), availability of natural salt licks in the area (79.4%), species of livestock kept (79.1%) and emergence of livestock diseases (72.8%) (Table 6.1). Most of the respondents (64.27%) mentioned livestock keeping as their major occupation while only 1.44% depended on formal employment. Although also practicing livestock keeping, most of the respondents

(80%) from Longewan study site in Samburu Central were mainly crop farmers (agro-pastoralists).

Table 6.1: Analysis of determinants of herd mobility at household level

Factor	Important	Unimportant
Water availability (n = 347)	336 (97.4%)	11 (2.6%)
Physical barriers (n = 345)	185 (53.6%)	160 (46.4%)
Type of livestock kept (n = 345)	273 (79.1%)	72 (20.9%)
Household labor (n = 345)	143 (41.4%)	202 (58.6%)
Pasture availability (n = 345)	345 (100%)	0
Emergence of livestock diseases (n = 345)	251 (72.8%)	94 (27.2%)
External Interventions (n = 345)	136 (39.4%)	209 (60.6%)
Conflicts (n = 345)	286 (82.9%)	59 (27.1%)
Availability of salt licks (n = 345)	274 (79.4%)	71 (20.6%)

6.4.3 Seasonal livestock herds distribution patterns in the study area

The findings demonstrate that during the dry season, animals move from lowland rainy-season grazing grounds to humid highland regions. In the pastoral zone, which is predominantly the Samburu North, the main dry season grazing areas include Baragoi, Elbarta, Masikita, Soito and Suyan areas, while in Samburu East it include Koiting, Lerata, Matakwani, Ngilai, Sesia, and Wamba. In Samburu Central that covers part of the Agro pastoral Zone, the dry grazing areas include Ledero, Kisima, Lorroki, Kirimon, Logewani, Lolmolog and Lbukoi. The seasonal distribution patterns are shown in Figure 6.4 and 6.5.

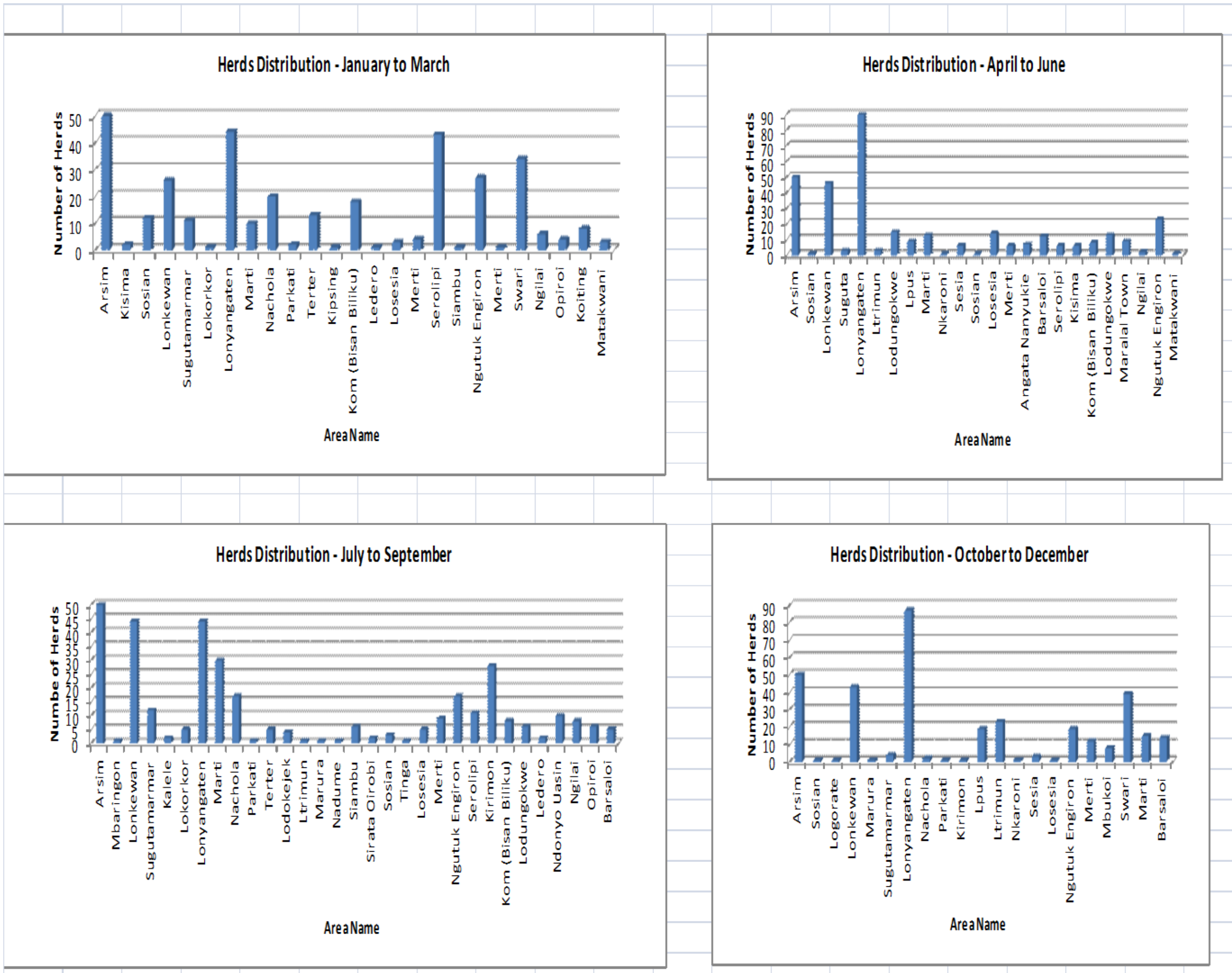


Figure 6.3: Distribution of livestock herds during different seasons of the year according to the respondents

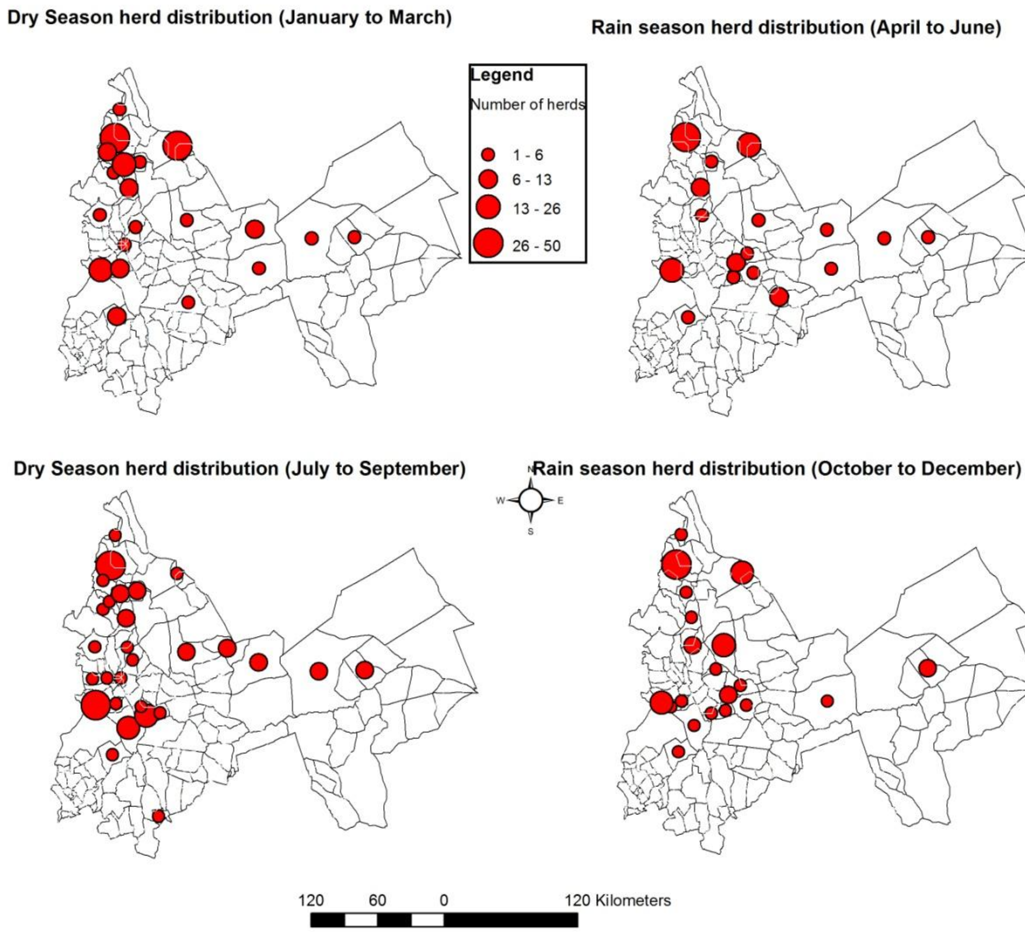


Figure 6.4: Spatial distribution of livestock herds during different seasons of the year

6.4.4 Seasonal grazing patterns of livestock in Samburu County

In Samburu central, livestock were said to graze around Kisima, Laikipia, Longewan and Suguta for most part of the year. Most of the pastoralists in Samburu central graze around their homes all year round. In the more severe droughts, these pastoralists move their livestock to Laikipia County especially around Sosian area and they can go as far as Marula and Mount Kenya areas.

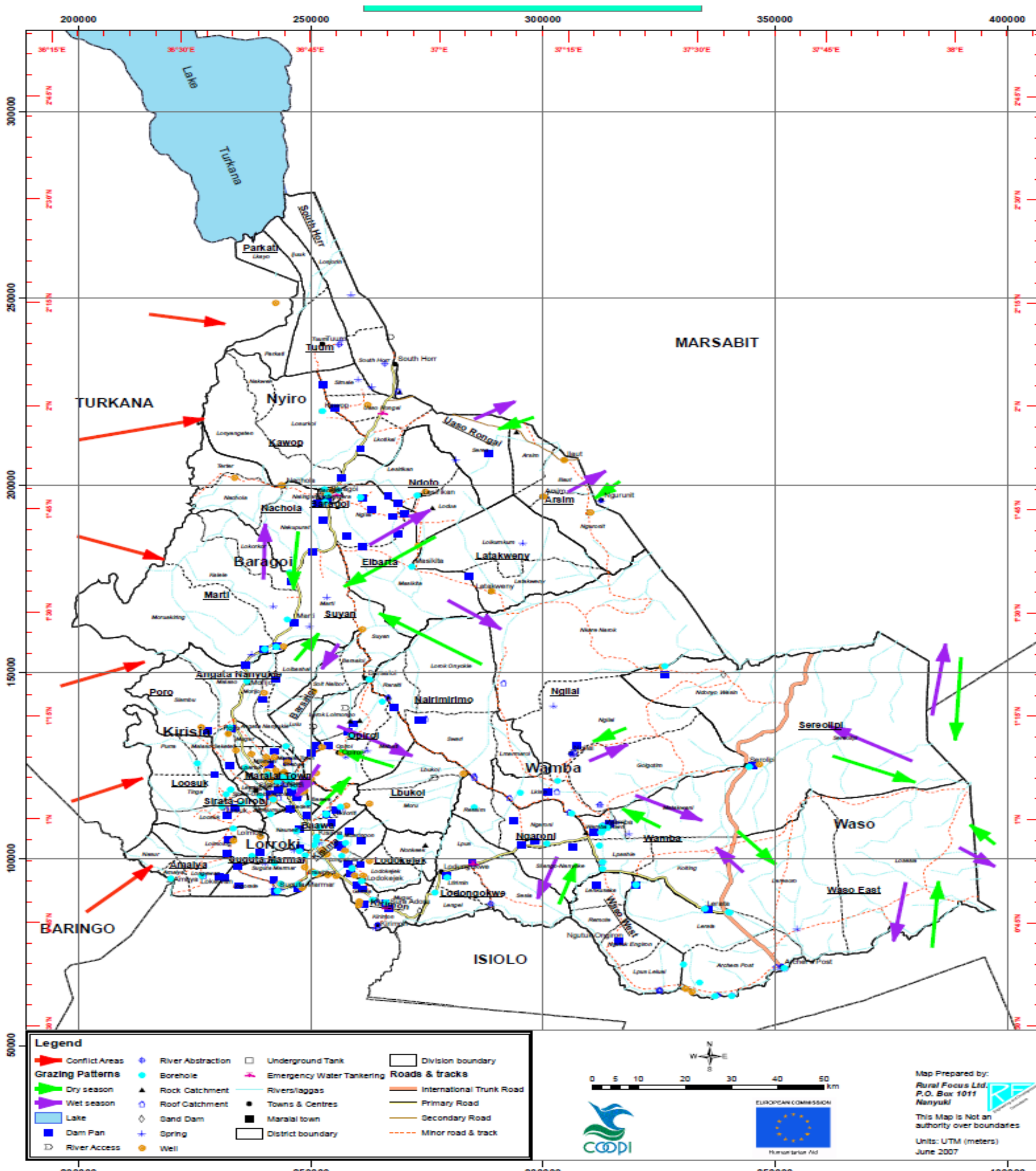


Figure 6.5: Seasonal grazing patterns of livestock in Samburu County

In Samburu East, livestock were said to graze around Kauro and Kom for most part of the year. In the more severe droughts, these pastoralists move their livestock to the community conservancies, Samburu National Reserve as well as to the Government National Youth

Service (NYS) land in Kirimun. Rarely do livestock in Samburu east (Wamba, Swari, Lodung'okwe and Ngilai) graze around homesteads.

In Samburu North, livestock grazing patterns were mainly dependent on the ethnic community that owns the livestock. Among the Turkana, the animals would mainly graze around the community's territorial boundaries of Nachola, Kawop, Lonyangaten, Terter, Lokorkor and Parkati. While among the Samburu mainly from Nyiro, Baragoi and Latakweny areas, they will move their animals to as far as Serolipi and Wamba in Samburu East (Figure 6.6). In the more severe droughts, the pastoralists from both communities will move their livestock to areas around Samburu North (Marti, Suyan, Morijo and Mbukoi) and in most instances this will result to resource-based conflicts in these areas.

6.4.5 Spatial distribution of livestock herds in relation to rainfall patterns

Between January and March, the livestock in Samburu North are concentrated within Nachola and Marti areas, while others move towards Samburu Central and East. The livestock in Samburu Central and East moves to Laikipia and Isiolo Counties (Figure 6.7).

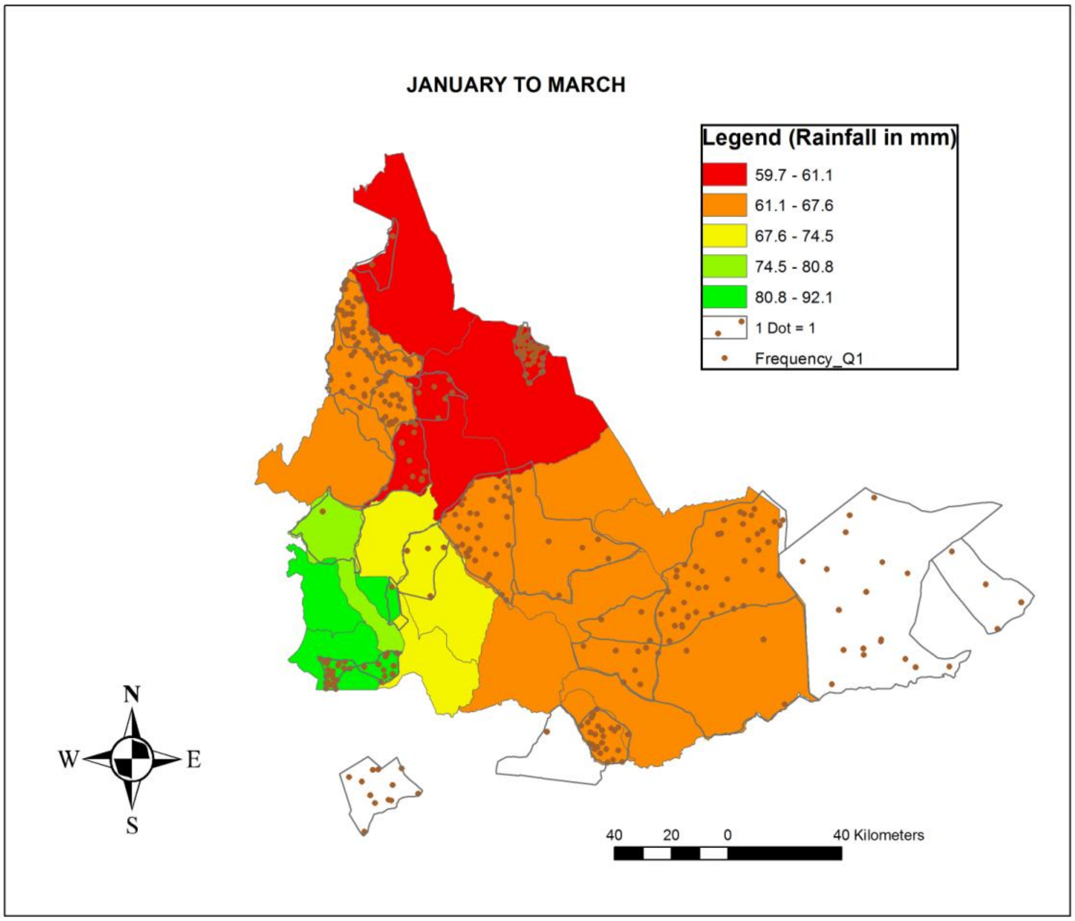


Figure 6.6: Spatial distribution of livestock herds (depicted by the dots) in relation to rainfall amount (January-March)

April to June are usually wet months with the Samburu Wards receiving between 116 mm and 260 mm of rains during this quarter except in cases where the rains have either delayed or failed. During these months, most of the pastoralists return back their animals and graze them around homesteads and therefore the distribution of herds is widespread over the study areas. The exception for this are people with large herds of animals who prefer to remain either in Laikipia or Isiolo/Samburu border. Also, due to the degraded nature of rangelands in Samburu East (especially Wamba East and Wamba North), most of the livestock herds in this Sub-County could still be found distributed within Waso Ward (Figure 6.8).

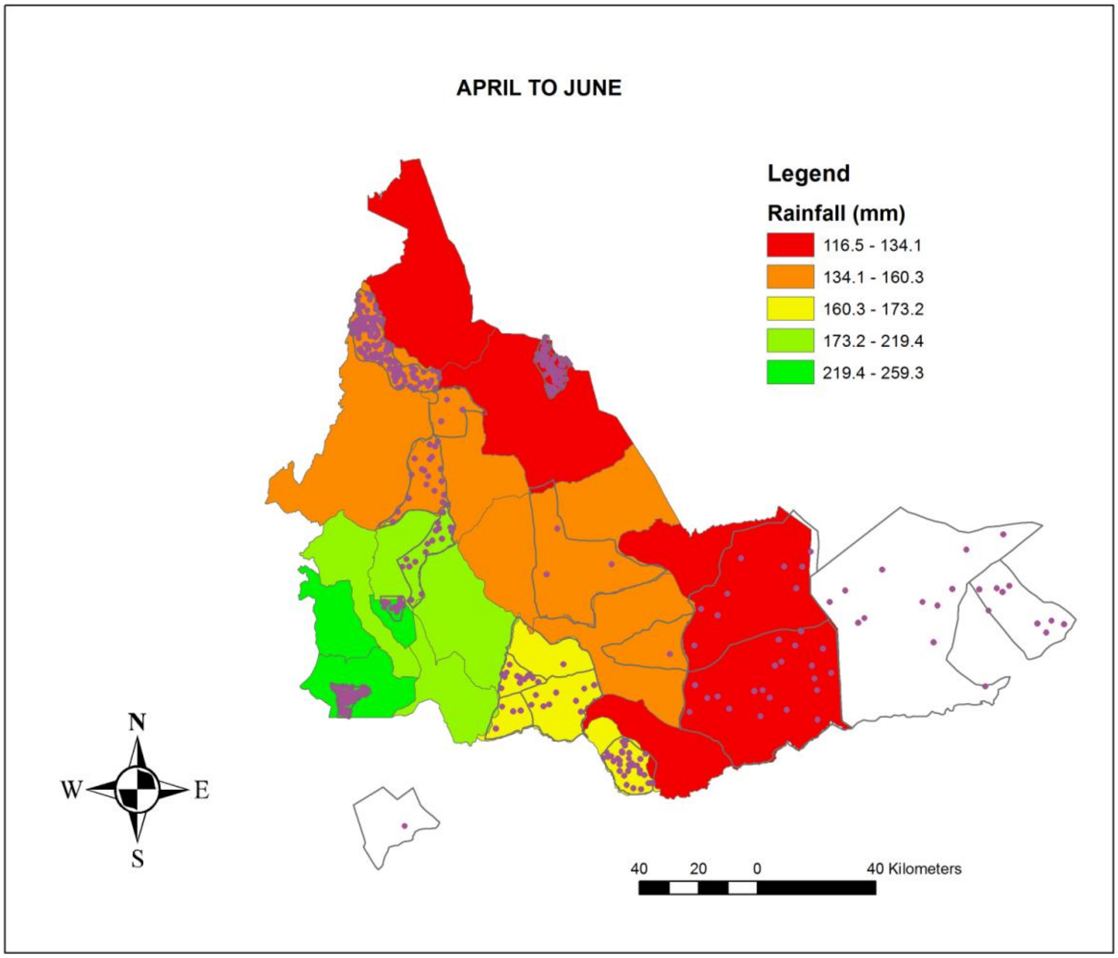


Figure 6.7: Spatial distribution of livestock herds (depicted by the dots) in relation to rainfall amount (April-June)

The months between July and September is usually considered the harshest especially among the pastoralists in Samburu East. During these months there's completely no rains in these areas. But some areas of Samburu Central usually receive rains between July and August. Therefore, livestock in Samburu East and North will concentrate around Samburu Central, patches of Laikipia and Isiolo/Samburu border (Figure 6.9).

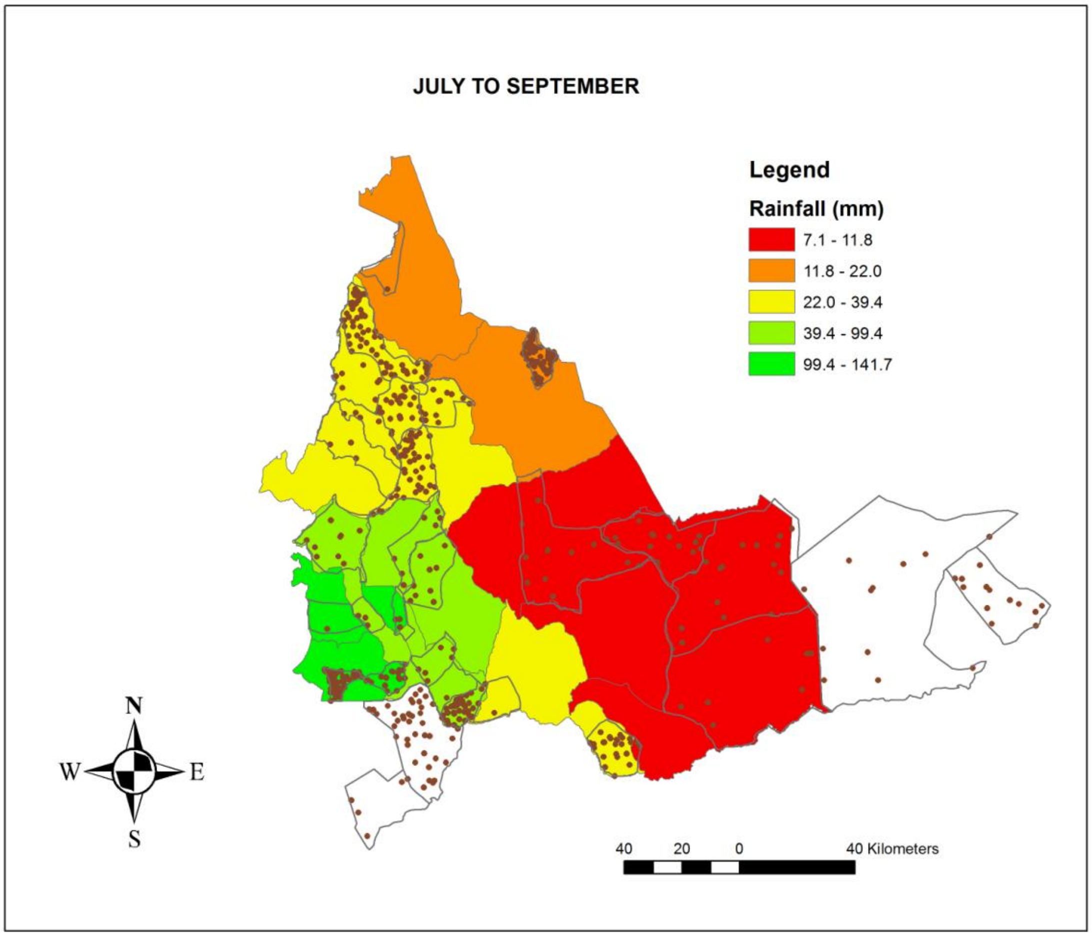


Figure 6.8: Spatial distribution of livestock herds (depicted by the dots) in relation to rainfall amount (July-September)

Heavy rains of between 130 mm and 160 mm are experienced in the lowlands of Samburu East between the months of October to December. Therefore, vegetation growth and pasture availability is enhanced in these areas. During these months, livestock graze within the homesteads and herds distribution is mainly around the study locations. However, some herds are still distributed in the areas around Kom in Isiolo County because pastoralists living in the degraded areas of the lowlands move their animals to these areas where pasture and browse is available (Figure 6.10).

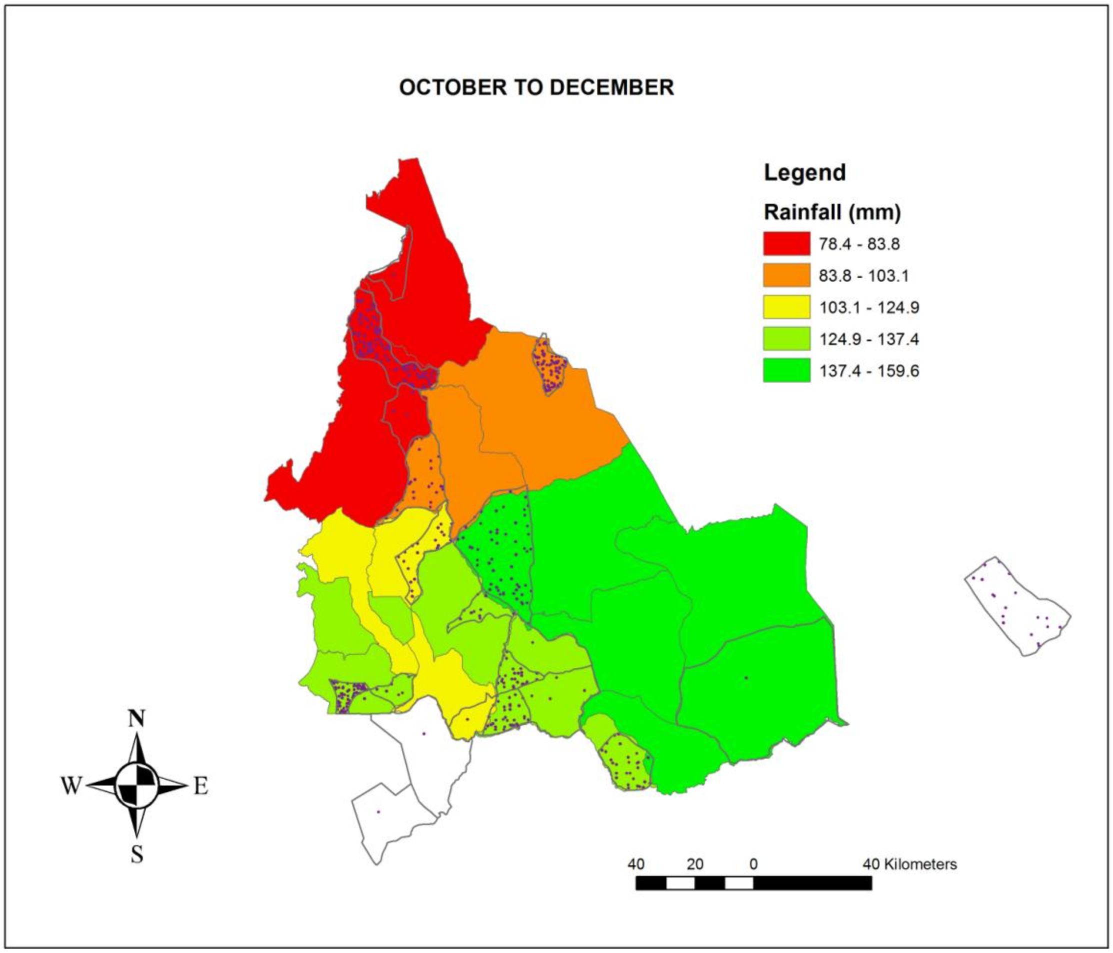


Figure 6.9: Spatial distribution of livestock herds (depicted by the dots) in relation to rainfall amount (October-December)

6.4.6 Spatial distribution of livestock herds in relation to NDVI

The months of January to March are usually dry in most parts of Samburu with the NDVI values of between 0.24 in the pastoralists grazing areas indicating low vegetation cover in these areas and 0.52 within areas covered by forests, therefore livestock herds were shown to be mainly concentrated in Samburu Central (Suguta Marmar and Baawa), Laikipia ranches (Kirimun and Sosian) and dry season grazing areas in Samburu/Isiolo border (Figure 6.11). However, due to the security situation brought about by inter-communal cattle rustling in Baragoi areas, the livestock from Nachola and Lonyangaten areas have always been restricted to their tribal boundaries despite the harsh climates (NDVI values of 0.24 and 0.31). Livestock from Arsim on the other hand are commonly distributed around Ndoto mountains during these months due to the favorable vegetation cover in these areas (NDVI values of 0.31 to 0.40).

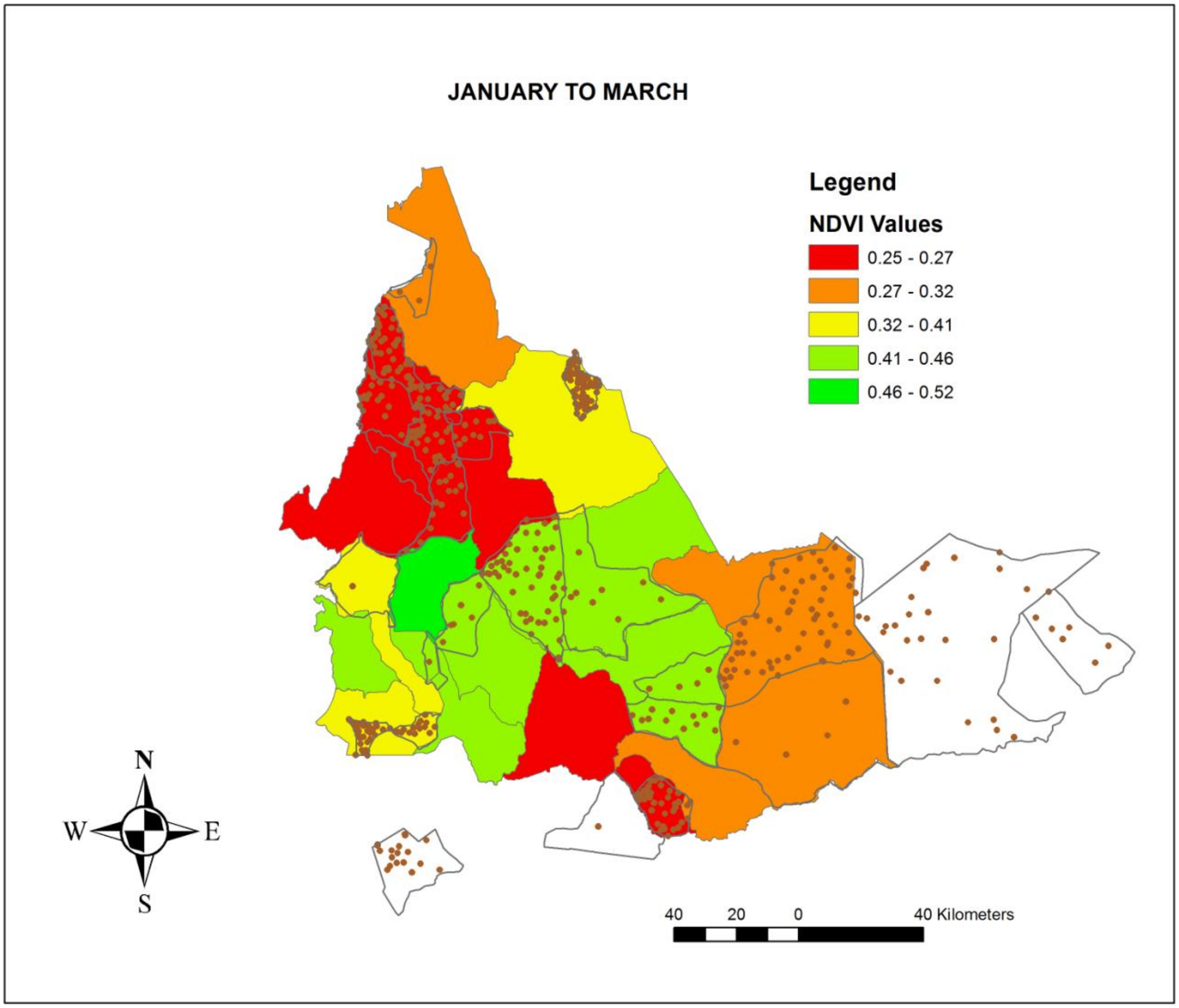


Figure 6.10: Spatial distribution of livestock herds (depicted by the dots) in relation to NDVI values (January-March)

April to June experiences an increase in vegetation for most parts of Samburu County (NDVI value of up to 0.6) with the exception of degraded areas of the lowlands. During these months, most of the herds are shown to have left Laikipia areas and distributed around homesteads in Lonyangaten, Swari, Longewan, Arsim, Lpus and Ngutuk Engiron (Figure 6.12). This period experiences higher NDVI values in almost all Wards of Samburu Central (0.5-0.6) and Wamba

North and East Wards of Samburu East (0.37 - 0.50). While in Samburu North, high NDVI values are noted in Ndoto Ward (0.37 - 0.50) and improvement of NDVI values in Nachola Ward (0.33 - 0.37). These values represent an increase in vegetation cover and the reason for the observed herd mobility patterns.

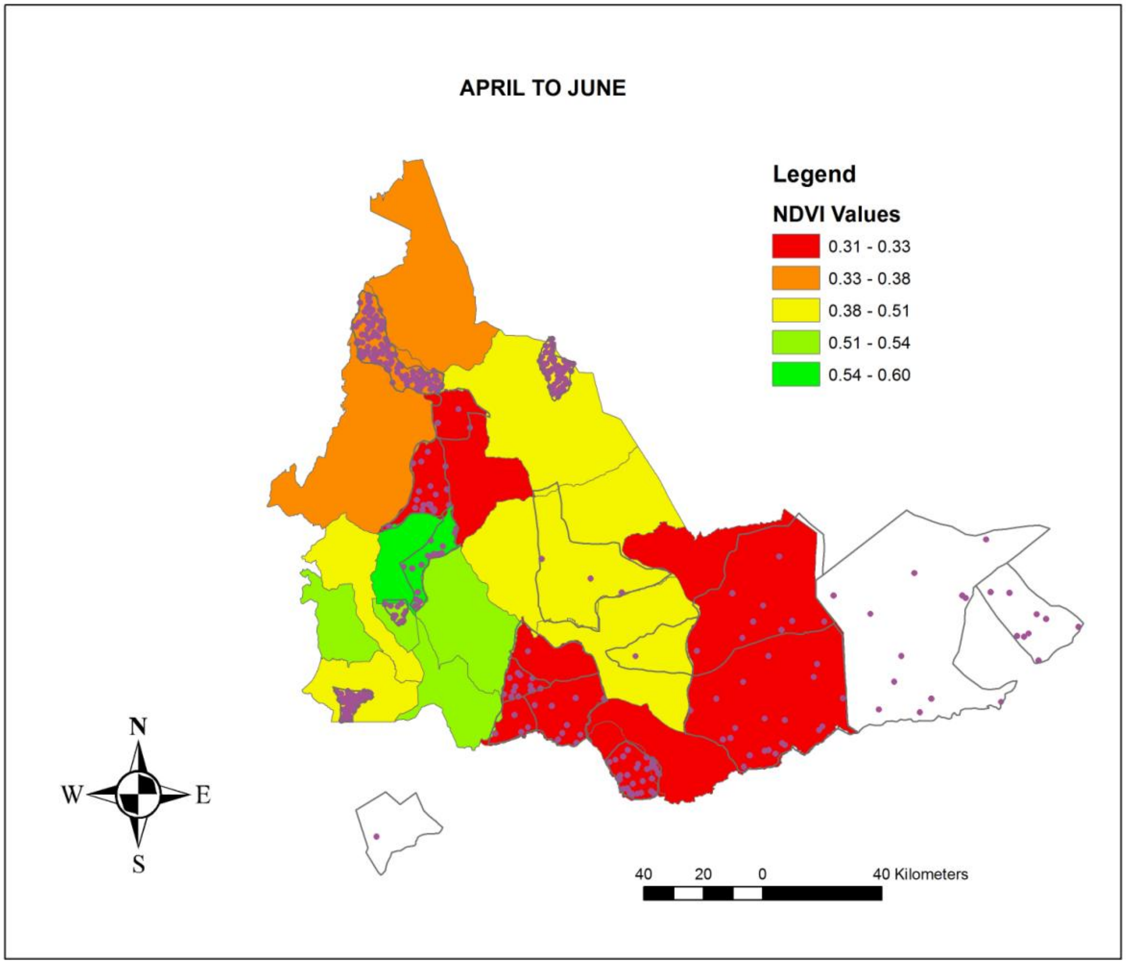


Figure 6.11: Spatial distribution of livestock herds (depicted by the dots) in relation to NDVI values (April to June)

The months of July to September sees an immense reduction in the NDVI values all over the County but most significantly in the lowland areas (0.23 - 0.26). This is because these areas experiences a dry spell during this period. Therefore, this situation makes pastoralists to move their animals to the dry season grazing areas. Livestock from Samburu Central and Wamba West Ward were distributed in Laikipia (around Kirimon, Sosian and Mt. Kenya) while those in Wamba North, Nachola and Elbarta Wards were distributed around Marti dry season grazing areas. Those in Wamba East and Waso Wards were distributed around Samburu/Isiolo border dry season grazing areas (Kom and Losesia) and Serolipi areas (Figure 6.13).

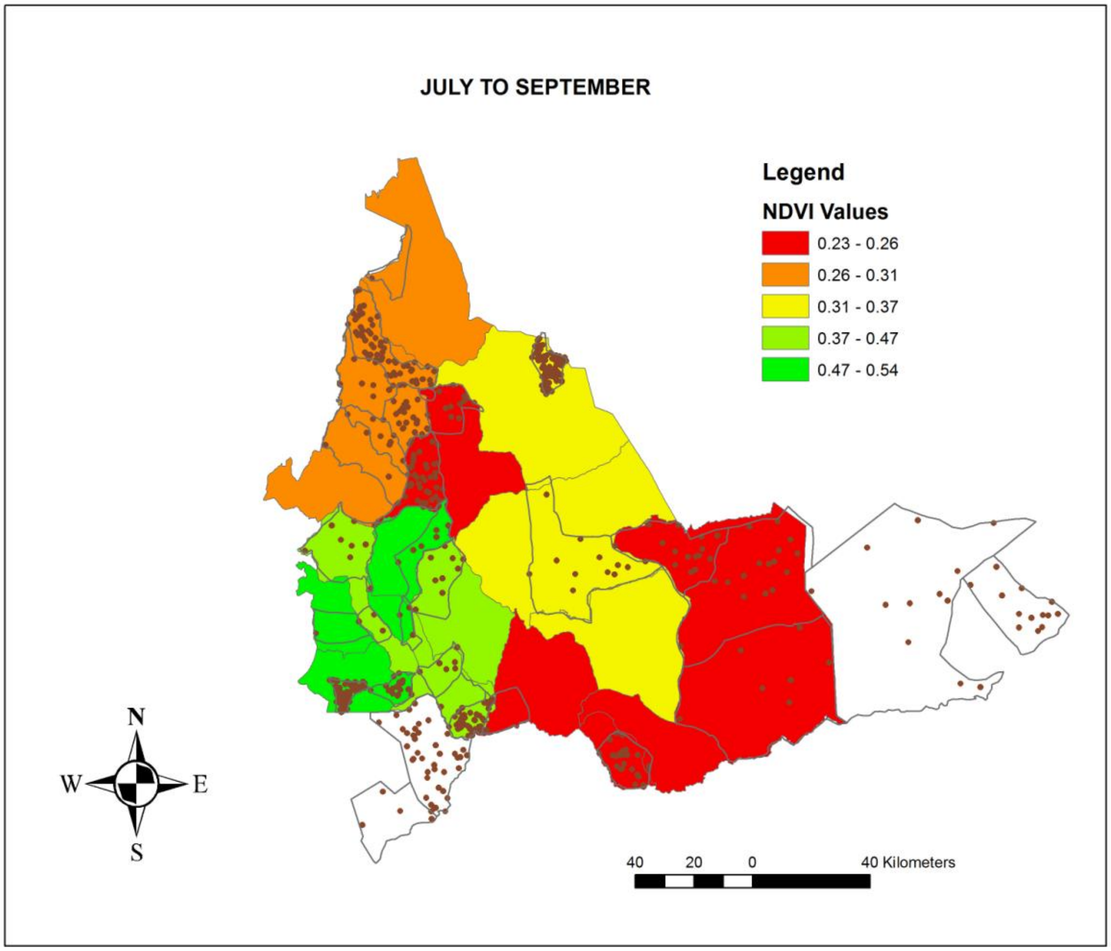


Figure 6.12: Spatial distribution of livestock herds (depicted by the dots) in relation to NDVI values (July to September)

The improvement of vegetation conditions in both the highlands and the lowlands of Samburu in the months of October to December (0.30 - 0.60) means that increased pasture is available. Most of the pastoralists, especially in the lowlands move their herds back home and graze them within the surroundings of their homesteads. As seen in Figure 6.14, most of the herds are no longer in areas around Laikipia and Losesia and are distributed around the study locations. The few that remain away are those in Kom area.

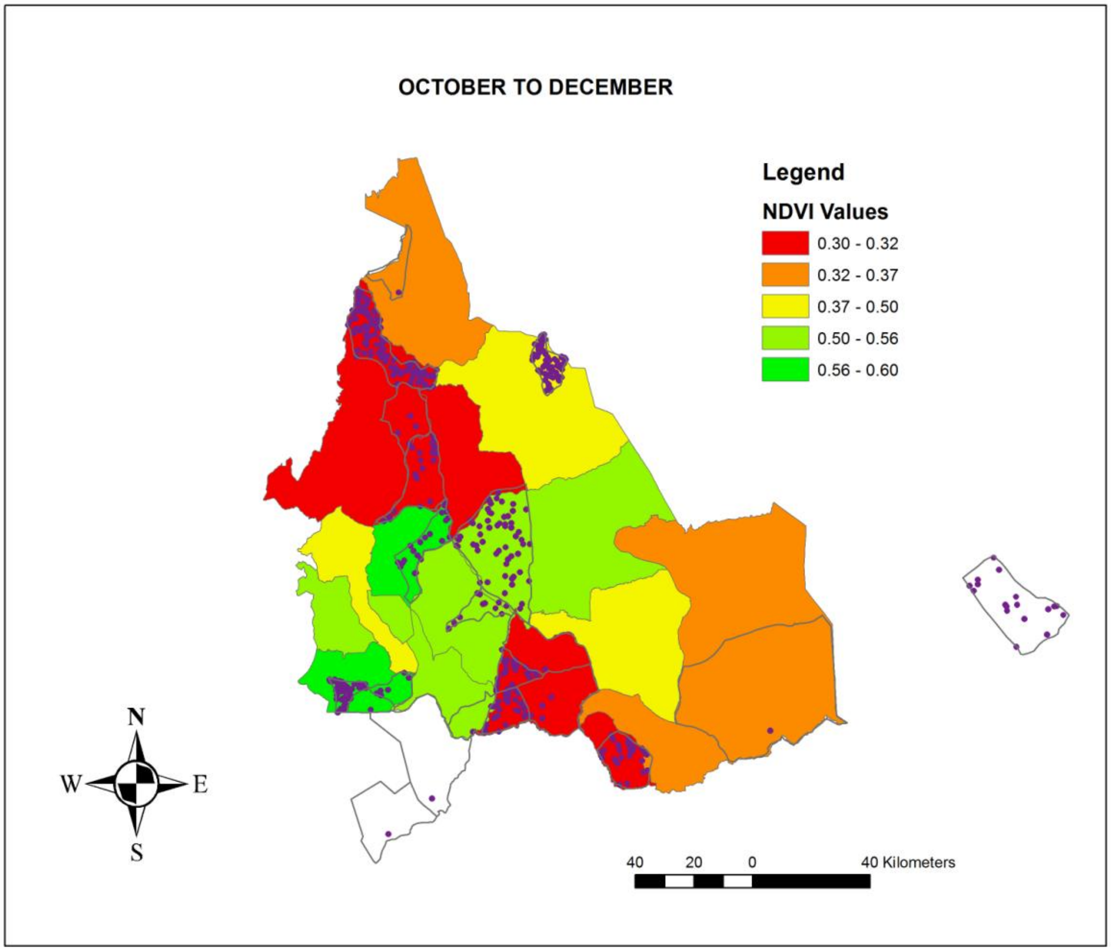


Figure 6.13: Spatial distribution of livestock herds (depicted by the dots) in relation to NDVI values (October to December)

6.4.7 Spatial distribution of livestock herds in relation to temperature variability

A spatial analysis of seasonal temperature variability in Samburu County indicated that there were no differences in spatial variability of this variable between January and December (Figure 6.15). The only differences was observed in the months of January to March and July to September. During the January-March season, there was a general increase in temperature in Poro, Suguta Marmar and Lodokejek Wards compared to the April-June and October-December seasons. While during the July-September season, there was a general decline in temperature in Nyiro, Nachola and El-Barta. Specifically, no general change in herd distribution was noted with the change in temperatures between the various Wards.

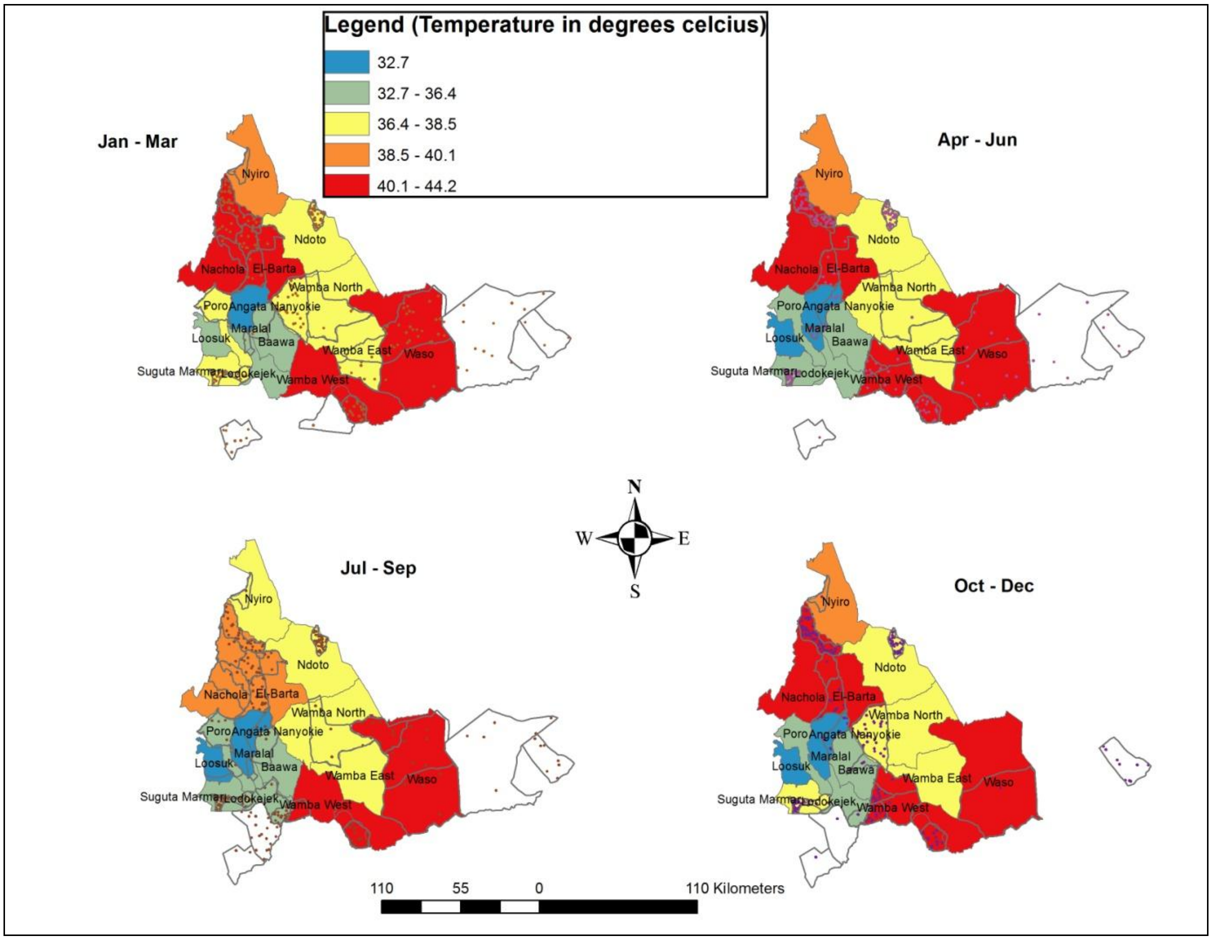


Figure 6.14: Spatial distribution of livestock herds (depicted by the dots) in relation to temperature variability (January to December)

6.5 Discussion

The analysis of climate data from both the USGS and the KMD shows the occurrence of four seasons in Samburu with the April-August period receiving more rains in the highlands than the lowlands while the October-December season received more rains in the lowlands than the highlands. The January to March season receives depressed rainfall throughout the County. In Samburu, the long dry season in the lowland lasts from June to September and parts of October, while the short dry season lasts from late December to March. This affects the seasonal mobility of herds from the lowlands to the highlands and vise-versa. Such mobility is more pronounced in the months of July to September which receives very low rainfall amounts and the pastoralists have to move their livestock to the highlands. Overall, Samburu's rains are inconsistent, highly localized, unreliable, and unpredictable in space and time (Pas-Schrijver 2019; SCG 2018). In addition, the rains frequently come in the form of brief, heavy storms. The soils absorb very little water, and the temporary rivers dry up within a few hours of rainfall (SCG 2018). This study also indicates a declining trend in rainfall amounts received in Samburu North and an increasing trend in rainfall amounts received in Samburu East and Central. The observation that the rainfall trend has been declining in Samburu North is in line with UNDP's observations. According to the UNDP's climate change assessment for Kenya, which indicates that instances of heavy rainfall are gradually increasing without a statistically significant trend (McSweeny *et al.,* 2010). Generally, Samburu has a complex rainfall pattern. This is primarily due to the extreme variability and unpredictability of rainfall throughout the year, but it is also due to the fact that the Samburu region includes both highlands and lowlands. The Lorroki highlands and the lowlands have significantly diverse rainfall patterns (Pas-Schrijver 2019).

Regular mobility of livestock is an important management technique in Samburu’s transhumant pastoral economies, with between one grazing area to another having distinct routes. As indicated in this study, the migration routes are north-south and south-north in Samburu County, with movements mainly occurring in the drier months (January to March and July to September) and the wetter months (April to June and October to December). When there is no enough grass for the livestock, the herders take them either to the hills (Kirisia forest, Mathew ranges and Ndoto hills), other parts of Samburu, and even locations like Kom in Isiolo, Marti in Baragoi, and some parts of Laikipia County. Pastoralists from the lowlands will relocate to the Lorroki Plateau, Matthews Range or even Samburu National Reserve (Pas-Schrijver 2019; Lengoiboni 2011). As a result, pastoralists' most important response to rainfall fluctuations in terms of geography and time is migration (Adriansen 2008). During prolonged droughts, when pasture in the dry season grazing reserves are exhausted, Samburu communities employ fallback grazing areas that are unusable during "normal" dry seasons due to remoteness, land ownership restrictions, animal sickness issues, and resource use disputes. Such areas includes Kom in Isiolo, Marti and Suyan in Samburu North and Sosian and Marula in Laikipia. However, significant fragmentation of communal grazing areas under group ranches to individual ownership, as well as changes in land use, have severely impeded pastoral mobility in recent years, particularly in Samburu Central (Lesorogol 2008). Over the last five years, the Kenya's National Land Commission has embarked on the process of sub-dividing land to individuals especially in Samburu Central (personal observation). Therefore, the grazing lands currently available for the pastoralists are the ones that are not yet sub-divided and the Kirisia forest reserve. Such areas includes Kisima, Kirimon, Ledero and Lbukoi.

For this study, NDVI has been used as a measure of pasture and browse availability. The values indicates different status of the land surface. Globally, very low values (0.1 and below) indicate bare surfaces for instance sandy, rocky, or snowy areas (Sonneveld et al 2008). In Samburu, grasslands and shrublands are represented by low values (0.2 to 0.3), whereas higher values of 0.5 to 0.6 represent areas with dense vegetation including Kirisia forest, Ndoto Mountains and Mathew ranges. Therefore, it was expected that herds will be concentrated in areas with higher NDVI values (0.3 and above). The NDVI values were shown to affect the distribution of livestock herds during the different seasons of the year. It is only in Samburu central endowed with good rainfall that the pastoralists graze around their homes all year round. This can be attributed to the good climatic condition within Samburu central with good rainfall patterns (500mm to 800mm annually). Rarely do livestock in Samburu east graze around homesteads due to low rainfall received and degraded pastures. The herds spatial distribution patterns followed pasture availability as shown by vegetation NDVI patterns. Areas with higher NDVIs of over 0.3 attracted herds concentration but with high *in situ* mobility to maximize on grazing of the most nutritious pastures. However, it is important to point out that temperature variability does not seem to affect spatial distribution of herds like in the case of rainfall and NDVI values.

The pastoralists mentioned pasture availability as a key factor considered when considering where and when to move their livestock. Watering points, vulnerability to resource-based conflicts, species of livestock kept and presence or absence of diseases followed in that order respectively. In another study by Lelenguyah *et al.* (2021) in Samburu County, Kenya, where they interviewed 22 key informants, similar observations on the determinants of herd mobility were made. While pasture availability is essential for the survival of livestock in an area, its scarcity also becomes a factor of insecurity and resource-based conflicts (Abroulaye *et al.* 2015). This is because conflict zones are often suitable grazing areas during dry seasons due to their non-utilization during the rainy seasons, and private ranches in Laikipia are also illegally invaded in order to exploit the grass available (Mulianga 2009). Factors influencing decision making on resource utilization by the pastoralists are many but attempts to order them has been futile (McCabe 2010). This study, particularly focused on nine of these factors. While the list cannot be said to be exhaustive, the factors are not independent of each other. For instance, even though pasture was ranked as a key factor that determines herd mobility, the livestock also need water and salts licks while at the same time the resources cannot be accessed if the area is prone to cattle rustling or infected by livestock diseases. But generally, decisions related to mobility involved a complex process of environmental, political and social factors. Pastoral decision-making or resource utilization are complex and incorporate information that goes beyond the size or reliability of a given resource, including disease, resource-based conflicts, water and pasture availability which are contextual factors (Millar *et al.* 2014). According to Nori and Scoones (2019), pastoralists' resource management and livelihood strategies can also be used to inform decision-making in a variable and uncertain environment.

Samburu and Turkana communities in Samburu north have their own livestock grazing areas. This is mainly because of the security situation brought about by inter-communal cattle rustling as well as resource use conflicts in the area. Due to a variety of factors, including a rise in the population of animals, a high level of insecurity, the availability of water sources, a growth of other systems of agriculture, particularly in Central Samburu, and a general deterioration of resource conditions, these tribal groups of North Samburu look for pasture beyond of their perceived ancestral territory (Lesorogol 2008). The persistent droughts in the region have been the main issue affecting these tribes. Pastoralists now spend more time in the southern Samburu's more appealing areas due to the declining quality of pasture lands, which puts them in competition with other tribes and leads to new resource-based conflicts. These strategies have been used by pastoralists for centuries and have been discussed in detail in the literature since the last few decades (Galaty and Johnson 1990; Scoones 1995; Niamir-Fuller 1999).

6.6 Conclusions and recommendations

Wet-season grazing areas and dry-season grazing areas characterize the Samburu pastoral system. Because of the irregular rainfall pattern, animals move around the area in search of pasture and water, and grazing patterns are always shifting. One of the solutions to sound range management in this pastoral system is grazing management embedded in observed herd mobility and grazing resource use patterns. This can be achieved by establishing and implementing grazing programs that can be reinforced within recognized community management structures such as elder councils, grazing committees, group ranch committees, and water resource management committees.

A spatial relationship was observed between distribution of livestock herds and rainfall patterns. In most of the dry seasons, pastoralists end up in private lands in Laikipia and Samburu Central or government gazetted Kirisia forest and Samburu National reserve where they have no formal access. As a result, there is expected to be violent clashes between Samburu herders and private land owners or reserve officials. Therefore, there is need to work with management of the reserve and Kirisia forest to develop formal grazing agreements with the community during dire drought periods.

Declining trends of rainfall was particularly observed in Samburu North over the last 40 years. If this trend continues, it will heavily impact on pastoral livelihoods and will make pastoralism an unsustainable venture. Diversification of livelihood sources will help the pastoralists to cushion themselves against the effects of climate variability. In Samburu North, introduction of honey production through modern bee hives provided by the County Governments and other partners is one such livelihood diversification strategy. Also, fodder conservation will go a long way to supplement the natural pasture grazing.

CHAPTER SEVEN

7.0 ANALYSIS OF THE LIVESTOCK DISEASES HOTSPOTS AND THE EFFECTS OF SEASONS ON DISEASE INCIDENCES IN SAMBURU RANGELAND

Manuscript published in the Tropical Animal Health and Production Journal on 15th July, 2023

Lelenguyah, G. L., Nyangito, M. M., Wasonga, O. V., & Bett, R. C. (2023). Spatio-temporal epidemiology of livestock diseases in the variable semi-arid rangelands of northern Kenya. *Tropical Animal Health and Production*, *55*(4), 272.

7.1 Abstract

Livestock diseases can have serious impacts on the animal, humans and the economy. Participatory Epidemiology and spatial analysis was conducted to assess livestock disease problems in Samburu County, northern Kenya. Key informants were selected purposively with the help of local leaders. Among the livestock, goats were identified to have the most economic importance. On the other hand, Foot and Mouth Disease (FMD), Pestes des Petits Ruminants (PPR) and Camel Trypanosomiasis diseases were identified to have the highest impact on pastoral livelihood. Spatial analysis indicated that all the disease hotspots were closely related to the distribution of herds during different seasons of the year. Correlations between the mean annual rainfall and selected livestock diseases was significant for East Coast Fever (ECF) ($r = -0.767$, $p = 0.001$, $N = 15$), Cattle Helminthiasis ($r = 0.639$, $p = 0.010$, $N = 15$), Cattle Anaplasmosis ($r = 0.631$, $p = 0.012$, $N = 15$) and Camel Pox ($r = -0.646$, $p = 0.044$, $N = 10$). There was a strong relationship between seasonality and livestock disease epidemiology. Disease control efforts should be focused towards the hotspots in the seasonal grazing areas.

Key words: Livestock Diseases, Northern Kenya, Participatory Epidemiology, Spatial Analysis

7.2 Introduction

Globalization provides a need for continuous information sharing on animal diseases across all countries for the purpose of regulating trade in animal and animals products. Kenya's arid and semi-arid lands are often remote regions occupied by marginalized pastoralists who are often underrepresented, with poor infrastructure and unreliable information and service delivery, despite having the majority of livestock populations in the country. Therefore, the pastoralists not only suffer a deficiency in service delivery but also pose a major epidemiological risk to major livestock populations in Kenya as a whole (Bayissa *et al.*, 2009).

Among the pastoral communities in the arid lands, sheep and goats form a key livestock resource of major economic importance (Bett *et al.*, 2008). This livestock resource productivity is often affected by livestock diseases (Islam, 2016). Reducing the number of livestock diseases especially the Transboundary Animal Diseases (TADs) in endemic countries is a common interest and therefore considered as a public good globally. TADs are major diseases of livestock with significant economic impact on the pastoral livelihoods within Samburu County and the country at large. The national strategies for eradication of TADs builds on the global framework for the progressive control of TADs (FAO and OIE 2004), as well as the global strategies for eradication of these diseases within defined timeframes. In the most serious case, death rates in arid and semi-arid lands (ASALs) can exceed 90%, while TADs-related morbidities can reach 100%. Although the mortality rate could be less in endemic areas, the diseases have a more pernicious effect on herd productivity. It is anticipated that the management and eradication of TADs will increase earnings from animals management systems and result in their increased productivity and economic viability. A key component in most of the eradication strategies is continuous disease surveillance to generate baseline data for diseases mapping and disease control planning (Akoyo and Songok, 2013; GoK, 2021; OIE and FAO, 2015).

Participatory epidemiology (PE) is a relatively new field which draws on participatory methods to gather qualitative epidemiological data from community assessments, veterinary expertise already in existence, and indigenous oral histories (Mariner and Paskin, 2000). The degree to which a society depends economically on a given agricultural activity is typically correlated with the depth of community knowledge about that activity. In animal production, the ethno-veterinary knowledge of pastoral and agro-pastoral communities is the best source of information and knowledge for guiding livestock disease surveillance and control. The Samburu herders are principally dependent on their livestock for their livelihoods, and therefore, the community possesses detailed information about small ruminant diseases down to clinical signs and post mortem lesions (Bizimana, 1994).

Another benefit of participatory epidemiology is that it allows locals to apply their own experience and expertise in disease surveillance and control, building on what they already know. The local population can be empowered through participation, especially the underprivileged and rural women (Catley and Admassu, 2003; Alders *et al.*, 2020).

Using participatory ethnographic methods, this study employed PE to assess the status, distribution, and effects of livestock diseases in the area and to rank the principal livestock diseases in selected Wards/Sites in Samburu County based on pastoralists' perceptions.

7.3 Materials and Methods

7.3.1 Description of the study area

The study area is as described in Chapter 3 (Figure 3.1).

7.3.2 Study design and sampling procedure

There are several methods for epidemiological analysis of livestock diseases. The most common one is the participatory epidemiological technique (Mariner and Paskin, 2000; Catley, 2005). Participatory epidemiology (PE) is used to categorize and rank animal species according to their abundance and value to human subsistence, to identify and rank animal diseases based on incidence, and to assess the effectiveness of treatment options that have frequently been employed to manage these diseases. In several prior investigations, this methodology has been used (Moenga et al., 2016; Bett et al., 2008). In order to investigate a range of animal diseases, epidemiologists are increasingly embracing new methodologies through the application of Geographical Information Systems (GIS). Disease prediction has leveraged connections between satellite-derived variables related to the environment such temperature, humidity, and vegetation changes (Kshirsagar et al., 2013; Martin et al., 2007). Another emerging method is the adoption of a combination of GIS technique and reviewing of previous livestock disease cases in order to identify disease hotspots and implement response strategies (Muse *et al.*, 2012; Gitonga, 2015). This study adopted a combination of methods involving PE, GIS and use of satellite-derived temperature and rainfall data to analyze livestock disease hotspots in the rangelands of Samburu.

The Kenya veterinary policy (GoK, 2015) considers 10 key livestock diseases as priority for Kenya. These are Foot and Mouth Disease (FMD), Contagious Bovine Pleuropneumonia (CBPP), Peste des Petits Ruminants (PPR), Rift Valley Fever (RVF), Brucellosis, Sheep and Goats pox (SGP), Lumpy Skin Disease (LSD), Contagious Caprine Pleuropneumonia (CCPP), Camel pox and Trypanosomiasis. The PPR, CCPP, SGP, LSD, FMD, Camel pox and Trypanosomiasis diseases were covered in this study. The selected diseases are known to have major effects on pastoral livelihoods and livestock markets and how they are managed attracts regional and international attention.

The study targeted to collect for each disease, information on number of incidences and geographical hotspots. According to Catley and Mariner (2002), in instances where there is no data or very little "hard data" available, to enable the development of disease control strategies, then it is important to use participatory approaches for veterinary epidemiology to obtain this information from experienced pastoral communities who have a wealth of livestock husbandry and disease diagnostic knowledge. The PE approach was therefore carried out in order to fill in the information gaps about livestock diseases in Samburu County. The PE exercise was undertaken on the premise that the local herders had the necessary information that was required.

7.3.3 Data collection

7.3.3.1 Participatory epidemiological study

Six PE groups (one per study site) were selected for this investigation. The PE exercise was necessary as it provided the bottom-up approach to solving animal health issues. The PE exercise involved identification and listing of common livestock diseases; matrix scoring of the identified diseases; participatory resource mapping entry points of the areas affected by the diseases and a discussion on seasonal calendar of the study locations.

Matrix Scoring tool tries to establish the communities' understanding of diseases compared with their respective clinical and post mortem presentations (Catley and Mariner, 2002). This tool was applied to determine the level of community perceptions of disease in relation to other risk factors such as ecto-parasites and weather changes.

Proportional piling for morbidity and mortality was applied to all the six PE groups to establish the communities' perceptions of the five priority diseases of each species in terms of morbidity and mortality.

Participatory resource mapping is a visualization tool that helps the PE team and respondents to appreciate key livestock infrastructure, social amenities, stock routes, and livestock disease hotspots/entry points. Probing the maps helped the PE team to appreciate the dry season grazing zones, conflict zones and the association between seasonality, livestock migration, intercommunity conflict and livestock health events.

Seasonal calendar was applied in order to appreciate the weather patterns, socioeconomic activities, livestock migration patterns, disease prevalence and forage status during various seasons as well as drought coping strategies and determining cause-effect relationships in relation to livestock health.

7.3.3.2 Participatory epidemiology data collection process

Participatory epidemiology (PE) data collection team comprised of five technical staff (a moderator, a translator, a recorder, a mobilizer and a supervisor). The technical team in collaboration with Community Disease Reporters (CDRs) and community leaders (village administrators and chiefs) mobilized communities from the selected study sites to select twenty livestock owners for the PE exercise.

The selection of informants was based on voluntary participation with the help of the village administrators and constituted of community members who could provide complete and reliable information based on their livestock practices/experience. Gender aspect was taken into account since the women are mostly involved in caring of small stock (poultry, sheep and goats) in an ideal Samburu community setting.

The PE interviews started by the supervisor giving brief introduction of the PE team members, before asking each participant to introduce themselves. The supervisor would first briefly describe the meeting's goal then invite the moderator to start the interview process. The moderator would start with straightforward, generic questions to ensure the flow of ideas. In order to get the necessary data, the potential for interview flexibility remained through the entire process. In every instance, the participants' perspectives were respected and not stifled by a select few of influential people. During the PE exercise, qualitative methods including pair-wise ranking and matrix scoring were applied. All information discussed was recorded. On average, the interview process lasted for about four hours. In order to validate the themes and obtain more information, as well as to enhance the quality of the data acquired, in-depth questions were utilized throughout the PE. Through participatory resource mapping, the complete Agro-ecological characteristics of the research area, as well as possible susceptibility factors for the emergence of disease such as livestock movement in search of grazing areas, water sources or livestock market routes were recorded using participatory resource mapping.

7.3.3.4 Temperature and rainfall data

Temperature and rainfall data were obtained from United States Geological Society's (USGS) Early Warning Explorer (EWX) software (https://earlywarning.usgs.gov/fews/ewx/index.html?region=af) and included the average monthly rainfall and temperature data for Samburu County. January 2002 to December 2020 constituted the climate baseline. The data included monthly rainfall and temperatures for the 15 Wards of Samburu County for a period of 18 years.

7.3.4 Data analysis

Spatial analysis using ArcMap 10.8 was used to map disease hotspots obtained through participatory epidemiology. The maps were used to show the relationship between disease hotspots and seasonal herd mobility patterns. In order to get information on the most important livestock species kept and diseases in various Wards of Samburu County, ranking was done in each of the study sites. Average scores were then allocated to each species of livestock as a mean of all scores for the Wards. This information was then transferred to a map in order to get a glimpse of the spatial distribution of livestock species in order of economic importance and the related diseases.

Bivariate correlation was used to confirm whether there were any significant correlations between cases of livestock diseases and mean annual rainfall and mean monthly temperature in the 15 Wards of Samburu County. This was conducted after Shapiro-wilk test for normality indicated that most of the disease ranking data was normally distributed. Dry season grazing areas and identified disease hotspots were analyzed to identify areas suitable for seasonal disease control.

Relationship between disease occurrence and location was analyzed using Detrended Correspondence Analysis (DCA) ordination. This was done using PAST software version 4.03.

7.4 Results

7.4.1 Economic importance of various livestock species kept by the community

The results indicates that goats were considered as a species of most economic importance by the respondents followed by cattle, while the least was chicken. Figure 7.1 shows that goats were rated highly in all the Wards apart from a few Wards in Samburu Central and Wamba East Ward while camels were rated poorly in all the Wards apart from Wamba East Ward where it was rated as the animal of most economic importance.

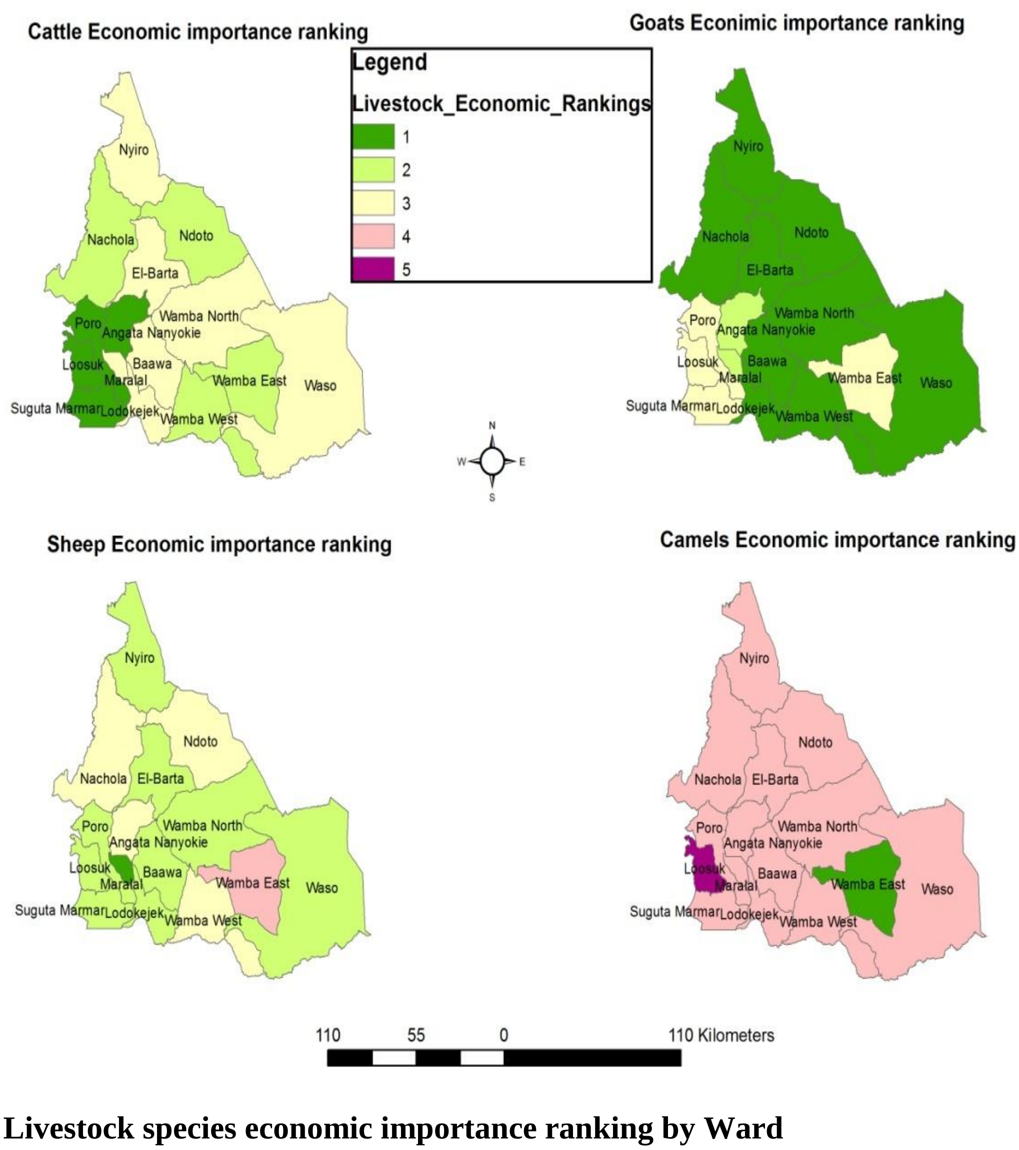


Figure 7.1: Livestock species economic importance ranking by Ward

7.4.2 Livestock diseases in relation to seasonal herd distributions

The results of the analysis indicated that PPR and CCPP are widespread among the small ruminants (sheep and goats) in all the Wards. The worst affected Wards for CCPP included Nachola, Ndoto, Porro, Wamba North and Lodokejek while for PPR are Nyiro, Waso, Wamba East, Wamba West and Suguta Marmar (Figure 7.2).

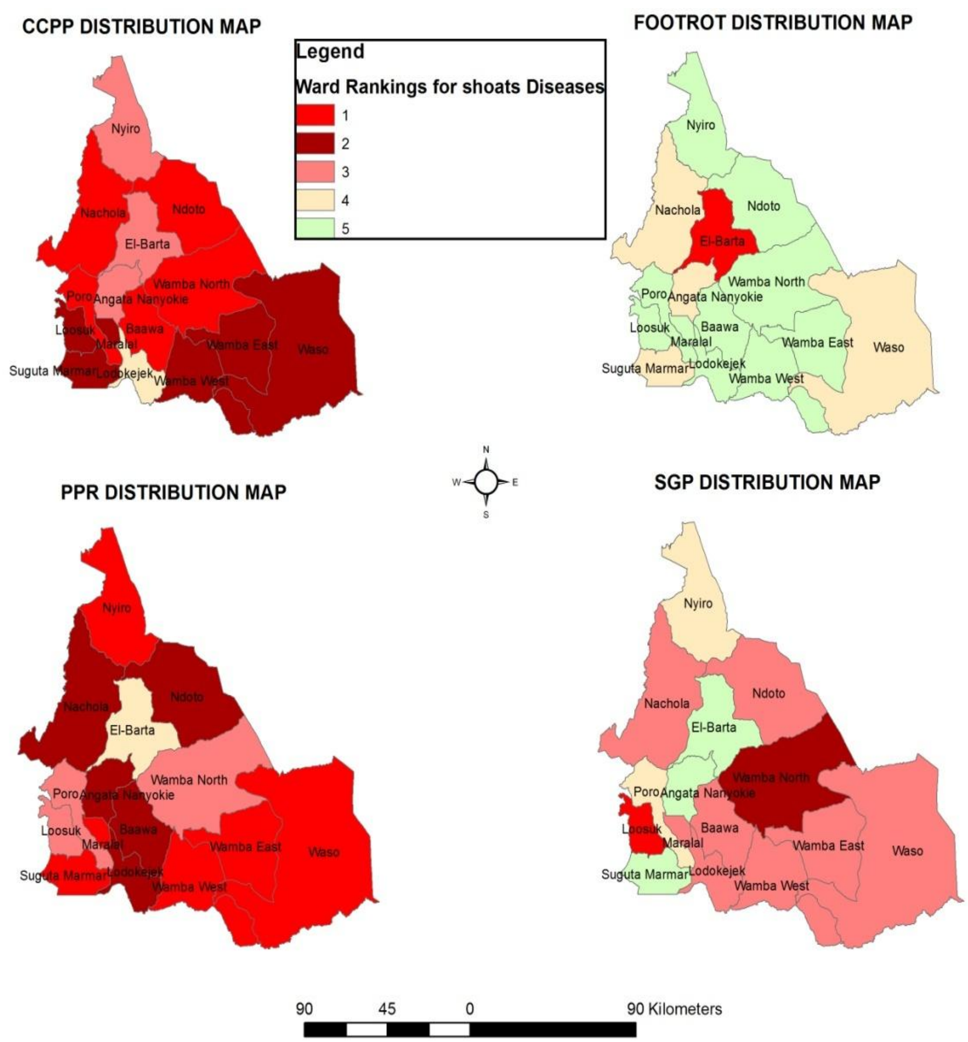


Figure 7.2: Spatial distribution of selected shoats diseases in various Wards of Samburu County

For cattle diseases, the results showed that FMD was the key livestock disease that affects cattle. This was followed by Anaplasmosis, while the least common was LSD.

FMD affected all the Wards (Figure 7.3). Anaplasmosis on the other hand affected Samburu East more than the other areas while ECF is seen to be affecting Samburu Central more than the rest of the County.

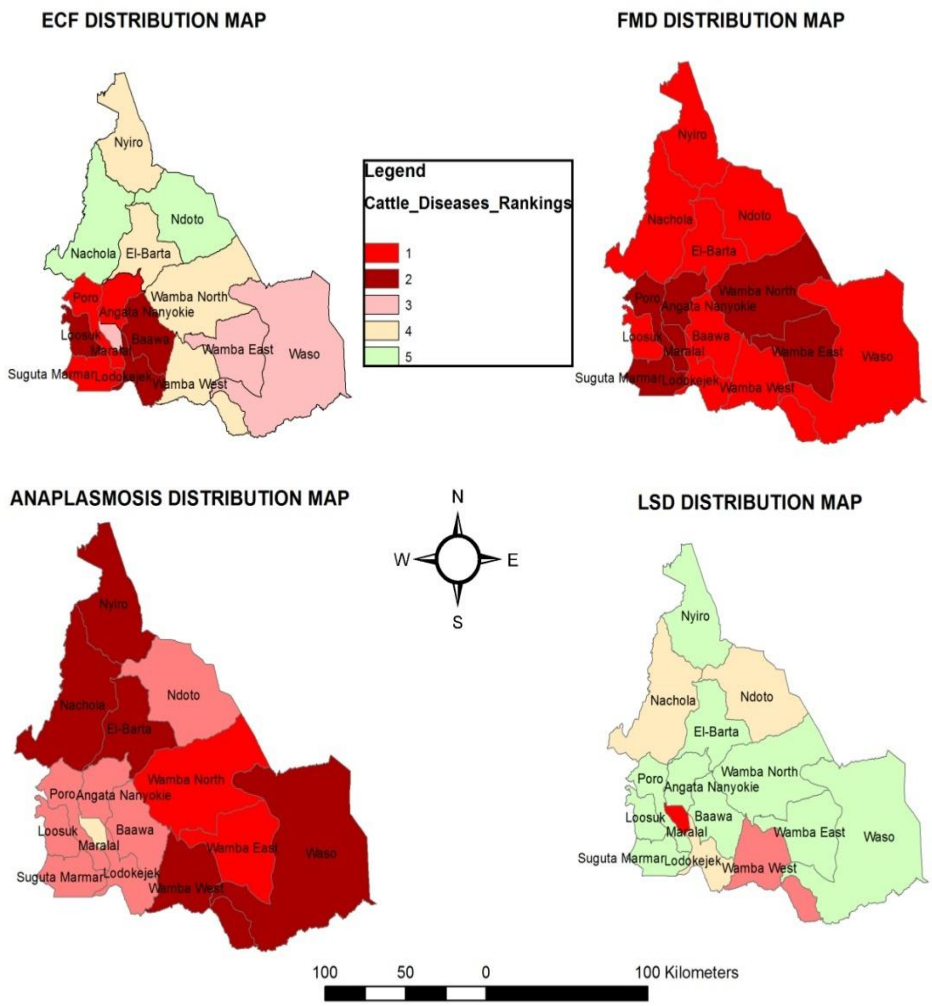


Figure 7.3: Spatial distribution of the selected cattle diseases in Samburu County

For the camels, it was only possible to identify and rank diseases from 10 of the 15 Wards of Samburu County. This is because the practice of camel rearing is common in the lowlands of Samburu East and Samburu North. Among the Camels, Trypanosomiasis (Surra) was ranked as the key disease affecting them in most of the Wards in the County. This was followed closely by Camel cough while the least prevalent disease was Camel pox.Hemorrhagic Septicemia and Trypanosomiasis were shown to be common in Samburu East while Camel cough was more common in Samburu North (Figure 7.4). Camel pox was more common in Lodokejek and Wamba East Wards.

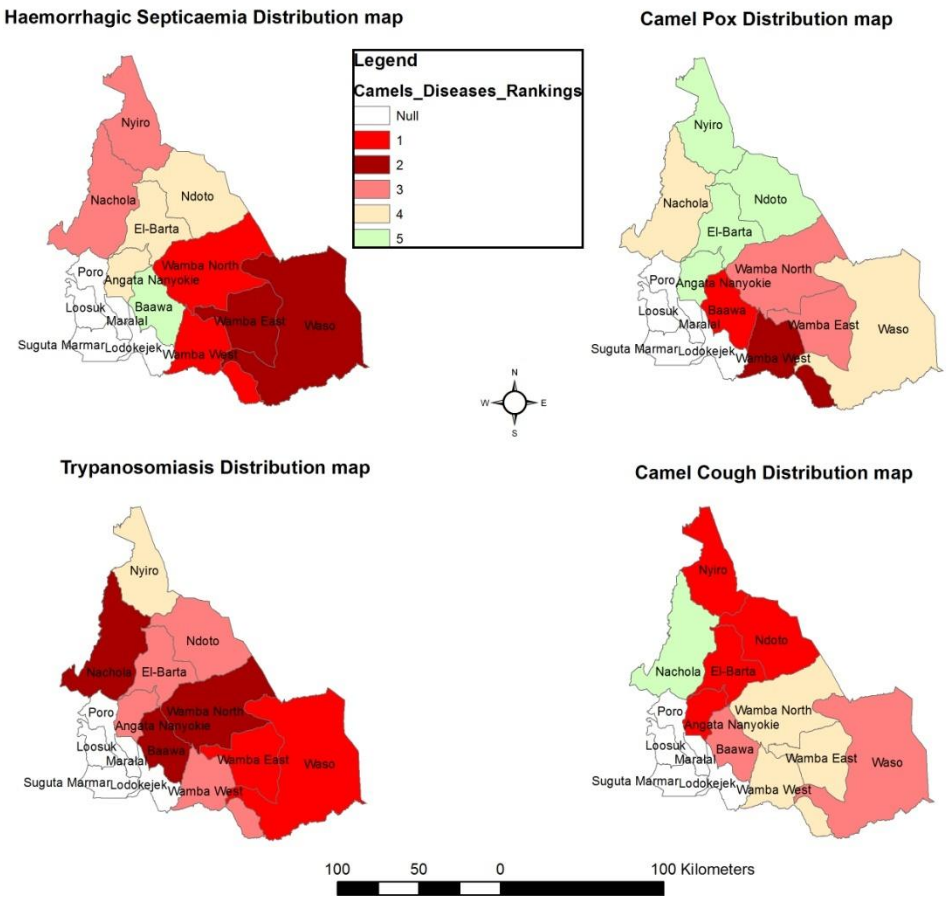


Figure 7.4: Spatial distribution of selected Camel diseases in various Wards in Samburu County.

7.4.3 Clinical presentation of various diseases reported by the community

Findings from matrix scoring of livestock diseases indicated that respondents had a good understanding of major clinical presentations of the five diseases of interest for cattle, sheep

,goats and camels. The use of clinical visualization tool was well appreciated by the respondents despite it being engaging. However, cases of mixed infections of diseases such as CCPP and PPR or PPR and helminthiasis were difficult to allocate weights on the matrix by the respondents without proper guidance. Overall, the community respondents were able to associate different livestock diseases with their clinical presentations. For instance in the case of PPR, the clinical symptoms identified by the community members were diarrhea, nasal discharges, lachrimation, and emaciation. The name commonly ascribed to the disease was *lodua lantare* (Rinderpest of sheep and goats) while other respondents described it as *Kinyoot* (Excessive nasal discharges). The detailed findings of the matrix scoring of livestock diseases are presented in table 7.1.

Table 7.1: Description of sheep and goat diseases by the informants

	Common name	**Local name**	**Clinical signs according to informants**
1.	Peste des petits ruminants	Nkorotit/Nkiriata/Lodua loo ntare/Kinyoot	Severe diarrhea, palor mucous membranes, wasting, abortions, bottle jaw, high mortality
2.	CCPP	Lkipei lo ntare	Coughing, dyspnea, emaciation, salivation and lacrimation.
3.	Footrot	Ngójini	Abscess on the foot, wounds between the toes, lameness, high morbidity.
4.	Sheep and goat pox	Nariri	Lumps on skin, anorexia, wasting, high morbidity
5.	Helminthiasis	Ntumwai	Diarrhea, bottle neck, wasting, stunted growth

7.4.4 Spatial distribution maps generated from mental sketches by the community

The informants described the areas where they merged with other pastoralists during the dry seasons to be the hotspots for disease transmission as well as areas with the disease vectors including tsetse fly, ticks and other biting flies. The participatory maps helped in knowing the resources the communities had in their locality, areas of human-wildlife conflicts and other resource-based conflicts. Probing the maps helped the PE team to appreciate the dry season grazing zones, conflict zones and the association between seasonality, herd mobility, intercommunity conflict and livestock health events (Figure 7.5).

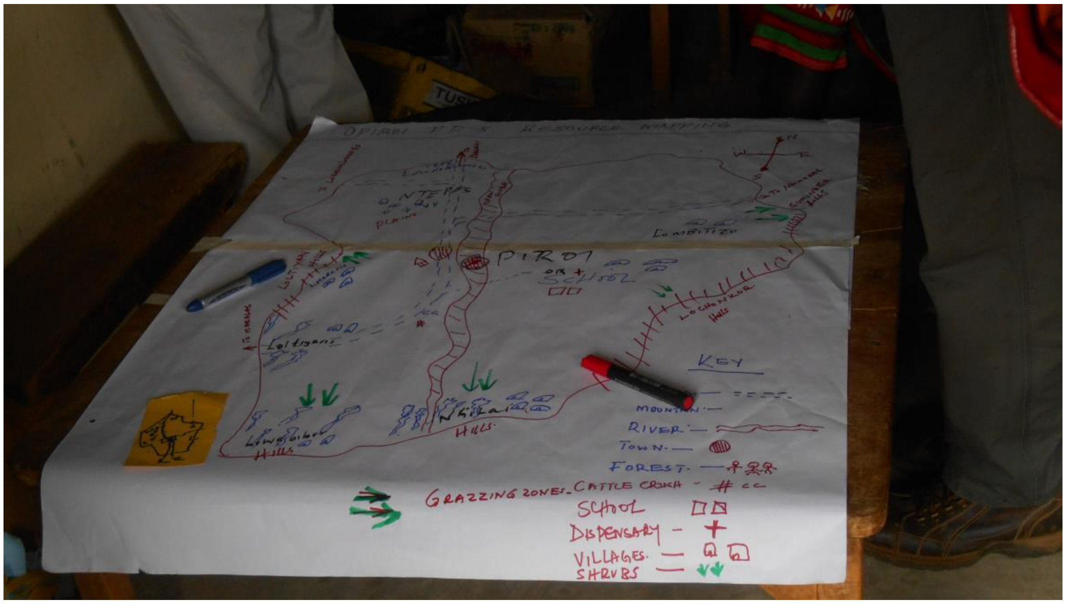


Figure 7.5: Mental sketch map generated by the Opiroi community representatives

A review of the community sketch maps indicated that most of the livestock herds were distributed around Lonyangaten, Kawap and Marti areas of Samburu North, Sirata and Siambu areas of Samburu Central and Sereolipi and Kom areas of Samburu East in the months of January to March and July to September while during the months of April to June and October to December, livestock herds were concentrated in Nachola (Figure 7.6).

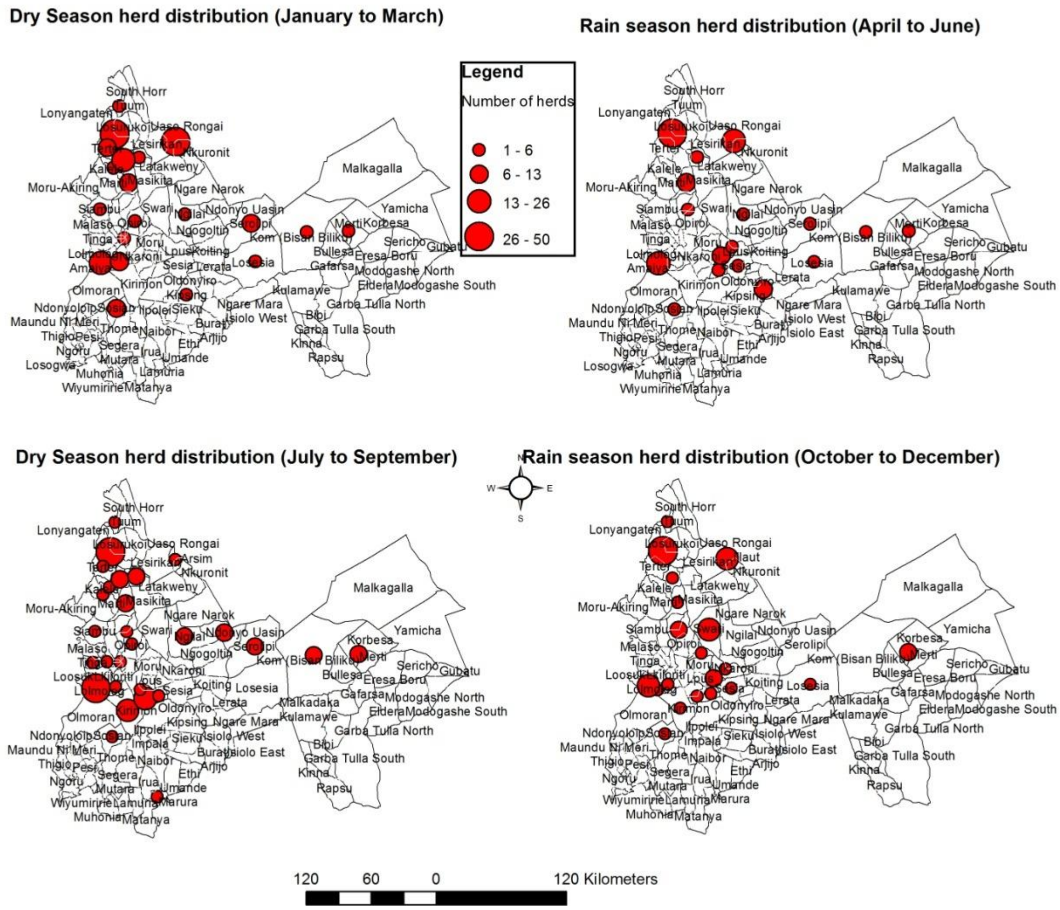


Figure 7.6: Spatial distribution of livestock during different seasons of the year

7.4.5 Herd mobility in relation to disease hotspots

Spatial analysis of cattle diseases against distribution of livestock herds during the months of January to March, showed that only Anaplasmosis and FMD were closely related to the distribution of herds in various parts of Samburu County (Figure 7.7). On the other hand, ECF and LSD seem to be uncommon during this period. This is a dry season for most parts of the County and therefore during this period, livestock move to dry season grazing areas.

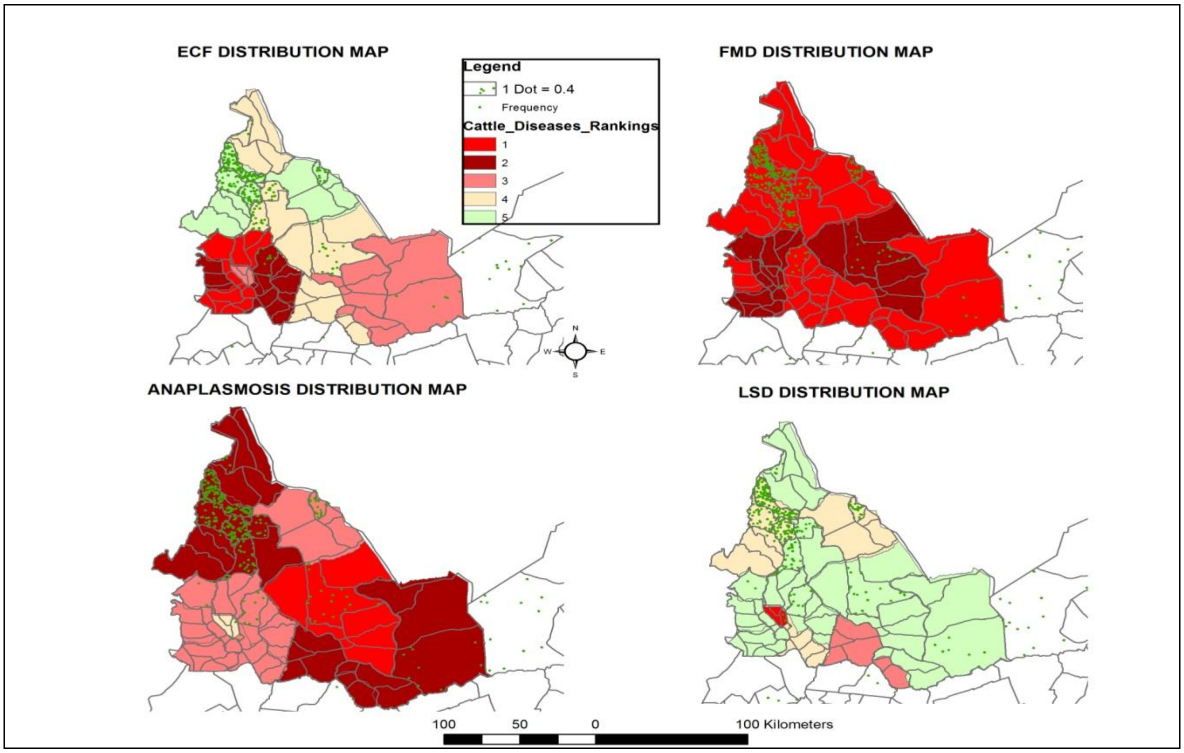


Figure 7.7: Cattle diseases in relation to spatial livestock distribution (January to March)

During the months of April to June, livestock herds were uniformly distributed across the County considering that this is a rainy season for most parts of the County. Anaplasmosis and FMD diseases among the cattle were positively related to distribution of herds during this period (Figure 7.8). On the other hand, ECF and LSD were not positively related to the distribution of herds.

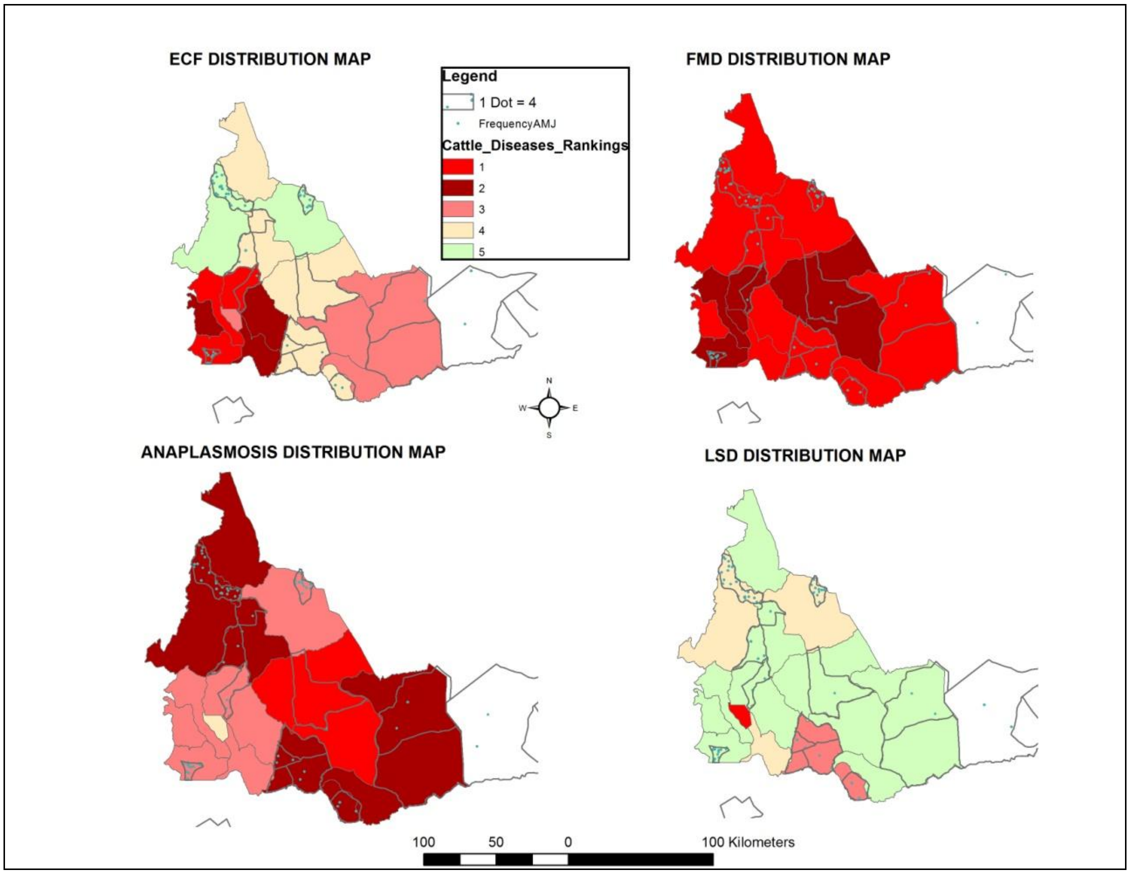


Figure 7.8: Cattle diseases in relation to spatial livestock distribution (April to June)

During the months of July to September, livestock were distributed across all the dry season grazing areas in the County and some crossing the borders to other neighbouring Counties. Three cattle diseases; ECF, FMD and Anaplasmosis, were closely related to the distribution of herds during this period while LSD was not (Figure 7.9)

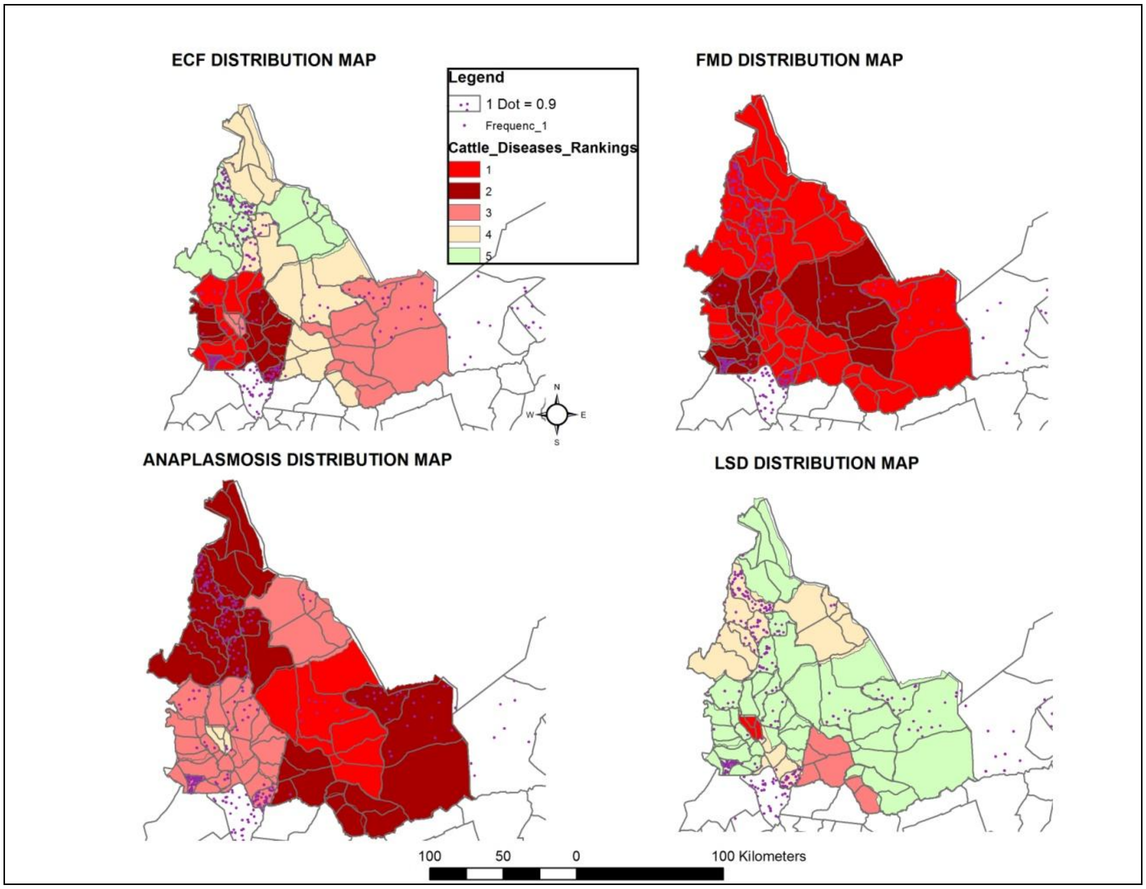


Figure 7.9: Cattle diseases in relation to spatial livestock distribution (July to September)

Between the months of October to December, most of the livestock were within their homestead ranges especially for the lowland areas of the County which receives more rainfall during this period. Spatial analysis indicated that all the four key cattle diseases (ECF, FMD, LSD and Anaplasmosis) were closely related to the distribution of herds during this period (Figure 7.10). The rankings of cattle diseases in relation to distribution of herds showed that FMD was the most closely related followed by Anaplasmosis, ECF then LSD in that order. Most of the livestock during these months were mainly in Samburu North and Samburu Central and these are the areas that FMD was common during this period.

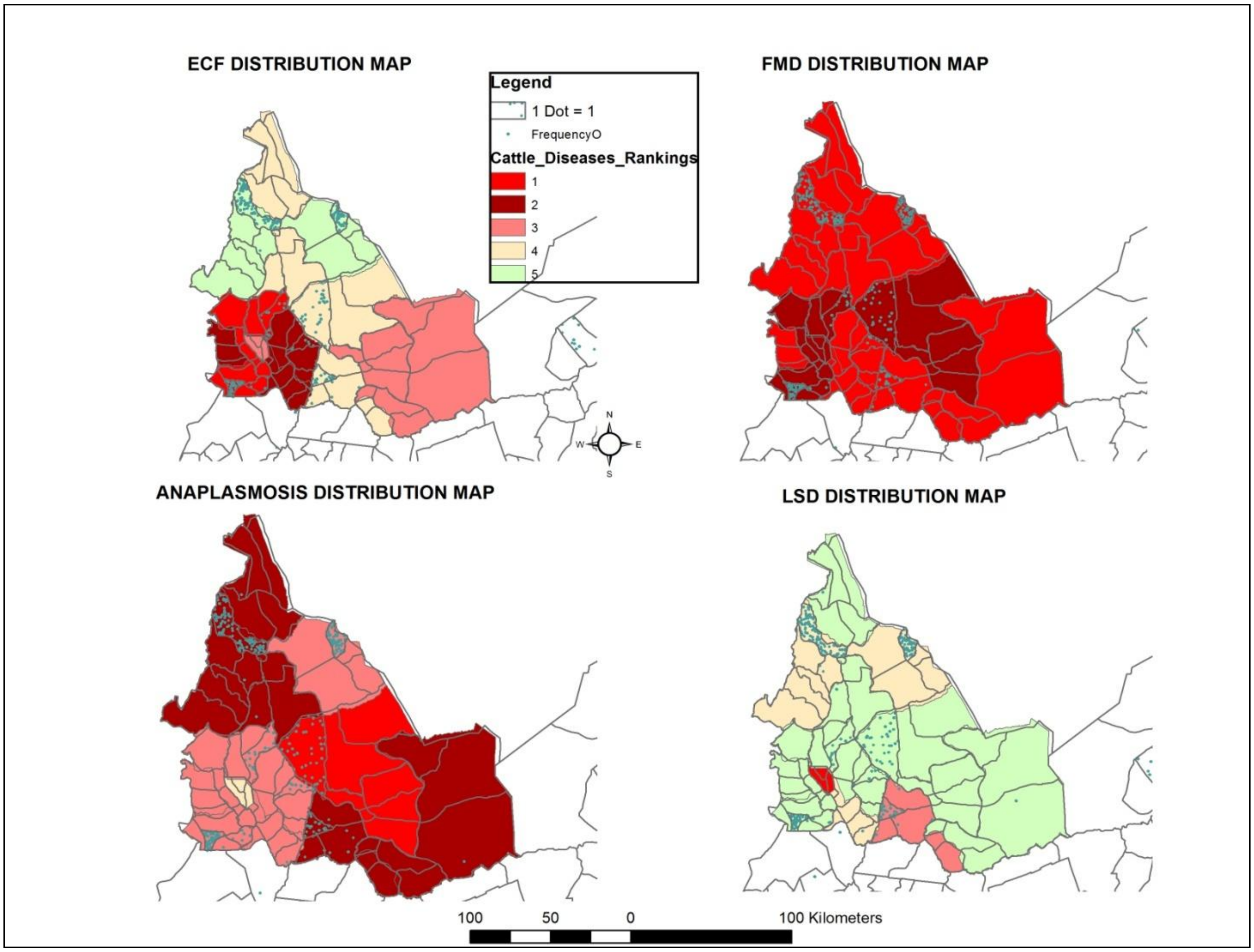


Figure 7.10: Cattle diseases in relation to spatial livestock distribution (October to December)

Two key diseases of small ruminants were shown to be closely related to the distribution of herds during the months of January to March (Figure 7.11). These are CCPP and PPR. During this period the herds are mainly concentrated in the dry season grazing areas. Such areas include Marti and Suyan in Samburu North and Sereolipi and Kom in Samburu East.

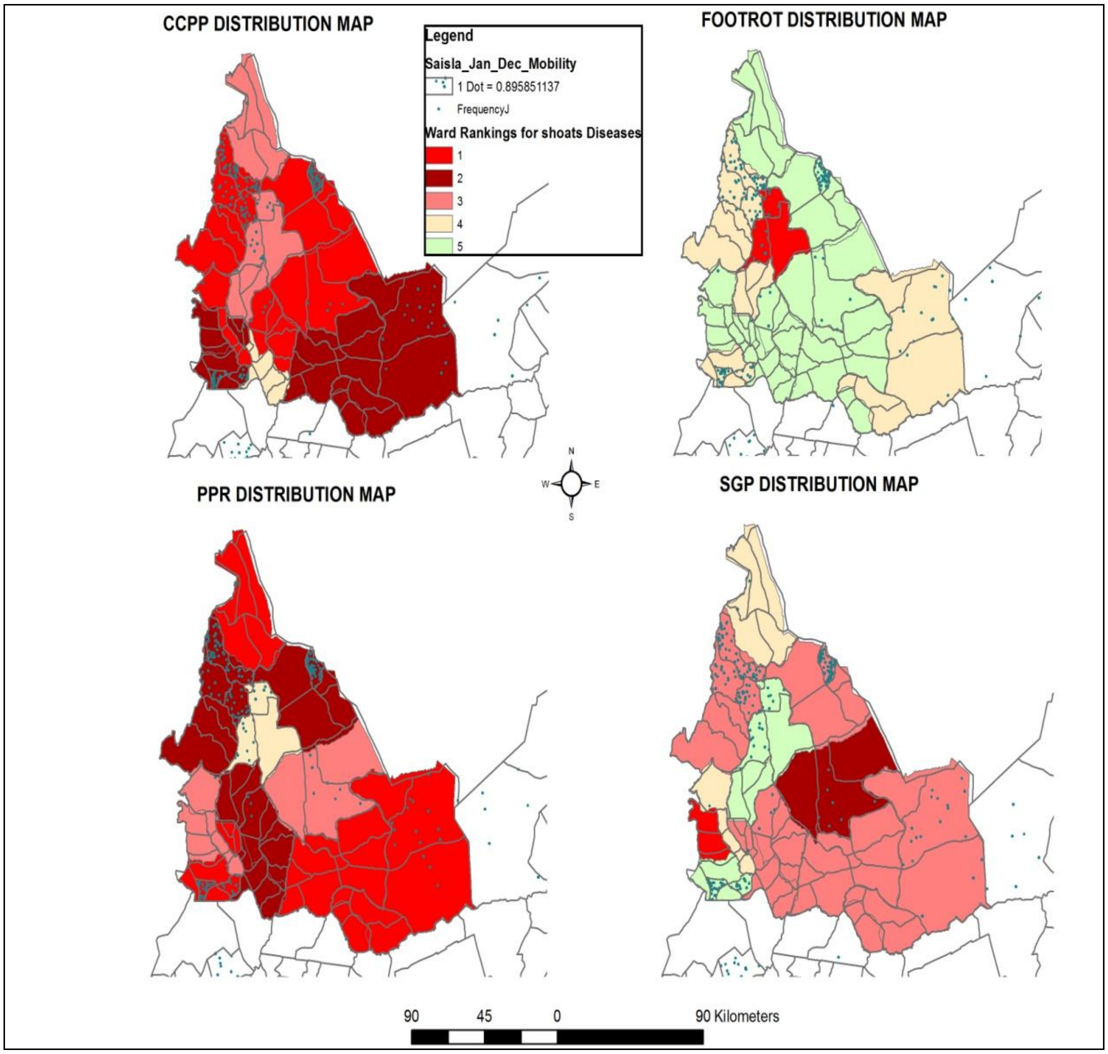


Figure 7.11: Sheep and goats diseases in relation to spatial livestock distribution (January to March)

During the months of April to June, CCPP, PPR and foot rot were closely related to the distribution of herds in the County (Figure 7.12). The SGP was also closely related to the distribution of herds especially in Samburu North. Out of the four diseases of the small -stock, the relationship shows that CCPP and PPR are especially common during this period.

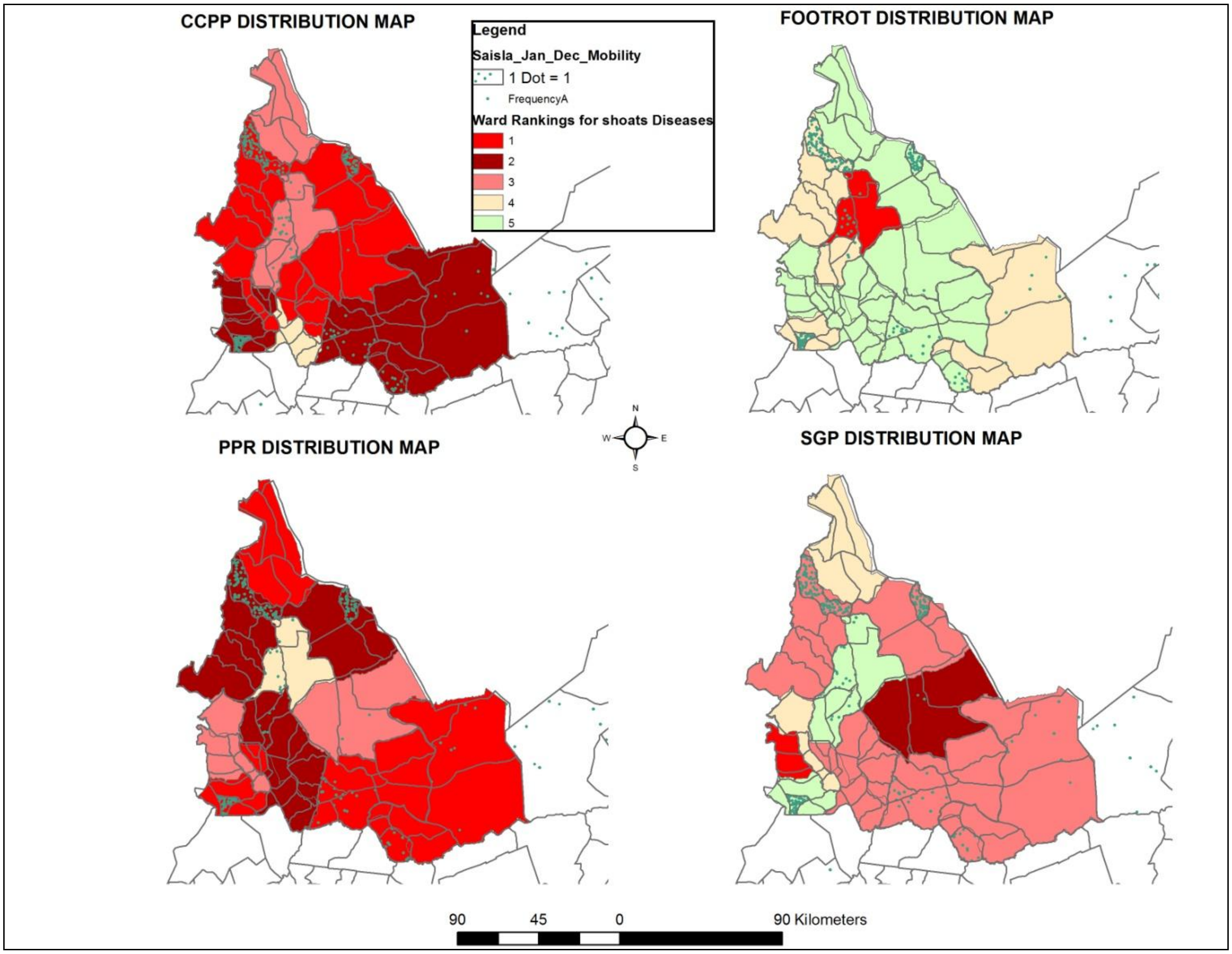


Figure 7.12: Sheep and goats diseases in relation to spatial livestock distribution (April to June)

For the months of July to September, CCPP, PPR, SGP and Foot rot were all closely related to the distribution of herds across the County (Figure 7.13). On closer observation, CCPP and PPR are more common diseases during this period followed by SGP and Foot rot in that order.

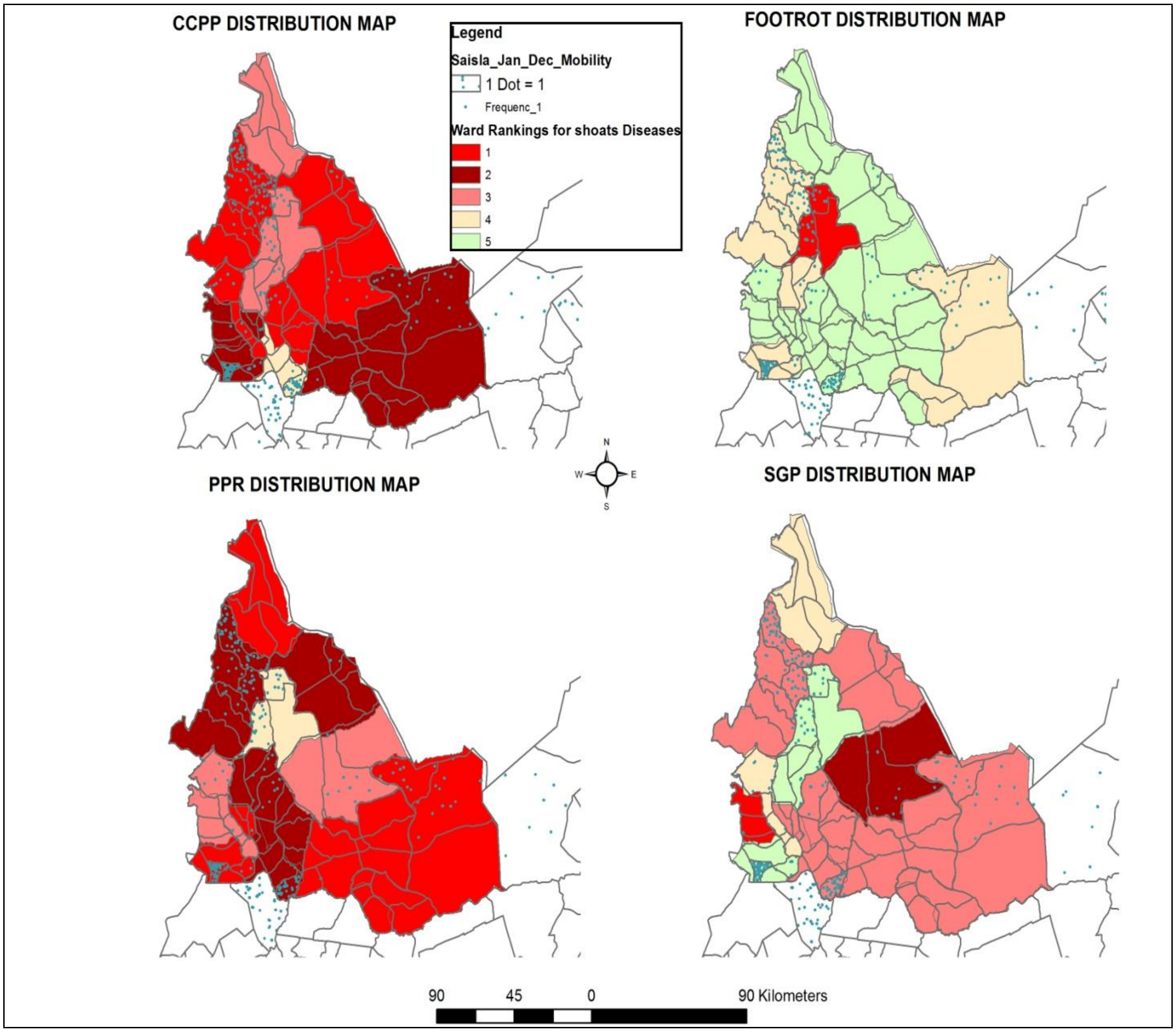


Figure 7.13: Sheep and goats diseases in relation to spatial livestock distribution (July to September)

In the months of October to December, the distribution of herds is also widespread in all the wards across the County but more so in the lowlands. During this period, CCPP, PPR and SGP are closely related to the distribution of herds (Figure 7.14). Foot rot on the other hand, though present was not as common as the other three diseases of sheep and goats.

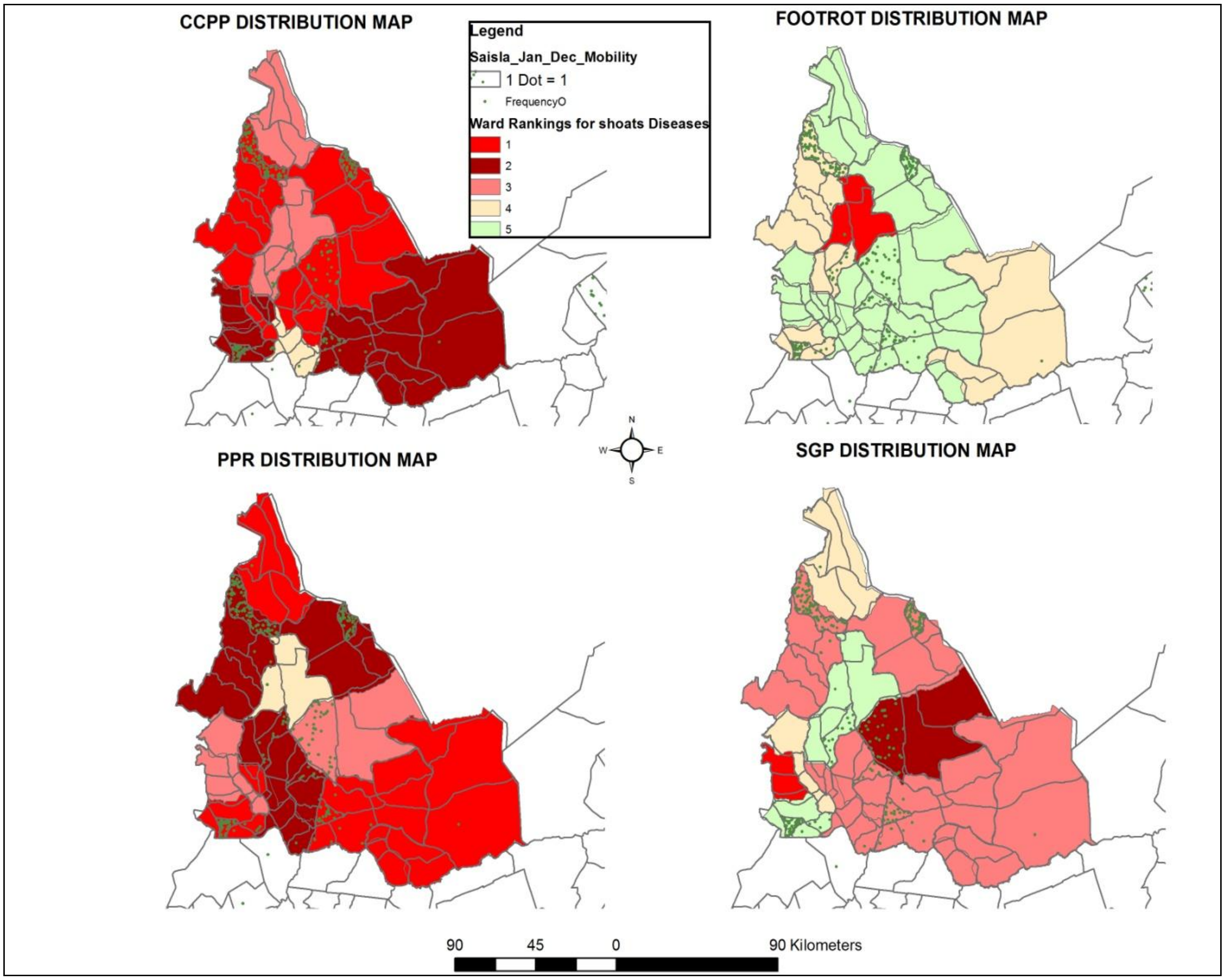


Figure 7.14: Sheep and goats diseases in relation to spatial livestock distribution (October to December)

Among the camels, Hemorrhagic septicemia and Trypanosomiasis are diseases that are closely related to the distribution of herds during the months of January to March (Figure 7.15). This was especially noted in the areas of Samburu East.

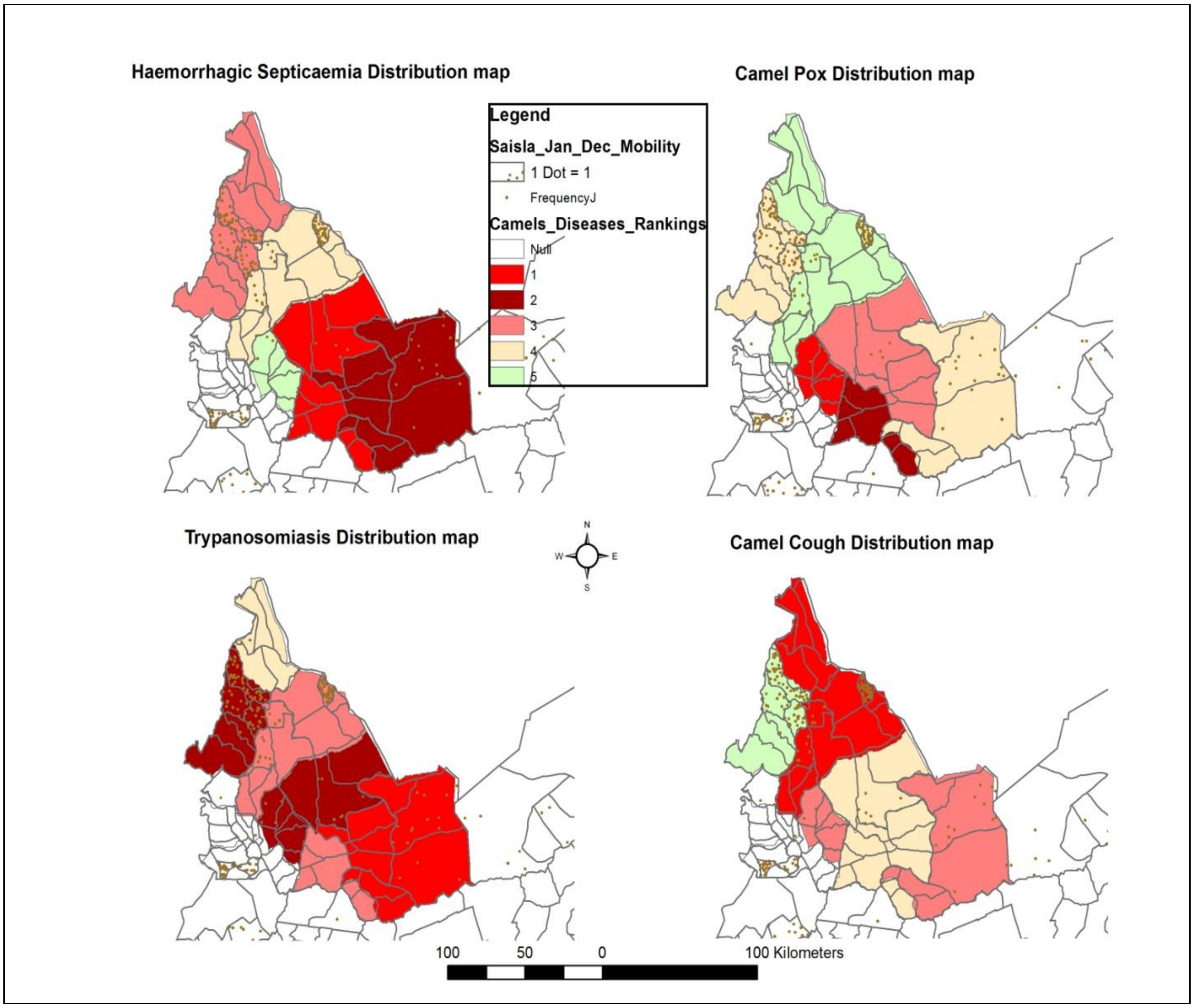


Figure 7.15: Camel diseases in relation to spatial livestock distribution (January to March)

For the months of April to June, all the 4 key diseases selected for camels (Hemorrhagic Septicemia, Trypanosomiasis, Camel Pox and Camel Cough) were related to the distribution of herds during this period (Figure 7.16).

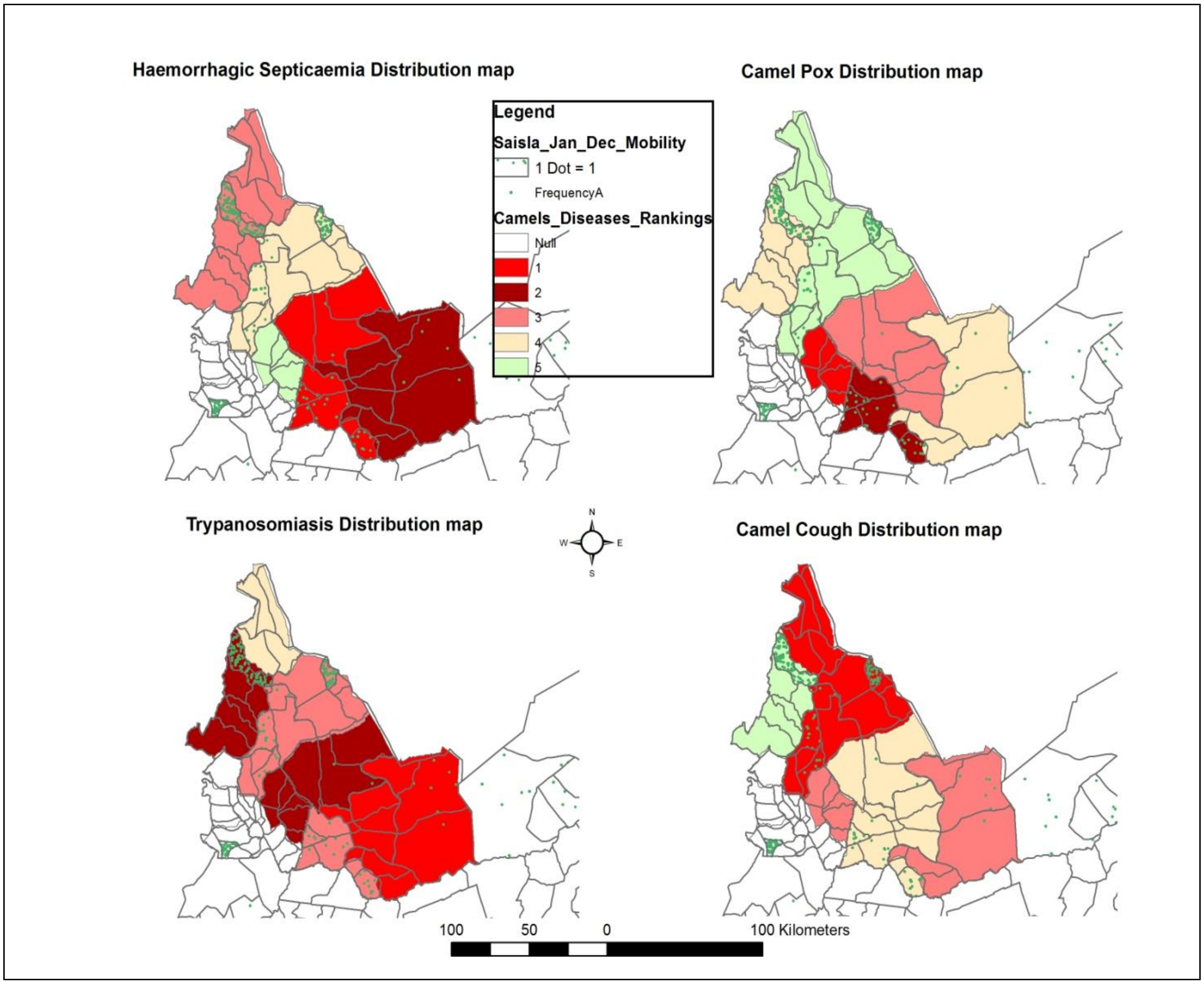


Figure 7.16: Camel diseases in relation to spatial livestock distribution (April to June)

The 4 key diseases selected for camels (Hemorrhagic Septicemia, Trypanosomiasis, Camel Pox and Camel Cough) were also related to the distribution of herds during July to September period (Figure 7.17).

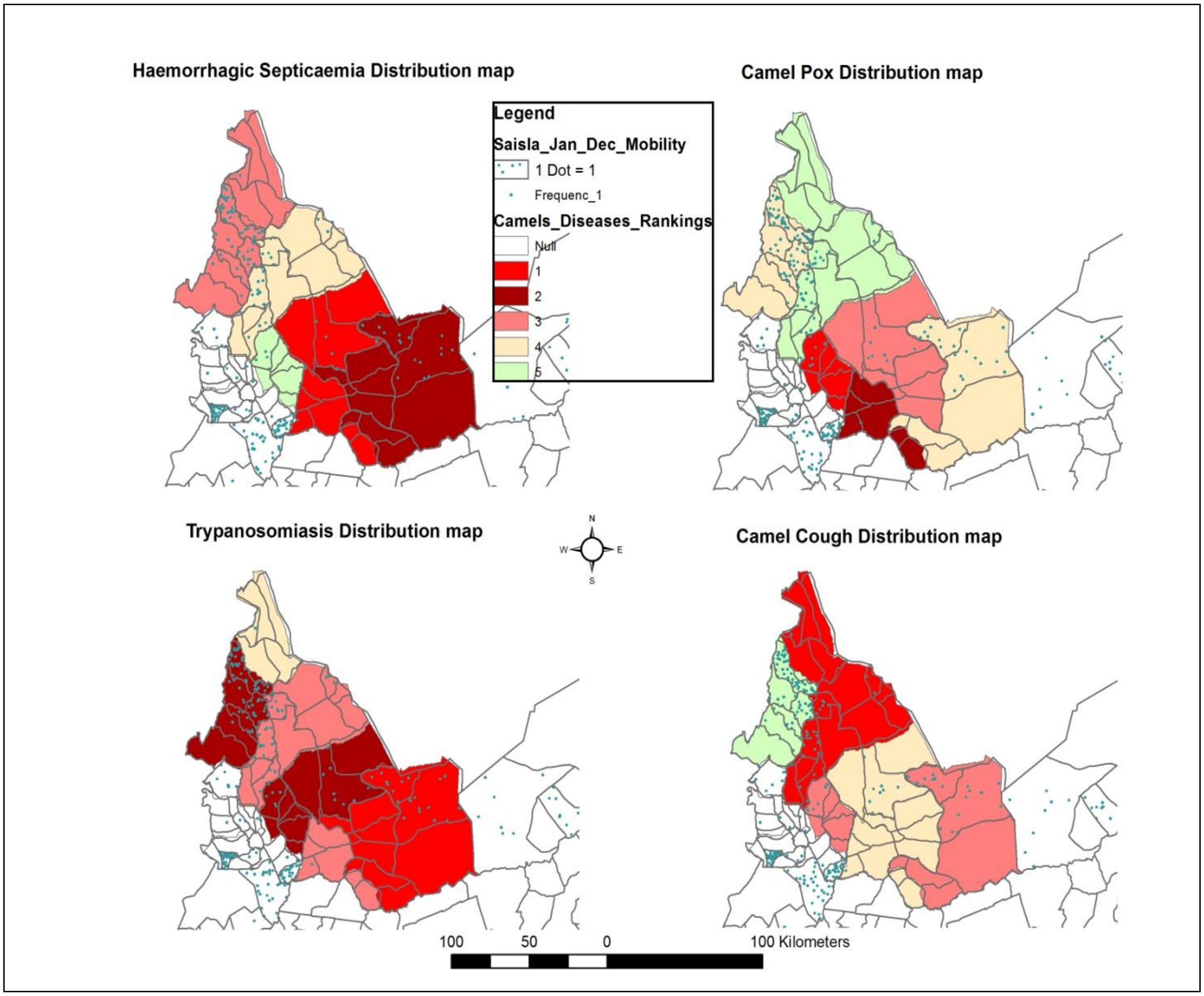


Figure 7.17: Camel diseases in relation to spatial livestock distribution (July to September)

On the relationships between camel diseases hotspots and distribution of herds, all the four camel diseases (Hemorrhagic Septicemia, Trypanosomiasis, Camel Pox and Camel Cough) were related to the distribution of herds during October to December s period (Figure 7.18). The analysis of the relationship between Camel diseases and distribution of livestock herds further revealed that the camel diseases were still common between April and December notwithstanding the distribution of herds.

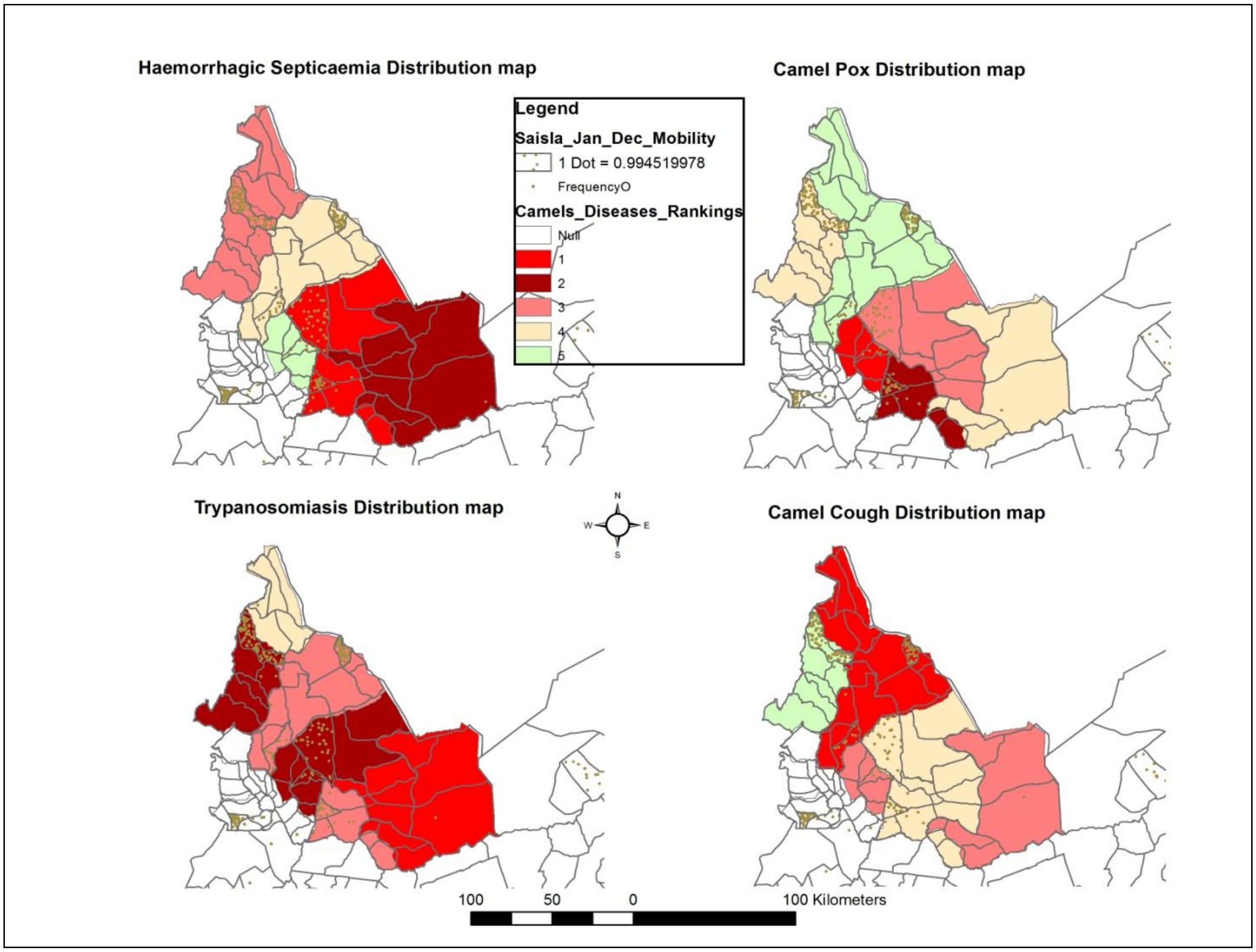


Figure 7.18: Camel diseases in relation to spatial livestock distribution (October to December)

7.4.6 Temperature and rainfall variability in relation to disease hotspots

The seasonal calendar provided by the informants (Figure 7.19) showed a similar pattern in the wet and dry seasons since the areas lie within the same climatic zone. Resource-based conflicts between the communities was mainly experienced during the dry seasons when there is merging together at the grazing and watering areas. This is also the high-risk period when the animals contract diseases such as CCPP and PPR. The community identified the presence of ticks, biting flies, drought and contact with the wild animals as the most important risk factors for disease outbreaks and transmission.

Given that the communities targeted belonged to the same ethnic grouping and most areas were of similar ecological zone, the seasonal calendars were similar in most activities, events, names of seasons and disease prevalence. However, livestock related infrastructure such as cattle crushes, communal dips, animal health service providers were largely non-existent creating a huge gap in animal welfare in the county.

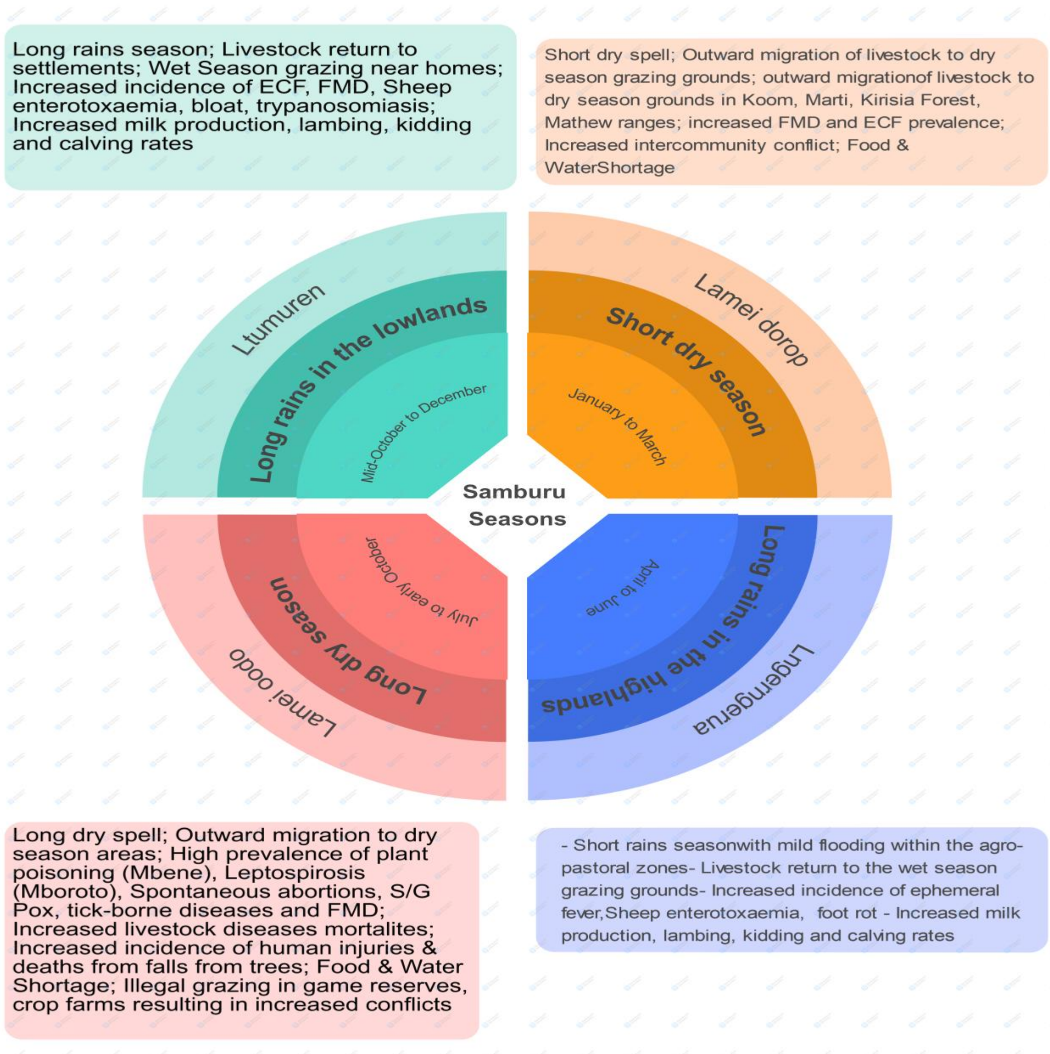


Figure 7.19: Seasonal calendar of the fifteen selected sites in Samburu County

The respondents indicated that the seasons do not follow the Gregorian calendar months but mostly follow lunar calendar as per the Samburu Culture. However, the literate respondents could align the lunar months to the Gregorian calendar months. It was established that climate change is an ongoing phenomenon characterized by disappearance and or decline in some short showers in August called *Nkakwai* rains and *Somiso* that now fall in the Kirisia forest and Mathew ranges only. From the calendar, PPR and CCPP had no seasonal variation but were reported to be prevalent throughout the year. Tick borne diseases pose a major threat to livestock when they migrate to dry season grazing grounds due to lack of tick control facilities and water shortage.

Mean annual rainfall and livestock diseases indicated that a significant correlation at the 0.01 level (2-tailed) for ECF (Pearson Correlation = -0.767, Sig. = 0.001, N = 15). Correlations were also significant at the 0.05 level (2-tailed) for Cattle Helminthiasis (Pearson Correlation = 0.639, Sig. = 0.010, N = 15), Cattle Anaplasmosis (Pearson Correlation = 0.631, Sig. = 0.012, N = 15) and Camel Pox (Pearson Correlation = -0.646, Sig. = 0.044, N = 10).

Correlations between the mean monthly temperature and livestock diseases indicated significance at the 0.01 level (2-tailed) for ECF (Pearson Correlation = 0.683, Sig. = 0.005, N = 15) and Cattle Anaplasmosis (Pearson Correlation = 0.642, Sig. = 0.010, N = 15). Correlations were also significant at the 0.05 level (2-tailed) for FMD in Cattle (Pearson Correlation = -0.541, Sig. = 0.046, N = 15).

Scatter plots analysis further revealed the relationships between rainfall (mean annual rainfall estimate) and livestock diseases (Camel pox and ECF) as well as temperature (Mean land surface temperature) and livestock diseases (Anaplasmosis and FMD).

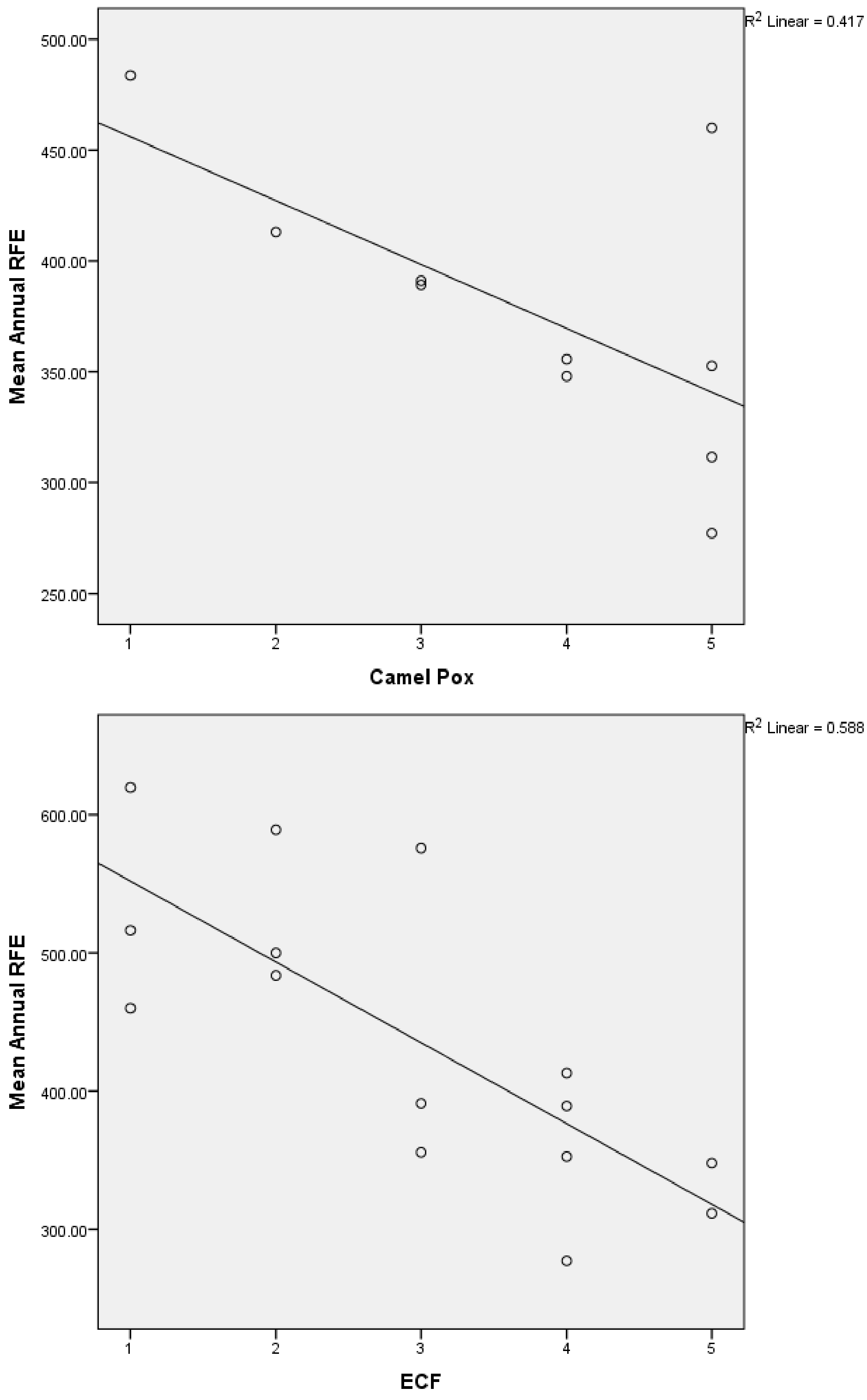


Figure 7.20: Scatter plots showing the relationship between Livestock diseases (Camel pox and ECF) and rainfall variability

For both cases (Camel pox and ECF), the disease prevalence increased with increase in rainfall amount with Camel pox peaking at above 450mm while ECF peaking at above 550mm (Figure 7.20). On the relationship between livestock diseases and temperature variability, scatter plots for both Anaplamosis and FMD also indicated an increasing disease prevalence with increase in temperature. The prevalence of Anaplasmosis peaked at over 40^{o}C while that of FMD peaked at about 38^{o}C (Figure 7.21).

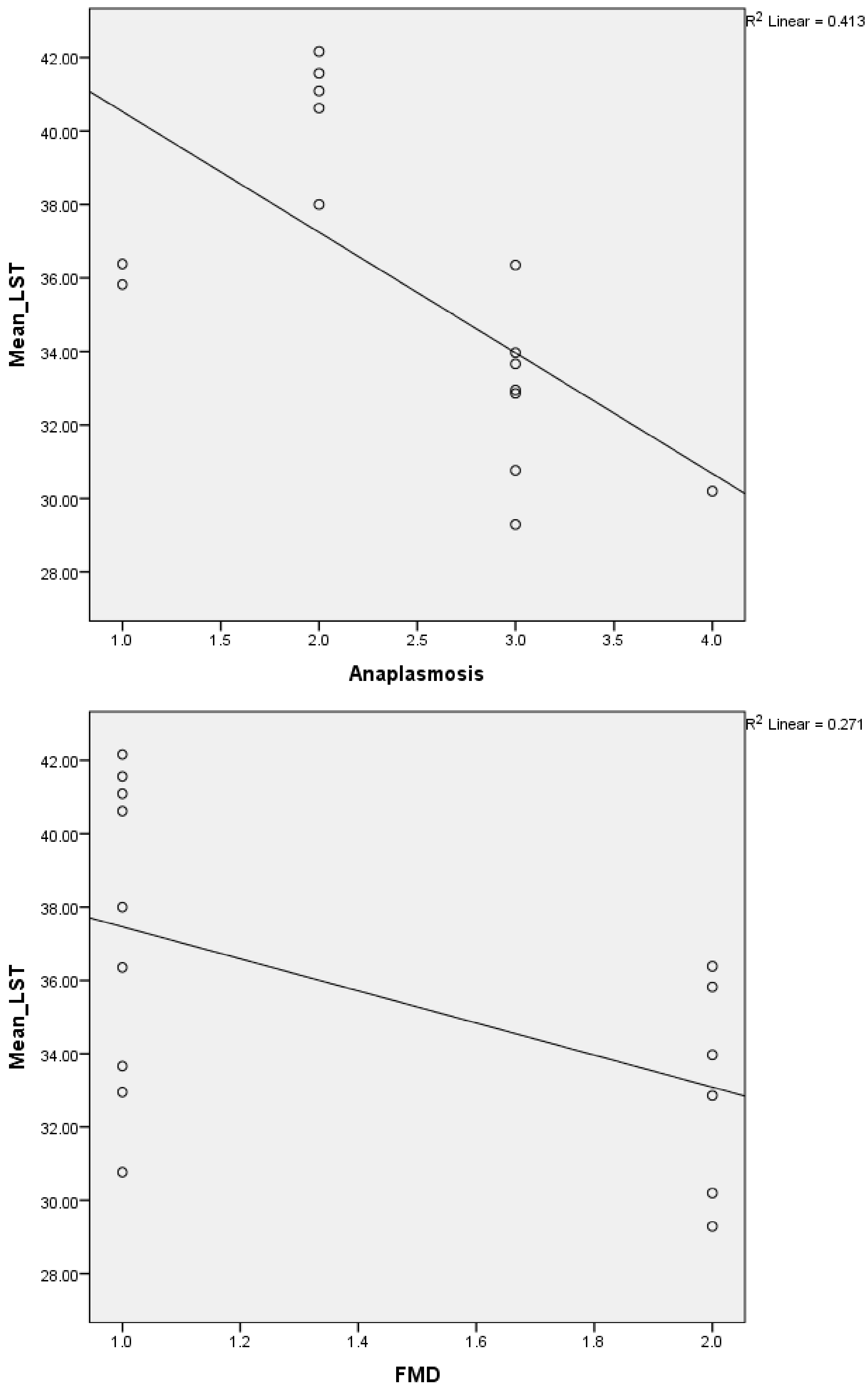


Figure 7.21: Scatter plots showing the relationship between Livestock diseases (Anaplasmosis and FMD) and temperature variability

7.4.7 Relationship between disease occurrence and location

Relationship between disease occurrence and location was analyzed using Detrended Correspondence Analysis (DCA) ordination. This was done using PAST software version 4.03. Among the sheep and goats, the occurrence of CCPP and SGP was closely correlated while the occurrence of foot rot and Helminthiasis was also closely correlated (Figure 7.22). Among the cattle, the occurrence of FMD and Helminthiasis was closely correlated (Figure 7.23). In camels, the occurrence of Haemorrhagic Septicaemia and Camel trypanosomiasis was closely correlated while that of Diarrhoea and Camel cough was closely correlated (Figure 7.24).

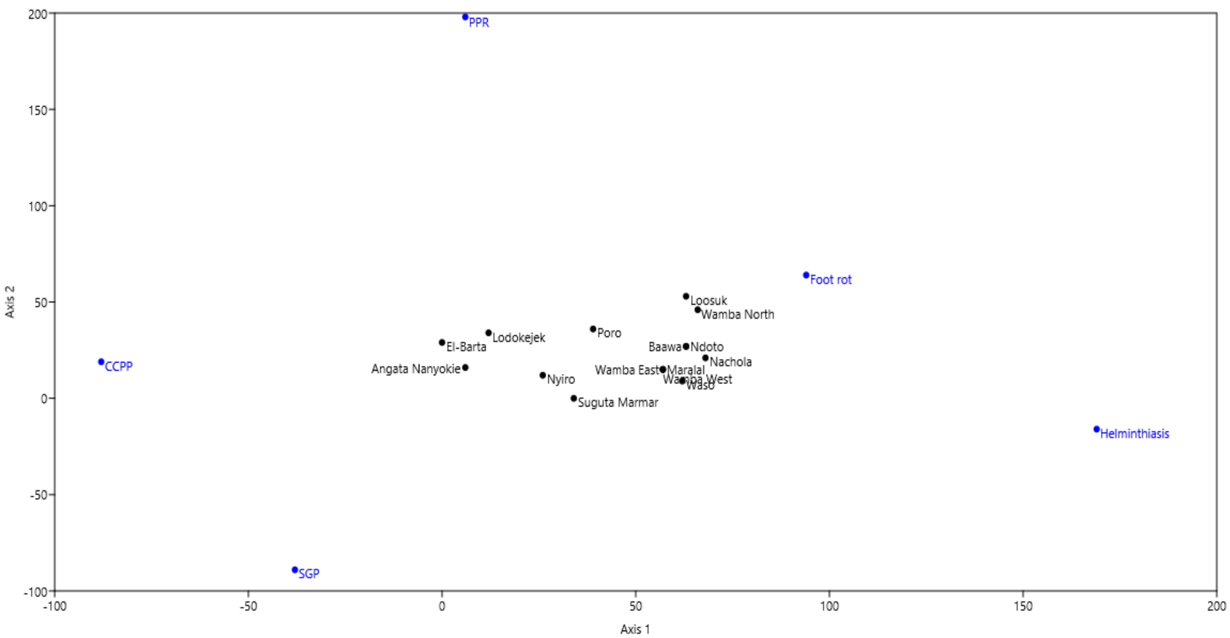


Figure 7.22: DCA results for correlation between sheep and goats Diseases and location

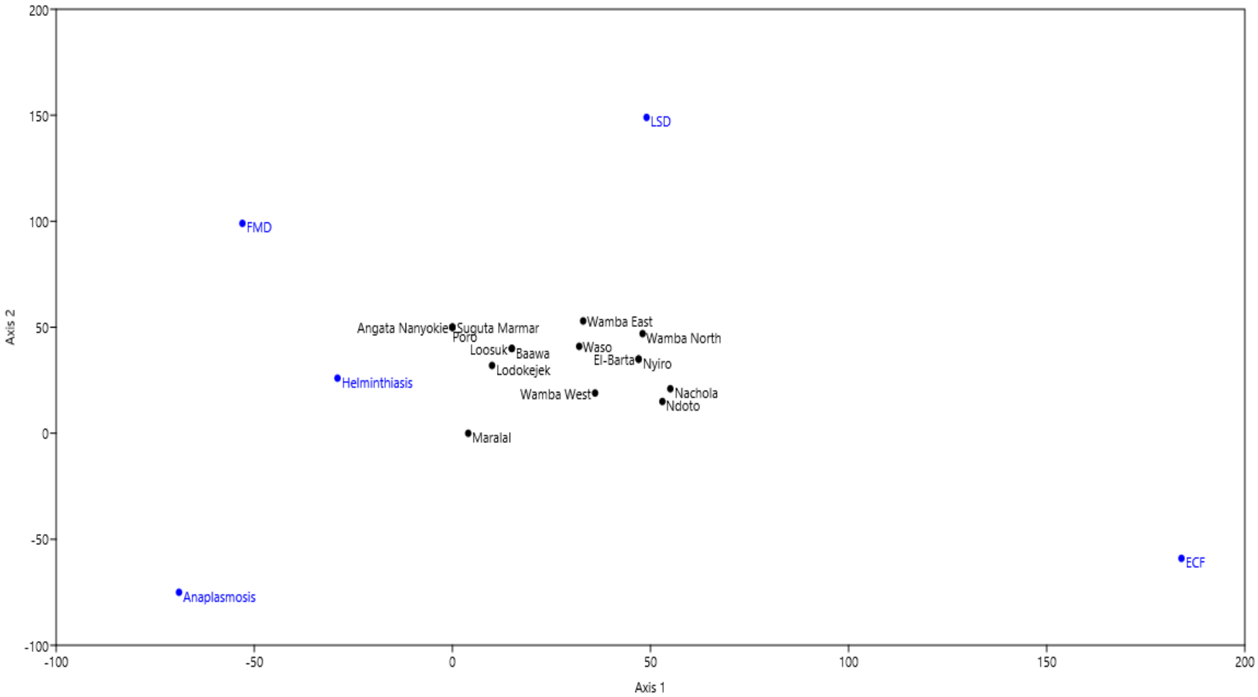


Figure 7.23: DCA results for correlation between Cattle Diseases and location

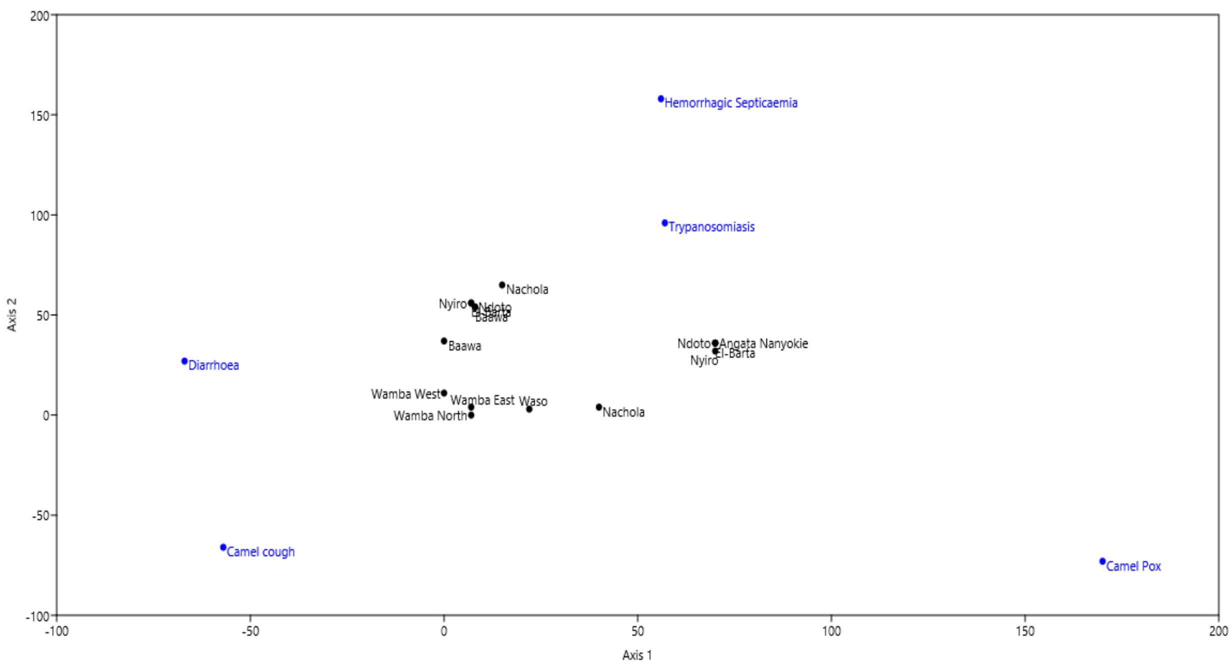


Figure 7.24: DCA results for correlation between Camel Diseases and location

7.5 Discussion

The results of the participatory epidemiology has shed some light on the major disease problems in livestock in Samburu County. According to the rankings of animal species in relation to their economic importance, small ruminants, notably goats, are crucial to the life of pastoralists in the area. Among the pastoralists communities, goats are the main livestock reared because they can easily be converted to income in form of cash to maintain the household when need arises (Imana and Greyling, 2008). However, the goats are faced with PPR and CCPP which were ranked as the priority health problems in the study area. Findings from the PE activity indicate that the PPR is the most prevalent disease among sheep and goats within the localities targeted followed by CCPP. Therefore, it follows that CCPP and PPR are most widespread health conditions among flocks within Samburu County as a whole. The prevalence of both CCPP and PPR can be associated with climate change as the changes in temperature and rainfall affects the frequency and duration of animal contacts (Moenga *et al*., 2016). In the areas where the community participants did not rank PPR or CCPP as a leading disease constraint, it was attributed to prophylactic vaccinations conducted in the study sites which have mitigated the impact of CCPP and PPR.

With the use of PE, the pastoral community's current expertise might provide reliable data that could be used to create more effective surveillance and control plans and initiatives for animal health. PPR, CCPP, and SGP diseases were, correspondingly, the most important health limitations according to the overall rating of sheep and goat diseases in the study areas. Despite this, pastoralists are leaning more toward the keeping of goats rather than cattle since they are more tolerant of scarce feed supplies than the latter (Imana and Greyling, 2008). This is because of climate change and the uneven distribution of rainfall in dry areas. In terms of their economic significance and social benefits, small ruminants play a significant role in the sustenance of pastoralists. They serve as both a capital asset and a source of readily available cash income for their everyday requirements. This is consistent with Tibbo's (2006) argument that small ruminant production, because of their quick reproductive turnover, is essential to sustaining livelihood and food security.

The respondents were able to associate different livestock diseases with their clinical presentations. The pastoralists knowledge of the clinical presentations of diseases can provide a fundamental basis on which to communicate between the veterinary office and the pastoralists (Jones *et al*., 2020). This will in turn enhance disease surveillance and management strategies leading to the improvement of pastoralism production system in ASALs. Despite the fact that there is a lot of literature that emphasizes the importance of participatory approaches towards disease control, participatory epidemiology has remained less commonly utilized and County governments have opted for the top-down approaches which fail to yield results in the long-term (Alders *et al*., 2020).

Most of the herds were distributed around Nachola Ward in Samburu North, Porro Ward in Samburu Central and Waso Ward in Samburu East during January to March and July to September seasons while during April to June and October to December seasons, the herds were concentrated around homesteads all over the County. Anaplasmosis and FMD among cattle, PPR and CCPP among goats and Hemorrhagic Septicaemia and camel trypanosomiasis among camels were closely related to the distribution of herds especially during the dry months of January to March and July to September. Seasonal migration of herds increases interaction levels in the grazing fields during the drier months because flocks from several various parts of the country converge and eventually disease infections from here are spread to other areas during the wet season when herds move back to the homesteads at the beginning of rainy season (Bett *et al*., 2008). During such migrations, there's a lot of interractions between livestock and wildlife especially in Waso Ward (around Samburu National Reserve), Wamba North, Lodokejek, Baawa and Porro Wards (around Kirisia forest reserve) and within the community ranches across the County. This further exacerbates the spread of diseases. Publications on the trends of infections at the wildlife-livestock interface shows an increasing trend of infections and a shift from parasitic to viral (Wiethoelter *et al*., 2015; Caron *et al*., 2013; Barasona *et al*., 2014). Further, a simulation study on the transmission of FMD among mobile herds demonstrated that herd mobility significantly influenced the dynamics of FMD (Kim *et al*., 2016).

Correlations between the mean annual rainfall and selected livestock diseases was significant for ECF, Cattle Helminthiasis, Cattle Anaplasmosis and Camel Pox while correlations between the mean monthly temperature and livestock diseases was significant for ECF, Cattle Anaplasmosis and FMD. Anaplasmosis and ECF are tick-borne diseases and therefore their occurrence closely corresponds to favorable climatic conditions for ticks to survive, reproduce and transmit the infections. Anaplasmosis was also shown to be very closely related to the distribution of herds during different seasons of the year. As highlighted earlier by Bayissa *et al*., 2009, herd mobility is the greatest impediment when it comes to disease control in these areas. FMD in cattle and PPR among the small stock are considered as high priority diseases in multiple rankings due to their impacts on animal productivity and human health (Grace *et al*., 2015).

The mobility of pastoralists and their animals should be considered a complex activity that affects both the health and epidemiology of diseases (Bouslikhane, 2015). Control of diseases in pastoralist areas is made difficult by the remoteness of these areas, poverty trap and illiteracy among the pastoralists (Sharma, 2021; Wilcox *et al*., 2019). Pastoralists in areas like Nachola and Wamba North can hardly access veterinary services and often resort to traditional methods of disease control such as ethnomedicine. Therefore, the process of controlling diseases is inseparable from lifting the constraints surrounding mobility and this calls for incorporation of pastoralism into the disease control strategies and frameworks. Investments such as water points, cattle dips and markets need to be made in areas where pastoralists regularly converge (Kiara *et al*., 2017). This will not only reduce transmission of diseases in these araes but also present an opportunity for the pastoralists to sell off part of their livestock for income to support family and purchase veterinary drugs while at the same time reducing their numbers to a manageable size.

7.6 Conclusions and Recommendations

This study has highlighted the major livestock disease problems as declared by the Samburu community participants. Extensive epidemiological, serological, and ecological studies are required to produce valid and reliable data for use in the future disease control measures.

Based on the knowledge of the local informants, a robust control program can be implemented to curb PPR and CCPP among the shoats, FMD and Anaplasmosis in cattle and Trypanosomiasis and Camel cough in camels as they came out as the most important diseases among the livestock in these areas. Prevention of livestock diseases through vaccination is essential in eradication and reduction of economic losses experienced by the local people in these areas.

This research also concluded that there was a significant association between seasonality and livestock disease epidemiology. Therefore, livestock disease control efforts should be focused towards the wet season and dry season grazing areas. The priority diseases identified by the communities should also be given due attention and regular epidemiological studies and serological surveys undertaken to generate information to be used for future control measures.

To enhance disease control efforts, County Governments in all the ASAL Counties needs to allocate more resources towards disease control infrastructural development. Priority should be given to crushes used as holding pens during vaccinations and mass treatments and also plunge dips for control of vector-borne diseases.

CHAPTER EIGHT

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

8.1 General Discussion

Eastern Africa rangelands have two rainfall seasons with the long rains mostly occurring during the months of April, May and June and the short rains being received in the months of October, November and December (Galvin *et al*., 2001; Mutai and Ward, 2000). These lands cover 80, 50 and 40% of Kenya, Tanzania and Uganda respectively and have provided livelihoods for millions of pastoralists in East Africa (Fratkin, 2001; Orindi *et al.,* 2007; Nyariki *et al.,* 2009). Pastoralists in these rangelands are accustomed to the climatic variations that have occurred in these areas throughout history, especially as it commonly occurs in ASALs. Kenya's Drylands cover 84 percent of the nation's land surface, support around 25% of the population, contain as much as 60% of the nation's livestock and over eighty percent of its ecotourism priorities (Davies, 2007).

Pastoralism is reliant on intricate interaction of the environment, effective oversight through well-established local organizations, and animals that have developed adaptation to the environment. Pastoralism's three main pillars are natural resources, organizations, and livestock, and are significantly influenced by seasonal patterns, which are affected by the changing climate. Pastoralists in the rangelands have lived harmoniously with their environment and herds. However, with increasing human population pressure, extractive market forces, land privatization and alienation from the pastoral system have precipitated grazing resource degradation and increasingly, resource conflicts in these areas. This situation is exacerbated by emerging diseases and other factors that pose challenges to access to pasture (Moenga *et al*., 2016). Climatic variability and change will increase the fluctuations of feed and fodder availability, further amplifying these risks. Moreover, increasing livestock numbers to meet increasing demand for livestock products in the context of human population pressure, loss of pastoral land to conservation and agriculture have constrained access to enough feeds by pastoral communities (Galvin *et al.,* 2001; Mulianga 2009). The major effect of these changes is reduced space that restricts seasonal mobility of their herds to exploit resources that vary spatially and temporally across the landscapes as dictated by both natural and climatic factors of the production system

(Adriansen 1999; Mulianga 2009; Lengoiboni 2011). Such mobility could either be regular and limited to short distances or irregular which involves large scale and trans-boundary movements (Macopiyo 2005).

On the other hand, environmental and socio-economic factors are exerting negative trends posing a threat to the livelihoods of the pastoral community (Michael 2017). This includes increased variability of rain days and extreme weather events, increase in disease incidences (Kitasho *et al.*, 2020). Vulnerability of pastoralists varies between places and changes over time and therefore this calls for development of a set of actions that are aimed towards adapting pastoralists to the changing climate (Eriksen and Marin 2011). The current adaptation practices employed by the pastoralists includes livestock destocking, migration, livelihood diversification while some have started growing fodder grass and engaging in petty trade (Kitasho *et al.* 2020; Cuni-Sanchez *et al.* 2019; Berhanu and Beyene 2015).

This study aimed at answering three key research questions; (1) What are the perceptions, impacts and coping strategies to climate variability in the Samburu pastoral production system? (2) What is the relationship between seasonal rainfall variability and herd mobility patterns in Northern Kenya? (3) What are the livestock diseases hotspots and the effects of seasons on disease incidences in the study area? Generally, this research has provided insights with regard to the research questions and greatly contributed to new scientific knowledge and its advancement. The study has promoted the use of GIS spatial analysis tools in creating, observing the effects of, and devising preventive measures for infectious diseases as recommended by Gitonga (2015). In addition the study fills a knowledge gap arising from a study by Sperling (1987) who conducted a study in Samburu which describes the labor requirements for herding and during herd mobility, but failed to describe any herd mobility trends, herd distribution in space and time or transhumance in her study.

On the investigation into the perceptions, impacts and coping strategies to climate variability in the Samburu pastoral production system, this study which incorporated both the household survey (Chapter 4 of this thesis) and the Key informant interviews (Chapter 5 of this thesis) revealed a number of issues including the upward trend of ticks and mosquitoes and declining trends of other biting flies. According to other studies (Githeko *et al.*, 2000; Kshirsagar *et al*., 2013; Lelenguyah *et al.*, 2014; and Nguku *et al*., 2010) precipitation, temperature, and moisture fluctuations have an impact on the ecology and physiology of vectors thus increasing or decreasing the population of such vectors. In addition, the cultivation and bush clearing and management activities typically destroys the habitat for livestock disease vectors and this leads to a decline in their populations (Yatich, 1987; Lelenguyah *et al.,* 2014). The trend of veterinary diseases under investigation revealed a declining trend of trypanosomiasis and camel pox and an increase in the cases of FMD, CCPP and PPR. Climate and weather variations contributes to the increasing or decreasing trends of disease outbreaks because such changes are known to affect both the spatial and temporal distribution and the intensity of the outbreaks (Githeko *et al.,* 2000; Kshirsagar *et al*., 2013; Lelenguyah *et al.,* 2014; Nguku *et al*., 2010). This affects most of the diseases including CCPP which commonly occurs during colder seasons (Lelenguyah *et al*., 2021). The observed changes have had negative impacts on the pastoralists' livelihoods (as described in chapter 4 and 5 of this thesis) including livestock deaths resulting to poverty and destitution, reduction in pasture and water availability as well as reduction of livestock productivity and market value. These impacts seem to cut across rangelands in most ASALs (Ayanda, 2013; Bailey, 2012; Catley *et al.,* 2005; Egeru, 2016; Onono *et al.,* 2010). As a coping strategy, pastoralists resorted to migration, resource-use planning, exploitation of natural resources, reducing herd size as well as livelihood diversification. The best ways to handle livestock diseases challenge in the pastoral areas according to the key informants is to sensitize the pastoralists so that they are able to report emergence of diseases while at the same time using the community animal health workers to control such diseases (Chengula *et al.*, 2013; Kshirsagar *et al*., 2013).

Secondly, on the relationship between seasonal rainfall variability and herd mobility patterns in Northern Kenya, the analysis of climate data from both the USGS and the KMD shows the occurrence of four seasons in Samburu with the April to June and July to August receiving more rains in the highlands than the lowlands and the October to December season receiving more rains in the lowlands than the highlands. The January to March season receives depressed rainfall throughout the County. Overall, Samburu's rains are inconsistent, highly localized, unreliable, and unpredictable from year to year and from location to location (Pas-Schrijver 2019; CGS 2018). This study also indicates a declining trend in rainfall amounts received in Samburu North and an increasing trend in rainfall amounts received in Samburu East and Central. This is consistent with the observation that the trend in rainfall has been declining. The UNDP's climate change assessment for Kenya indicates that instances of heavy rainfall are gradually increasing without a statistically significant trend (McSweeny *et al.*, 2010). Regular livestock mobility is an essential management technique in the mobile pastoral systems of the Samburu. For the rainy and dry seasons, distinct routes are used to show when animals move between grazing areas. Pastoralists from the lowlands will relocate to the Lorroki Plateau, Matthews Range or even Samburu National Reserve (Pas-Schrijver 2019; Lengoiboni 2011). Pastoralists' most important response to rainfall fluctuations in terms of geography and time is migration (Adriansen 2008). However, significant fragmentation of communal grazing areas under group ranches to individual ownership, as well as changes in land use, have severely impeded pastoral mobility in recent years, particularly in Samburu Central (Lesorogol 2008).

Finally, on the livestock diseases hotspots and the effects of seasons on disease incidences in the study area, the results of the participatory epidemiology has shed some light on the major disease problems in livestock in Samburu County. Goats were found to be very important for the livelihood of the pastoralists, however, they faced challenges mainly associated with PPR and CCPP diseases. According to the general rating of sheep and goat diseases in the areas under investigation, PPR, CCPP, and SGP diseases were the three most important health challenges respectively. This is despite the fact that small ruminant production plays a crucial role in supporting food security and livelihoods of the families due to their faster rate of reproduction (Tibbo 2006). The Findings from the PE activity indicate that the PPR is the most prevalent disease among sheep and goats in most of the Wards followed by CCPP. Therefore, it follows that CCPP and PPR are most widespread health conditions among flocks within Samburu County as a whole. Correlations analysis was sgnificant between mean annual rainfall and ECF, Cattle Helminthiasis, Cattle Anaplasmosis and Camel Pox while correlations between the mean monthly temperature and livestock diseases was significant for ECF, Cattle Anaplasmosis and FMD. Anaplasmosis and ECF are tick-borne diseases and therefore their occurrence closely corresponds to favorable climatic conditions for ticks to survive, reproduce and transmit the infections. Anaplasmosis was also shown to be very closely related to the distribution of herds during different seasons of the year. As highlighted earlier by Bayissa *et al*., (2009), herd mobility is the greatest impediment when it comes to disease control in these areas.

8.2 General Conclusions

The following are the key conclusions from this study;

Pastoralists' perception indicates that there has been general decline in rainfall and an increase in temperature, drought and floods incidences in Samburu County. The observed changes have had negative impacts on the pastoralists and their livelihoods including livestock deaths resulting to poverty and destitution, reduction in pasture and water availability as well as reduction of livestock productivity and market value. Other effects included human deaths as well as livestock migrations.

Wet-season grazing areas and dry-season grazing areas characterize the Samburu pastoral system. Because of the irregular rainfall pattern, animals move around the area in search of pasture and water, and grazing patterns are always shifting. A spatial relationship was observed between distribution of livestock herds and rainfall patterns. In most of the dry seasons, pastoralists end up in private lands in Laikipia and Samburu Central or government gazetted Kirisia forest and Samburu National reserve where they have no formal access. As a result, there is expected to be violent clashes between Samburu herders and private land owners or reserve officials. Declining trends of rainfall was particularly observed in Samburu North over the last 40 years. If this trend continues, it will heavily impact on pastoral livelihoods and will make pastoralism an unsustainable venture.

Livestock diseases were perceived to be among the major challenges affecting pastoralists and their livelihoods. Critical livestock disease control facilities includes decentralized veterinary services, crushes and cattle-dips. These facilities are few and unable to serve the huge livestock populations in the county. The study findings affirm a significant association between seasonality and livestock disease epidemiology.

8.3 General Recommendations

Following the findings of this research, the study recommends the consideration of the following towards the improvement of disease control measures in light of climatic variability and change and to improve livestock productivity in the pastoral production systems of Kenya;

1. Concerted efforts amongst all the stakeholders is required to ensure that the pastoralists and their livelihoods are secured against climatic shocks. The measures should include improvement of veterinary services, infrastructure development and enhancing information dissemination mechanism to suit the pastoral areas.

2. To improve veterinary services, it is very important to streamline communication channels, conduct timely and regular vaccinations, improve infrastructure and enhance knowledge and skills of pastoralists/herders on disease control as well as streamlining animal diseases preventive measures. The relevant agencies need to identify the most appropriate channel of communication that is convenient for most of the community members. For instance, the use of community disease reporters (CDRs) in collaboration with local administrators can be very appropriate.

3. One of the solutions to sound range management in this pastoral system is grazing management embedded in observed herd mobility and grazing resource use patterns. This can be achieved by establishing and implementing grazing programs that can be reinforced within recognized community management structures such as elder councils, grazing committees, group ranch committees, and water resource management committees. Both the County and National Governments should recognize and promote the critical role of pastoral institutions in facilitating pastoral adaptation and sustainably managing rangeland resources. Pastoralism has been enabled most effectively by policies that encourage customary governance and provide pastoralists with a sense of security over their land. Dry land grazing areas, if well managed, can have multiple benefits of enhancing ecosystem services and improvement of livelihood adaption to climate change impacts. There is need to work with management of the reserve and Kirisia forest to develop a formal grazing agreements with the community during dire drought periods.

4. Diversification of livelihood sources will help the pastoralists to cushion themselves against the effects of climate variability. In Samburu North, introduction of honey production through modern bee hives provided by the County Governments and other partners is one such livelihood diversification strategy. Also, fodder conservation will go a long way to supplement natural pasture grazing. Several pastoralists in Samburu have begun to experiment with pasture cultivation, harvesting and making hay, and this will supplement the pasture available in the dry season grazing areas. Investments

in veterinary extension, livelihood diversification and social safety nets can reduce pastoralists' vulnerability to extreme weather events.

5. Based on the knowledge of the local informants, a robust control program can be implemented to curb PPR and CCPP among the shoats, FMD and Anaplasmosis in cattle and Trypanosomiasis and Camel cough in camels as they came out as the most important diseases among the livestock in these areas. Prevention of livestock diseases through vaccination is essential in eradication and reduction of economic losses experienced by the local people in these areas.

6. Livestock disease control efforts should be focused towards the wet season and dry season grazing areas. The priority diseases identified by the communities should also be given due attention and regular epidemiological studies and serological surveys undertaken to generate information to be used for future control measures. To enhance disease control efforts, County Governments in all the ASAL Counties needs to allocate more resources towards disease control infrastructural development. Priority should be given to crushes used as holding pens during vaccinations and mass treatments and also plunge dips for control of vector-borne diseases.

8.4 Recommendations on areas for Further Study

1. Indigenous peoples are more aware and informed on their surrounding and what affects them. Therefore, need for more studies on their knowledge on the interface of disease emergence, climate change and rangeland management.

2. More research is needed on the herd mobility patterns in various Counties or cluster of Counties. This study only focused on Samburu County. Such study will inform various interventions including inter-County rangeland planning, grazing management as well as disease control.

3. Extensive epidemiological, serological, and ecological studies are required to produce valid and reliable data for use in the future FMD, PPR and CCPP disease control programmes.

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10.0 APPENDICES

10.1 HOUSEHOLD QUESTIONNAIRE

General Information

Questionnaire ID:		**Date of interview:**	
Name of Enumerator:			
Name of Sub-location:		**Name of village:**	
Altitude (m asl):	……………………	**Coordinates of manyatta:**	…………………… ……………………
Name of respondent:			
Age:		**Sex:**	
Ethnicity of respondent:		**Education Level:**	
Gender of Household head		**Marital Status**	
Occupation		**No. of children**	Boys: ___________ Girls: ___________

A. **Resources Accessibility Profile**

1	Give your income-generating activities by order of importance.	(see ranking table below)
2	Do you own livestock? Yes ( )	Cattle:__________ Sheep: ____________ Goats:____________ Chicken: __________ Others

Rank	**1**	**2**	**3**	**4**	**5**	**6**
Cultivation/farming						
Fishing						
Livestock keeping						
Casual labour						
Charcoal burning						
Formal employment						

	No ( ) (If yes, give numbers).	(Specify): ____________________
3	In total, approximately how many animals do you herd?	Cattle:__________ Sheep: ____________ Goats:____________ Camels: __________ Others (Specify): ____________________
4	What role do livestock play in providing income compared to other sources?	0-25% ( ) 26-50% ( ) 51-75 % ( ) 76-100% ( )

B. Perception of changes

i. Please describe the main weather events that happen during the year (e.g., rainy season, dry season, snowfall, hailstorms, and so forth)

Weather event	Extend/duration	Any changes over the years? Describe.	Reasons for observed changes?

ii. Describe the weather parameters/events below over the study period (Jan. 2009 – Dec. 2018)

Weather parameter/ event or other conditions	Description of change
Rainfall	More rain( ) Normal ( ) Less rain( ) Not sure ( )
Temperature	Hotter ( ) Normal ( ) Colder ( ) Not sure ( )
Floods	More severe ( ) Normal ( ) Below normal ( ) Not sure ( )
Droughts	More severe ( ) Normal ( ) Less severe ( ) Not sure ( )
Water Sources (availability)	More ( ) Normal ( ) Fewer ( ) Not sure ( )
Vegetation	More ( ) Unchanged ( ) Less ( ) Not sure ( )

iii. In your opinion, what would be the trend of different climatic/hazard variables towards the future?

Climatic Variable	Increase	Constant	Decrease	Uncertain
Temperature	( )	( )	( )	( )
Rainfall	( )	( )	( )	( )
Floods	( )	( )	( )	( )
Droughts	( )	( )	( )	( )
Diseases	( )	( )	( )	( )

C. Disease outbreaks and their effects.

a. Describe any major diseases outbreaks experienced over the last 10 years.

Year	Disease	Intensity/Severity			
		Very severe	Moderately severe	Less severe	Not sure

b. Give the average number of livestock deaths from your homestead from previous disease outbreaks (specifying the location where the deaths occurred).

Year	Location	Disease Name	Number of livestock dead				
			Cattle	Sheep	Goats	Camels	Donkeys

c. State the trend of various vectors over the study period (January 2009 to December 2018) (specifying the locations with the highest infestation).

Vector	**Location**	**Trend of Vectors**			
		Increasing	**Decreasing**	**Normal/constant**	**Not sure**
Mosquitoes		( )	( )	( )	( )
Ticks		( )	( )	( )	( )
Tsetse fly		( )	( )	( )	( )
Other biting flies		( )	( )	( )	( )

d. State the trend of livestock diseases over the study period (January 2009 to December 2018).

Livestock diseases	**Trend of livestock diseases**			
	Increasing	**Decreasing**	**Normal/Constant**	**Not sure**
RVF	( )	( )	( )	( )
Trypanosomiasis	( )	( )	( )	( )
CCPP	( )	( )	( )	( )
PPR	( )	( )	( )	( )
FMD	( )	( )	( )	( )
Lumpy skin	( )	( )	( )	( )

disease				
Sheep and Goat pox	( )	( )	( )	( )
CBPP	( )	( )	( )	( )
Camel pox	( )	( )	( )	( )
Brucellosis	( )	( )	( )	( )

D. **Herd mobility**

Where exactly do animals from this homestead graze in the following months?

Month	Area moved to	Land use type	Condition on arrival	Duration stayed in this area	Condition on departure	Reasons for selecting this area

Do you maintain a similar pattern each year? If no, explain:

____

What are the factors that inform your decision to move your animals?

S/No	Factor	Yes	No
1	Water availability?	( )	( )
2	Physical barriers?	( )	( )
3	Type of livestock kept?	( )	( )
4	Household labour?	( )	( )
5	Vegetation/pasture availability?	( )	( )
6	Emergence of livestock diseases	( )	( )
7	External interventions?	( )	( )
8	Conflicts?	( )	( )
9	Availability of salt licks?	( )	( )

E. **Rainfall patterns**

Area moved to	Months with rainfall in this area	Months with highest rainfall in this area	Months with lowest rainfall in this area	Months with no rainfall in this area

Does rainfall exhibit a similar pattern each year? If no, explain:

____

F. **Areas for seasonal targeting in disease control**

i. Are livestock diseases a challenge during herd mobility?

Yes ( ) No ( )

ii. List the livestock diseases that pose a major challenge during herd mobility?

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________

iii. What effects does these diseases have on your livestock?

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________

iv. What do you/your relatives do when the livestock are affected by the above diseases?

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________

v. How and to whom do you report disease outbreaks in your herd?

....

vi. Are there ways that livestock diseases can be controlled/treated during mobility? Describe them

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

vii. Please, specify the area or location that can be used for livestock vaccinations/treatment in the following months:

Month	**Area moved to**	**Where you get veterinary drugs/services**	**Location/area for disease control targeting**	**Reasons for selecting this area**

10.2 KII GUIDE - Agriculture, CLMC and KPRs

Questionnaire ID: …………… Date of Interview: ……………………..............……...

Name of County/SubCounty: ………………… Name of Institution: ……………………......

Name of Respondent: ……………………………………...................……………………

1. Do you know of any major livestock diseases outbreak that have occurred over the last 10 years? What was the severity?
2. Does livestock disease outbreaks affect crop production/livestock markets/security situation? Explain?
3. What are the contributions of your institution towards the control of livestock diseases?
4. Do you know of any areas infested or perceived to be infested by the veterinary vectors in this County? (Mosquitoes, ticks or tsetse flies)
5. Do you know of the areas that livestock graze during different seasons in this County/SubCounty? Mention them.
6. Does herd mobility maintain a similar pattern each year? If no, explain:
7. Does livestock pose any challenge to crop production/livestock markets/security situation during herd mobility? What are the challenges?
8. How does the local community cope with these challenges?
9. How do you or your organization intervene during such challenges?
10. Are there ways that such challenges can be mitigated during mobility? Describe them

Thank you!

10.3 KII GUIDE - NDMA, Special Programs, CARITAS and FAO

Questionnaire ID: …………… Date of Interview: …………………….............……..

Name of County/SubCounty: ………………… Name of Institution: ……………………......

Name of Respondent: ……………………………….................…………………

1. Please provide a list of the major diseases outbreak that you have participated in its intervention over the last 20 years describing the severity and the locations of your intervention. What was the contribution of your institution?
2. How many animals did your intervention serve?
3. Do you know of any areas infested or perceived to be infested by the veterinary vectors in this County? (Mosquitoes, ticks or tsetse flies)
4. What is the trend of the TADs in this County over the last 20 years.
5. Describe the areas that livestock graze during different seasons in this County/SubCounty.
6. Does herd mobility maintain a similar pattern each year? If no, explain:
7. Are livestock diseases a challenge during herd mobility?
8. What are the livestock diseases that pose a major challenge during herd mobility?
9. What are some of the effects of the diseases mentioned above
10. How does the local community cope with these diseases/challenges?
11. How do you or your organization intervene during such disease outbreaks?
12. List factors that determine how and when your organization intervenes in disease control
13. Are there ways that livestock diseases can be controlled/treated during mobility? Describe them
14. Please, specify the area or location that can be used for livestock vaccinations/treatment in different months of the year.

Thank you!

10.4 KII GUIDE - Veterinary and Livestock directorates

Questionnaire ID: …………… Date of Interview: ……………………..............……...

Name of County/SubCounty: ………………… Name of Institution: ……………………......

Name of Respondent: ……………………………………..................…………………

1. Please give a list of major diseases outbreak experienced over the last 20 years describing the severity and the areas affected by the each outbreak.
2. Give the estimated number of livestock deaths from your County/Sub-County from the above disease outbreaks.
3. State the areas infested or perceived to be infested by the veterinary vectors in this County.
4. What is the trend of the Trans-boundary Animal Diseases (TADs) in this County over the last 10 years.
5. Describe the areas that livestock graze during different seasons in this County/SubCounty.
6. Does herd mobility maintain a similar pattern each year? If no, explain:
7. Are livestock diseases a challenge during herd mobility?
8. What are the livestock diseases that pose a major challenge during herd mobility?
9. What are some of the effects of the diseases mentioned above
10. How does the local community cope with these diseases/challenges?
11. How do you or your organization intervene during such disease outbreaks?
12. List factors that determine how and when your organization intervenes in disease control
13. Are there ways that livestock diseases can be controlled/treated during mobility? Describe them
14. Please, specify the area or location that can be used for livestock vaccinations/treatment in different months of the year.

Thank you!

10.5 KII GUIDE - Veterinary drugs outlets

Questionnaire ID: …………… Date of Interview: …………………….............……...

Name of County/SubCounty: ………………… Name of Institution: ……………………......

Name of Respondent: ………………………………….................…………………

1. Do you know of any major livestock diseases outbreak that have occurred over the last 10 years? which ones? What was the severity?
2. Does livestock disease outbreaks affect the sales of the veterinary drugs? Explain?
3. What are the contributions of your institution towards the control of livestock diseases?
4. Do you know of any areas infested or perceived to be infested by the veterinary vectors in this County? (Mosquitoes, ticks or tsetse flies)
5. Do you know of the areas that livestock graze during different seasons in this County/Sub-County? Mention them.
6. Does herd mobility maintain a similar pattern each year? If no, explain:
7. Does herd mobility pose any challenge to agrovet business? What are the challenges?
8. How does the local community cope with these challenges?
9. How do you or your organization intervene during such challenges?
10. Are there ways that such challenges can be mitigated during mobility? Describe them.
11. Are there ways that livestock diseases can be controlled/treated during mobility? Describe them
12. Please, specify the area or location that can be used for livestock vaccinations/treatment in different months of the year.

Thank you!

10.6 PARTICIPATORY MAPPING GUIDE

Guide ID: …………….........   Date of Activity: ……………………..............…….

Name of County/SubCounty: …………………… Name of Ward: …………………

Participatory mapping Group composition: ………...................……………………….

A. Herd Mobility

i. Let us all take time to study this map and understand in relation to your current location, grazing fields, forests, private ranches and other resources.
ii. Please show me on this map where your homestead (manyatta) is
iii. Please show me on this map where you start your migration and in which month
iv. Is this a rangeland, game park, forest, crop land or a ranch?
v. What is the condition of the land when you arrive to your dry season grazing area?
vi. What is the condition of the land use when you left the place?
vii. How many days/months do you stay in this dry season grazing area?
viii. Do you have any reason for choosing this grazing area?
ix. Please show me on the map where you go to after leaving this place.
x. What is the condition of the land cover when you arrived to this second location?
xi. Which month do you leave for this area?
xii. Which month do you leave the area?
xiii. How many days does it take you to arrive to this area?
(Repeat step ix to xiii for any additional locations)
xiv. Are there any places you take longer than others along this migratory route? Please show me on the map.
xv. Do you have any reason for choosing these grazing area?
xvi. Please show me on the map where you get water for your livestock?

B. Rainfall patterns

(Questions to be asked for each of the locations)

i. Which months do you experience rainfall in this area?
ii. Which months have the highest rainfall amount?
iii. Which months have the lowest rainfall amount?
iv. Which months have no rainfall at all?

C. Pasture use

i. How do you select where to graze your animals?
ii. What is the role of traditional committees in pasture selection?

D. Disease cases during herd mobility

i. Are livestock diseases a challenge during herd mobility? Name the diseases
ii. List the livestock diseases that pose a major challenge during herd mobility?

10.7 DATA COLLECTION CONSENT FORM

<u>Analysis of the nexus between climate variability, herd mobility and livestock disease incidences in the rangelands of northern kenya</u>

My name is Geoffrey Lelenguyah, a PhD student from the University of Nairobi. I am conducting a study that will collect information on the herd mobility and its relationship to livestock diseases. I am requesting your consent to ask some personal questions concerning your animal husbandry practices and your understanding of various issues concerning the study especially in relation to climate variability.

Confidentiality Clause

Your name and personal details will be kept confidential and will not be disclosed in any publication or to third parties other than the members of this research project.

Benefits

There will be no immediate benefits to you. However, study findings will be forwarded to you through the County Veterinary Office representative. The information given will allow the institutions concerned with animal health in your area to make informed choices when designing disease control and surveillance programmes.

Withdrawal from the study

You can refuse at any point from participating in the study

Consent

I ____ Tel contact ______________________

Agree/ do not Agree to take part in this study.

Signature of respondent or thump print:_________________ Date:_________________

Signature of Researcher:_________________________ Date: ____________________

10.8 RESEARCH LISENSE

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **910852**

Date of Issue: **25/February/2022**

RESEARCH LICENSE

This is to Certify that Mr.. Geoffrey Lenyayon Lelenguyah of University of Nairobi, has been licensed to conduct research in Samburu on the topic: ANALYSIS OF THE NEXUS BETWEEN CLIMATE VARIABILITY, HERD MOBILITY AND LIVESTOCK DISEASE INCIDENCES IN THE RANGELANDS OF NORTHERN KENYA for the period ending : 25/February/2023.

License No: **NACOSTI/P/22/15712**

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Applicant Identification Number

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