UNIVERSITY OF SOUTHAMPTON

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The Role of Risk Management in Pastoral Policy Development and Poverty Measurement: System Dynamics Simulation Approach

by

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Abstract

Livestock-based agriculture plays an important role in the development of sub-saharan Africa, especially those countries whose livestock industry contributes significantly to the Gross Domestic Product (GDP). In Kenya, agriculture alone accounts for 21% of the GDP and provides employment directly or indirectly to over 75% of the total labour force. The livestock industry, mainly arid rangelands, contributes 50% of the agricultural productivity. However, these Arid and Semi-Arid Lands (ASALs) are exposed to a myriad of risks affecting the environment which is the pastoral core asset. These risks arise from climatic change and variability, growth in human population and expanding settlements, changes in the land use systems, poor infrastructure, diseases, wildlife predation, and inter-ethnic conflicts. The consequences of these pastoral risks include: (1) declining per capita asset value, (2) increased health problems, (3) increased poverty, and (4) declining GDP generated from pastoralism. While a lot of resources have been invested in responding to the pastoral crisis associated with droughts, there is still inadequate understanding of the policy measures to put in place as mitigation strategies. The aims of this research are (1) identify the main pastoral risks and community response strategies, (2) assess the impact the identified risks on the wellbeing of pastoralists based on financial, human, physical, natural and social capital measurements (5 C's), and (3) develop a System Dynamics (SD) model to assess the holistic impact of community and government response strategies on pastoral wellbeing. Samburu district, in northern Kenya, was chosen as a study area because it is classified as 100% ASAL and experiences frequent droughts and changing land use systems. The research process involved literature synthesis, analysis of both cross-sectional and a 5-year panel data, and the development of a System Dynamics model. Cross-section data was primarily collected for the purposes of identifying the extent to which risks affect households, while the 5-year panel data was sourced from the Arid Lands Resource Management Project (ALRMP). Descriptive and empirical analysis showed that droughts, land use system and human population were considered as the main cause of shrinking rangeland productivity and as a result declining per capita livestock. This was further confirmed from the panel data analysis indicating climate variability as the main driver of pastoral wellbeing. Droughts affect rangeland pasture productivity, market prices, livestock assets, and households' nutritional status and poverty levels. These results imply a multifaceted nature of pastoral system with compound affects. The SD simulation result, which was run over the period January 2006 to December 2030, provided insights on policy evaluation and the state of pastoral wellbeing. Baseline scenario indicated reducing livestock ownership, causing high malnutrition and poverty rates. Strategies which incorporated rangeland rehabilitation, planned settlements, livestock disease control, insurance against droughts, reducing inter-ethnic conflicts, and timely destocking offered better policy

options. These strategies resulted in reduced malnutrition, increased pasture productivity, reduced livestock losses and ultimately reducing poverty rates among the pastoral communities.

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Declaration of Authorship

I, Saidimu Leseeto

Declare that the thesis entitled

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and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

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Definitions and Abbreviations

5 C's	Human, Social, Natural, Financial and Physical Capitals
AIRMIC	Association of Insurance and Risk Managers
ALARM	The Public Risk Management Association
ALRMP	Arid Lands Resource Management Project
ANOVA	Analysis of Variance
ARIMA	Autoregressive Integrated Moving Average
ASAL	Arid and Semi-Arid Land
CBA	Community-Based Approaches
CDF	Constituency Development Fund
CDI	Combined Drought Index
CLDs	Causal Loops Diagrams
CMR	Cereals-Meat price Ratio
DFID	Department for International Development
DM	Dry Matter
DMA	Drought Management Authority
DMI	Drought Management Initiative
DRR	Disaster Risk Reduction
EWS	Early Warning Signs
FEWS-NET	Famine Early Warning Systems Network
GDP	Gross Domestic Product
GoK	Government of Kenya
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
IMF	International Monetary Fund
IPAL	Integrated Project in Arid Lands
IRM	Institute of Risk Management
KMC	Kenya Meat Commission
LEWS	Livestock Early Warning System
LINKS	Livestock Information Network and Knowledge system
LPS	Livestock Production Systems
MCP	Meat Cereals Price index
MDGs	Millennium Development Goals
MLD	Ministry of Livestock Development
MoE	Ministry of Education
MUAC	Middle Upper Arm Circumference
NDCF	National Drought Contingency Fund
NDVI	Normalised Differenced Vegetation Index

NGOs	Non-Governmental Organisations
NRT	Northern Rangeland Trust
OLS	Ordinary Least Square
PDI	Precipitation Drought Index
PDSI	Palmer Drought Severity Index
PHEWS	Pastoral Household and Economic Welfare Simulator
PRSPs	Poverty Reduction and Strategy Papers
RM	Risk Management
SCC	Samburu County Council
SD	System Dynamics
SST	Sea Surface Temperature
SSU	Small Stock Unit
TDI	Temperature Drought Index
TLU	Tropical Livestock Unit
UNEP	United Nations Environment Program
VDI	Vegetation Drought Index
WHO	World Health Organisation

1 Introduction

1.1 Chapter Introduction

Agriculture plays an important role in the development of many sub-Sahara African countries, especially towards meeting the Millennium Development Goals (MDGs) (IMF, 2012). It is understood that vibrant agricultural-based economies rely on strong underlying policies regulating the practices (Homewood, 2004). Not much effort has been employed in the development of policies regulating livestock-based agriculture in East Africa, despite it being the only economic activity for more than a third of the region's population (Ellis and Mdoe, 2003). Livestock plays a big role, both directly and indirectly, in the economy, contributing to the Gross Domestic Product (GDP) while at the same time supporting the micro-economies in rural areas (Aklilu and Catley, 2010, Muriuki, 2001). However, this sector is affected by a myriad of risks affecting not only the primary households but also the national economy (Konczacki, 1978, Bollig, 2006). The following sections introduce the role of livestock, the nature of risks pastoral system face and particularly droughts' role in shaping policy development.

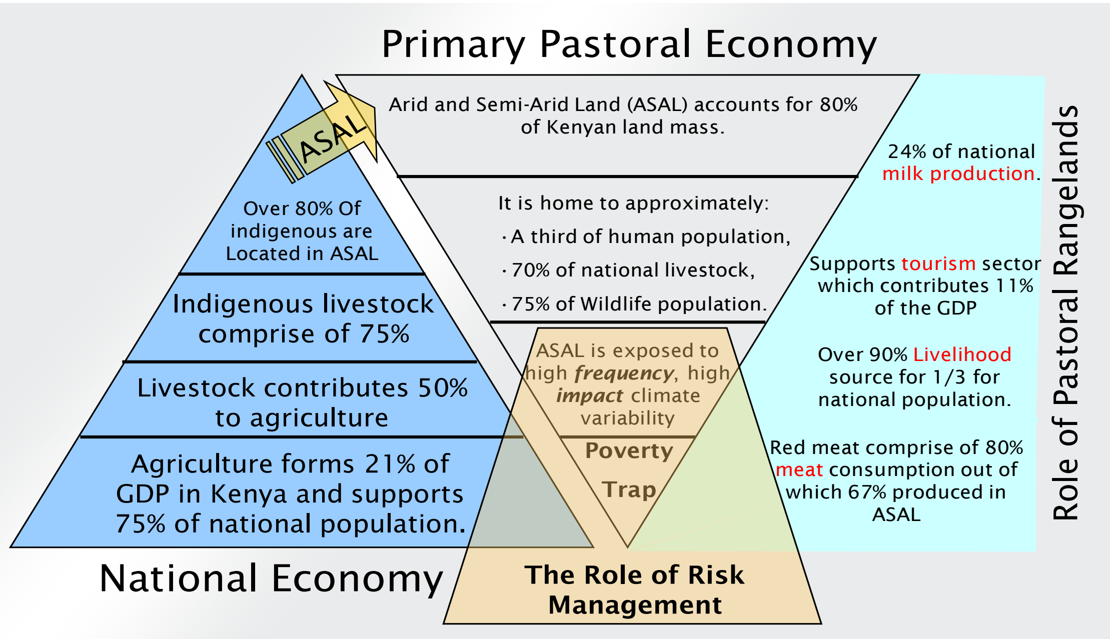
1.2 Pastoral System

1.2.1 The Role of Livestock

Agriculture in Kenya plays an important role in both national and the local economy by generating over 21% towards GDP and supporting over 75% of the national population directly or indirectly (Odhiambo et al., 2004). Half of the Agriculture sector in Kenya is comprised of livestock farming mostly found in the Arid and Semi-Arid Lands (ASAL) (Aklilu and Catley, 2010). The ASAL is also home to over a third of the national human population, and over 70% of both national livestock and wildlife (De Leeuw et al., 2001). However these rangelands are prone to a myriad of risks the consequences of which, if not managed, could affect both national and local economy. At the national level, such risks affect tourism, milk production, meat supply and rural livelihoods (Aklilu and Catley, 2010). This study however focuses on pastoral risks and their influence on the pastoral community wellbeing. Figure 1:1 illustrates the importance of pastoral systems management at the local and national level. It demonstrates the need for a comprehensive risk management framework to assess the pastoral risks, in terms of frequency and impact so as to support both the local and the national economy and ensure continued supply chain.

Pastoral communities derive their diets from livestock such as milk, meat and blood (Dahl and Hjort, 1976, King et al., 1984, Fratkin, 2004). These households supplement consumption of these products with market products mainly from cereals by selling livestock (Barrett and Luseno, 2004, Turner and Williams, 2002). Reduction of per capita livestock ownership has however changed the dietary composition of these households into a more market product dependency (Little, 1992, Holtzman, 2007). Poor households bear the brunt of the complex pastoral system arising from rangeland sensitivity to biotic and non-biotic factors (Vetter, 2005). Such risks have far reaching consequences on the socio-economic activities and the health of the pastoral communities. This requires close evaluation of practical solutions (Little et al., 2008). Pastoral households faced with challenges affecting livestock productions have diversified into other sources of livelihoods that can be supported by the environmental conditions (McPeak and Little, 2003). Some pastoralists engage in seasonal crop farming where the climatic conditions were favourable (Adano and Witsenburg, 2005), while others stock more of some specific livestock species, such as goats and camels, believed to be resistant to droughts and diseases (Roth, 1990), thereby affecting pasture requirement. Policy planners require an understanding of these dynamic adaptations by pastoral communities in order to focus on the real problems and propose sustainable economic diversification (Campbell, 1999, Desta and Coppock, 2002b).

Figure 1:1: Pastoralism and the economy in Kenya



Pastoral households keep livestock as a form of self-insurance against unforeseeable shocks in addition to providing them with nutritional requirements (Lybbert et al., 2004a). Livestock accumulation is found to be the strategy used by households to sustain their livelihoods and avoid severe poverty traps (Lybbert et al., 2004b). They argued that households with a large herd size prior to disasters come out better off with ex-ante livestock ownership determining the ex-post wealth. Since droughts affects households in similar ways by causing proportionate losses in livestock, households with bigger herd sizes are likely to be better-off than those with smaller pre-drought herd size. Post disaster recovery for pastoral households is therefore significantly dependent on the remaining herd size.

1.2.2 Pastoral risks

Agricultural activities are high risk in nature and their output is dependent on various variables (Bollig, 2006). For instance, farm production is a function of pests and diseases, water availability and temperature conditions among other factors. The system, which is a form of agriculture dealing with animal husbandry, is also faced with a myriad of risks arising from physical and bio-physical factors (Chantarat et al., 2009b, Desta and Coppock, 2004, Lybbert et al., 2004a). According to the available statistics on socio-economic conditions in Kenya, many households dependent on pastoral livelihood are relatively poorer (Aklilu and Catley, 2010, Thornton et al., 2007). This is largely contributed to by risks facing their economic activities creating both asset and income shocks (McPeak, 2004, Mogues, 2004). Past studies on pastoral risks focused their attention on environmental hazards in relation to livestock populations (Angassa and Oba, 2007, Boone and Wang, 2007, Desta and Coppock, 2002b). This was extensively debated by various researchers on optimal stocking rates and sustainable rangeland (Campbell et al., 2006). Extensive studies on pastoral systems in East Africa indicate increasing pressure on grazing land resulting from population growth, increasing poverty levels due to lower per capita livestock holding and enhanced livelihoods diversification such as agriculture causing rangeland imbalances (Bekure and de Leeuw, 1991, Homewood and Lewis, 1987, Thornton et al., 2003, Solomon et al., 2007). Poor rangeland conditions are further affected by droughts, overgrazing and high competition for the pastoral land (Kassahun et al., 2008, Kassas, 1995).

Pastoral wellbeing, which is hinged on livestock ownership, is pegged on the effects arising from livestock mortalities (McPeak, 2004). Some researchers argued on stocking policy which places importance on limiting livestock population to land capacity to prevent degradation and ensure vibrant livestock keeping (Angassa and Oba, 2007). Whichever the line of debate adopted, it remains that livestock mortality varies with pasture availability and the risks affecting pasture amount and access directly affect pastoral livelihoods (McCabe, 1987). Continuous decline of household per capita livestock is regarded as an important indicator of the poverty trap facing pastoralists (Desta and Coppock, 2004). The decline in livestock in arid areas of Kenya is however mainly caused by insufficient rainfall (Lybbert et al., 2004b, McCabe, 1987).

Livestock markets play an important role in converting livestock assets into liquid cash used to acquire market products to supplement nutritional requirements and to meet other financial requirements (Thornton et al., 2006). In many pastoral areas, wealth ranking is based on livestock ownership and studies empirically found that wealthy households earn higher monthly incomes than poorer households who depend on casual labour and miscellaneous trade (Lesorogol, 2008b). Risks affecting livestock markets are commonly found to affect the livelihood of these farmers (Fafchamps and Gavian, 1996). Other than the forces of demand and supply, livestock markets are influenced by many other factors such as livestock diseases, rainfall and pasture condition as well as distance to the market (Barrett and Luseno, 2004). Outbreak of diseases and the government's response by quarantine negatively affects livestock pricing ultimately impacting on financial capital (Barrett et al., 2003). During the events where the survival of livestock is threatened, market failure discourages disposal of livestock ultimately causing losses (Burra et al., 2009). Low financial capital coupled with depleted herd size drives pastoral households into food insecurity reducing their coping capabilities (Lybbert et al., 2004a, Holtzman, 2007).

Lack of timely and accurate drought forecast information is an important pastoral risk whose absence or inaccuracy leads to households making systemic responses that are more idiosyncratic (Lybbert et al., 2007). The study also found that the minority of households update their rainfall beliefs in response to adverse rainfall forecast information. Many households respond to these challenges on a need basis and the general response to shortages of pasture is therefore not consistently applied at community level. The value of climate forecast information is immense for pastoralists as it triggers community-wide sales prior to droughts, cutting down on potential losses (Luseno et al., 2003). Efforts to incorporate socio-physical factors in policy processes and forecasting of pastoral shocks are still at the development stage in most arid areas in Kenya (Mude et al., 2009a, Khan et al., 1992).

Changes in land use system have been argued widely as a threat to pastoral systems in sub-Sahara Africa. The changes emanate from an increase in human population, changes in socio-economic activities from pastoralism into large scale crop farming and extension of wildlife conservation areas. Increases in human population has proved to be a challenge towards a sustainable pastoral system (Homewood, 2004). Settlements have so far taken up rangeland previously used as buffer zones during drought years leading to a faster diminishing of pasture resource even during good rainfall years. In some cases, land privatisation limited livestock and wildlife movement into specific areas (Kimani and Pickard, 1998, Thornton et al., 2006). Similarly, pastoralism is competing for rangeland with wildlife for pasture and water. While livestock dynamics is dictated by household and external factors, their existence is threatened by wildlife population pressure arising from predation and pasture competition and vice versa (Ogutu, 2000). Conversion of pastoral land, which is home to other wild habitats, threatens not only the future of pastoralism but also wildlife conservation efforts (Homewood et al., 2001, Lamprey and Reid, 2004). Some programs have been designed to allow communities to cull wildlife prescribed by the government to compensate them for the use of their rangeland as well as reduce their population (Van Kooten et al., 1997). Due to risks of extinction for some wildlife species found in arid areas, seclusion for their effective protection is advocated by many conservationists. Such policy measures coupled with human population have changed the land use creating new challenges on pastoral livelihoods (Lambin et al., 2003).

In the past, there existed strong and elaborate social relationships among pastoral communities used to mitigate risks by absorbing short periods of income shocks (Mogues, 2004). Households deprived of livestock by droughts, diseases, conflicts or any other causes were compensated by relatives. Increased poverty arising from reduced livestock ownership among many pastoralists has reduced the ability of households to compensate each other (McPeak, 2005). There are indications of failure in these social institutions arising from the changing society to capitalism and urbanisation (Lesorogol, 2009). Failed social networks expose pastoral communities to further risks likely to exacerbate poverty and create a wider wealth variation. This leads to slow livestock recovery, absence of food sharing and extreme poverty trap for households hit by disasters.

1.2.3 Droughts

Droughts are defined based on their causes and are differentiated into meteorological, hydrological and agricultural (Mainguet, 1994, Dracup et al., 1980). Meteorological drought occurs when precipitation falls below average expected rainfall (Smith, 2004). Studies have indicated that a 25% decline in the normal precipitation causes savannah drought; such a decline reduced grass productivity by about 90% in the Sahel region in Sub-Saharan Africa (Ridder and Breman, 1993). Different countries however use different meanings attached to droughts as dictated by the level of risk appetite and attitude. The attitude of the people and the governments involved determined the level of risks they are able to respond to (appetite) depending on the resources available. In the United States, the term drought is *"used when an extensive area receives 30% or less of its normal rainfall over a minimum of 21 days"*. In Australia, severe drought occurs when rainfall deficiency persists at the lowest 5% for a minimum of three months, whereas in India, a shortfall of annual rainfall below 75% is declared a drought year (Coenraads, 2006). In all these examples, drought is determined based on a deficiency from normal rainfall, for a particular area for a given period of time.

Although rainfall failure causes droughts, its effects slowly manifest and may run for a very long time. These effects at the household level include rise in food prices, fall in prices for farm products, destruction of farming activities (Little, 1992), and water and fodder resource scarcity which leads to livestock mortalities (Begzsuren et al., 2004). Reduced household level activity influences national level economy where industrial inputs are limited and through diversion of government spending into importation of foodstuffs to assist starving households. Some projected outcomes of climate change have shown variability in future agricultural yields, consumption and economic growth (Kane et al., 1992). Droughts have been found to be common in China, India and Africa causing famine and to some extent land degradation. Droughts causing famines have been widely documented in various countries and communities alike, most of which affect farmers directly. The severity of droughts has been associated with a lack of appropriate policies and knowledge transfer mechanisms for future events. In China, the 1907 and 1958-61 droughts led to starvation and the death of 24 million and 43 million people respectively (Coenraads, 2006). In India, nine droughts have been recorded in the past forty four years prior to 2006; one every 4.5 years. The Sahel drought that hit Africa from 1968 to 1974 claimed over 50,000 lives in Ethiopia only and hundreds of thousands of deaths in other parts of Sub-Saharan Africa. Similar effects were also recorded during the droughts of 1984/5 in Ethiopia where an estimated 1 million human lives were lost due to starvation. Harsh drought also hit the United Kingdom in 1975 to 1976 causing farm losses estimated at over £500 million, rising temperatures and increased water rationing in England and Wales. Droughts, leading to vulnerability are linked to myriad of causes such as overstocking, deficiency in both the amount and duration of seasonal rains, degradation, and changes in land use patterns (Coenraads, 2006 p. 382).

Efforts have been directed by many governmental and non-governmental organizations alike towards predicting drought occurrences with the objective of providing a basis for planning. Statistical models using rainfall trends and Sea Surface Temperatures (SST) have particularly provided a forecasting tool for El Niño (Ellis et al., 2010). While Australia measures droughts based on the degree of rainfall deficiency, United States applies a Palmer Drought Severity Index (PDSI) which considers temperature and rainfall trends (Palmer, 1965). Another product that has gained worldwide popularity as a tracking tool for drought existence and severity is the use of the Normalized Difference Vegetation Index (NDVI) (Tucker et al., 2005) measured using satellite-based optical sensors. NDVI measures vegetation cover and productivity by computing the proportion of absorbed radiation from the photosynthesis process. This ratio of visible and near infrared wavebands ranges between -1 and +1 with zero or less indicating non-vegetation ground cover. Values close to +1 indicate a high level of green vegetation cover or biomass while bare soil cover records lower NDVI values of between 0.1-0.2.

Droughts are common phenomenon in Kenya occurring with some temporal pattern. Severe droughts occur due to low precipitation and its severity associated with livestock losses is felt across pastoral communities. Bollig (2006) conducted an empirical study on the cost of droughts on livestock and found that severe droughts in arid areas in Kenya occurred in 1980, 1984 and 1991/2 claiming 42%, 64.8% and 33.6% respectively. Several institutional changes have been done, including setting up of the Drought Management Authority (DMA) and establishment of a National Drought Contingency Fund (NDCF) to plan and respond to issues on drought. Droughts impact households at different phases influencing various forms of livelihoods. Literature on drought cycles has suggested multiple impacts of drought on the environment, household assets, markets and nutrition. Droughts account for the highest livestock mortalities among the pastoral communities, some of which causes pastoralists to exit from the pastoral system (McPeak and Little, 2005). The 2000/2001 drought for example raised stockless households from 7% to 12% in Northern Kenya (McPeak and Little, 2005) while the drought in 1984 resulted in a 95% livestock mortality in Sudan (Hjort and Dahl, 1991). Table 1:1 provides statistics on the impact of droughts on livestock dynamics in the East Africa region. Reduced per capita livestock translates into a worse household wellbeing.

The associated economic loss is evident from the proportion of stock lost through droughts. Established financial losses from the literature include about US$300 million worth of livestock arising from the major droughts of 1984 and 1991/2 in southern Ethiopia between 1980 and 1997 (Desta and Coppock, 2002b). In Kenya, a single drought which occurred during the period 1999-2001 in northern Kenya caused livestock losses valued at US$ 77.3 million (Swift et al., 2002). Many severe droughts have ended up into famine situation where households are food insecure and suffer significant wealth decline causing malnutrition among the children (Sellen, 2003). Droughts have also been associated with livestock market crashes and ultimately diminished purchasing power of pastoral households (Barrett and Luseno, 2004). During drought years, costs associated with transportation of livestock to better markets are high and sometimes account for about 60% of the selling price (Osterloh et al., 2003). The volatility of pastoral assets has exposed pastoralists to a myriad of challenges and has hugely contributed to the poverty trap (Birch and Grahn, 2007, Kassahun et al., 2008, Lybbert et al., 2004b). Vulnerability arising from highly frequent drought has indicated exponential growth (Desta and Coppock, 2002b, Angassa and Oba, 2007) which is compounded by adverse pastoral system interactions (Birch and Grahn, 2007).

Generally, the biggest risk affecting the pastoral economy is drought. Time and finances have been invested by governments and non-governmental organisations, national and international, to try and predict, plan for responses and mitigate the effects of droughts. They have responded to pastoral risks in various ways. The common strategy adopted by the government in drought prone areas of sub-sahara Africa is the supply of relief food to households at risk of famine. Strategies adopted by other institutions include sale of livestock for slaughter to be distributed back to the community and schools, creation of a common market to purchase emaciated livestock during droughts and provision of veterinary services (Aklilu and Wekesa, 2002). Water is also distributed during severe droughts to meet water shortages through water bowsers, a process now commonly referred as tinkering. In the report by Birch and Shuria (2002) on the achievements of the pastoral institutions in developing the arid areas of northern Kenya, human health care, water supply, conflicts resolution, restocking and education were highlighted as practical means of minimizing the negative impacts of pastoral shocks.

Table 1:1: Regional droughts and the impact on livestock dynamics

Year	**Impact**	**Inter-drought duration**	**Livestock mortality in East Africa**	**Source**
1979-1980	Severe	-	50-70%,Turkana, Kenya 63% Cattle, 45% camels & 55% sheep and goats	Ellis and Swift (1988) McCabe (1987)
1984	Severe	4 years	50% in Baringo, Kenya 56%, Ethiopia	Homewood & Lewis (1987) Angassa and Oba (2007)
1987-1988	Mild	4 Years	None established	
1991-1992	Severe	4 years	38%, Ethiopia 50%,Garissa,Northern Kenya	Angassa and Oba (2007)
1997/8	mild	5 years	40% Samburu, Kenya	ILRI data, 2009
1999-2001	Severe	2 years	50% cattle & 20% goats, Samburu district, Kenya 53%, Ethiopia	Lesorogol (2008) Angassa and Oba (2007)
2005-2006	Severe	4	43% TLU mortality in Kitengela, Kenya	Nkedianye et al. (2011)

1.3 Aims of this study

The overall aims of this study can be split into three broad categories. The first aim is to understand the sources of pastoral risks and mitigation strategies available for effective policy development. Swift et al.(2002) noted that Kenya has developed an efficient drought management structure but still lacks effective policy and institutional requirements. Further, the efficiency of drought management not only lies with proper identification of the subjects at risk but also the application of the right response strategies. Desta and Coppock (2004) placed an important emphasis on the need to continuously search for new emerging issues which may lead to improved holistic risk management among the pastoral systems. Bollig (2006) however noted that research on "hazards, risk perception and minimization strategies is relatively new in the social and environmental sciences". To develop and implement policies, appropriateness should focus not only on the known risks but also on those emerging that could potentially harm livelihoods. This study endeavours to bring to the fore the following: firstly, identify pastoral risks and mitigation. Secondly, investigate whether those perceived risks and mitigation strategies are homogeneous across income levels and regions.

The second aim examines the impact of selected identifiable pastoral risks on pastoral socio-economic wellbeing. Although many studies have indicated adverse effects of droughts on pastoral wellbeing economically (Lybbert et al., 2004b), environmentally and socially (Abule et al., 2005), there is no available empirical evidence on a complete interlink of covariates on pastoral wellbeing. This is partly due to unavailability of longitudinal data. To achieve this aim, the study empirically examine the drivers of pastoral capital using household datasets collected by the Arid Lands Resource Management Project (ALRMP) between the period January 2006 and March 2010. ALRMP is a World Bank funded project aimed at monitoring the environmental, economic and social status of selected pastoral communities living in arid areas in Kenya.

The third aim is to develop a System Dynamics (SD) model to help in the evaluation of effective pastoral strategies aimed at reducing the risk of households falling into a poverty trap. The model is developed following a wide range of literature synthesis, expert opinion and community level interviews. The structure developed then used data collected in support of the first and second objectives for model parameterization. The option selected as mitigation strategies for scenario runs were collected from the interviews and expert opinion expressed partly on the government and non-governmental short and long run targets.

1.4 Importance of the Study

Effective management of rangeland, which forms the main source of livelihood for the impoverished pastoral community, has attracted the attention of scholars and development practitioners. This study seeks to contribute towards the understanding of pastoral risks and development of effective policies for mitigation and avoidance of those risks. The most immediate users of the result of this work are the policy makers responsible for arid and semi-arid rangeland management, conservation experts and those charged with the duty of care to ensure sustainable development. This group includes government departments, development partners and conservation organisations. The second level users are the community level institutions. Most impacts of pastoral risks are borne by the communities by way of declining livelihoods causing counteracting effects on the whole system. Understanding the causes of risk and ultimate effects allows the community to act from an informed viewpoint to mitigate further effects on the system. Finally, the study contributes towards the growing literature on pastoral risk management and poverty reduction strategies to ensure sustainable development. The study introduces holistic risk management aspect on pastoral rangelands and its integral role in poverty policy evaluation by developing SD simulation model which incorporates as much pastoral variables as possible.

1.5 Objectives of the study

Research on sustainable development of African pastoral system has been characterised by enormous diversity of interests driven mainly by the funding institution (de Leeuw et al., 1995). These interest groups are made up of ecologists, conservationists, social scientists and economists (see figure 1:2).The main objective of this study is to develop a dynamic simulation model on the complex pastoral system to examine the economic, social and environmental effects of the main pastoral risk drivers by combining findings from these distinct fields of study. The study evaluates the impact of land use changes, pasture condition, livestock risks and human nutritional requirements on household wellbeing. To achieve this, the study focuses on the following key objectives:-

1. Identify the main pastoral system drivers and their mitigation strategies. The study commences with a thorough synthesis of pastoral literature review and supplemented by primary cross-sectional data. A series of data collection methods involving focus groups and survey questionnaires were employed to collect the cross-sectional data. Descriptive and inferential analysis is carried out to determine the main pastoral system drivers and possible mitigation strategies employed by households, to respond to their consequences.

2. Examine the impact of pastoral system drivers on pastoral wellbeing. To measure wellbeing, the study adopted a vulnerability framework, explained further in section 1.7, to investigate the effects of droughts on the financial, natural, social, physical and human capital assets of the Sustainable Livelihood (SL) framework (DFID, 1999). The Arid Lands Resource Management Project (ALRMP), with the support from the World Bank has since collected data on socio-economic and environmental variables to monitor vulnerability. The variables of interest are explained in details under section 3.6. The data was supplemented with satellite generated pasture conditions, measured using the Normalised Differenced Vegetation Index (NDVI) explained in section 3.6, to identify drought years. Fixed effects regression models are employed on a 5-year panel data to investigate significant drivers for pastoral wellbeing by establishing their strength of influence and their coefficients. Further details on how to achieve this objective is explained in section 3.7.

3. Develop a System Dynamics (SD) model complete with livestock asset, human population, rangeland, and other resources dynamics. The aim of the SD model is to assist in understanding the complex pastoral system interaction on the causal relationships observed in our second objective. It is made possible by the ability of SD models to incorporate non-linear interaction and the knock-on effects of sources and consequences of these risks. The results of the SD model are tested with actual data for the period during and after the simulation. The SD model utilises the coefficients generated in our second objective to parameterise system variables. The structure and parameterisation of the SD model is detailed in chapter 4.

4. Recommend the most effective pastoral policies. Pastoral policy options with greater impact on wellbeing are examined and those with maximum benefits recommended for implementation. Various policy options are tested against the vulnerability framework and policy choice made based on the impact on wellbeing. Mitigation strategies gathered during the focus group discussion and others generated from the statistical analysis are applied in the model. The outcome variables relating to poverty, malnutrition and livestock ownership are examined and propose simulation scenarios with maximum benefits in reducing poverty and malnutrition. The details of the SD simulation runs are discussed in section 4.4 as risk mitigation strategies.

The objectives set in this study are achieved by focusing on Samburu East district in Northern Kenya which is classified as 100% ASAL (see figure 2:5). The area is also covered by the mandate of ALRMP collecting data since 1996 to monitor socio-economic and environmental vulnerability making it possible to examine the second objective set out for this study.

1.6 Research Gap

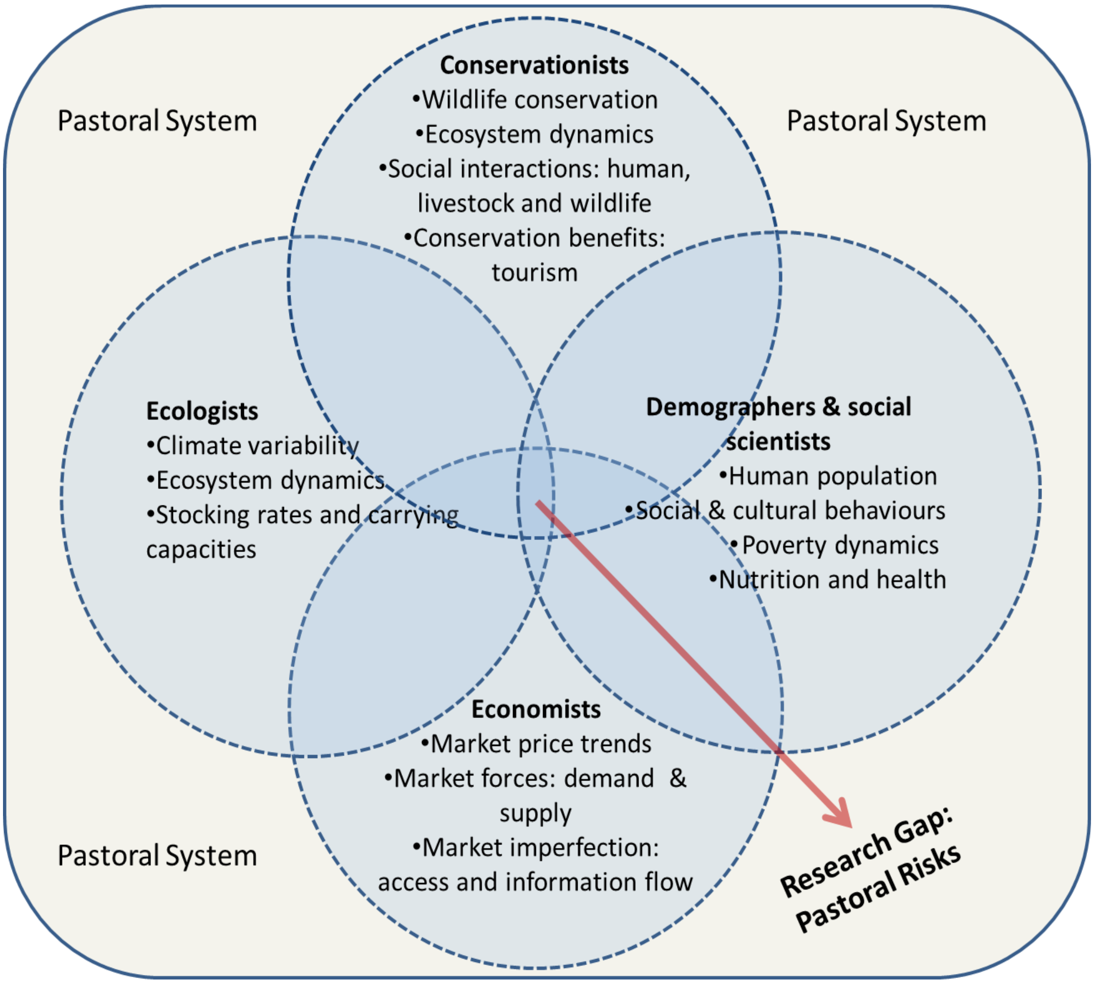
Pastoral systems are complex and uncertain but critical to the development of Kenya, especially the ASAL region (Little et al., 2008). It is complex and uncertain because it involves many interest groups with diverse objectives operating in the same area (Little et al., 2008, Garedew et al., 2009, Thornton et al., 2006). Further, the uncertainty associated with climatic conditions highly influence the success or otherwise of this system (Angassa and Oba, 2007). Pastoral systems are critical in the local and national economy in many ways (Aklilu and Catley, 2010). In the local level, pastoralism provides nutritional and economic means to a majority of households (Fratkin, 2004, King et al., 1984). These households derive their economic and social power from livestock ownership. The complexity, uncertainty and importance of pastoral system have however attracted many researchers from varied backgrounds ranging from anthropologists, natural scientists and environmentalists. Studies on pastoralism revolve around four main sectors that interact to support the system. The literature identifies these sectors as (1) pastoral economies and markets (Barrett and Luseno, 2004, Fafchamps and Gavian, 1996) (2) rangeland productivity (Pickup, 1995, Reid et al., 2000, Snyman and Du Preez, 2005) (3) socio-cultural systems (Sandford, 1980, Fratkin and Roth, 2005) and (4) ecosystem management (Chandrasekhar et al., 2007, Bollig, 2006). The current study relies on these past studies to inform the System Dynamics (SD) model development. It therefore brings these clusters together and utilises empirical survey data to parameterise the SD developed and finally appraise policies.

Although there is extensive agreement on the causes of poverty among the pastoral communities, that is, the cycles of livestock which result from resource imbalance (Lesorogol, 2009, McCabe, 1987, McPeak and Barrett, 2001, Carter and May, 2001), there is divergent opinion on methodological considerations to resolve these issues (Campbell et al., 2006). Both natural and social science literature on the pastoral economy is undergoing various developments, partly because of the underlying dynamic biological, social and economic environment (Sandford, 2004, McCarthy and Swallow, 1999, Homewood and Lewis, 1987). There is still much to explore further about these risks and the ways in which to evaluate their effects on the socio-economic wellbeing of pastoral households. Rangelands resource management strategies have been tailored towards range conservation, but the new philosophy of building a sustainable rangelands production while improving household income levels is being advanced (Behnke and Kerven, 1994). In order to integrate the biological, social and economic environment, the evaluation of pastoral risks is appropriate (Campbell et al., 2006). There is a need to examine possible uncertainties caused by the influence of these multi-faceted resource management strategies for poverty reduction.

Past studies have failed to bring out the facts surrounding the complexity and uncertainty with respect to policy evaluation (Aklilu and Catley, 2010). This is partly caused by the methods applied, data used, context and the underlying framework (Adger, 2006). On the methodology, pastoral studies have in the past depended on cross-sectional data to assess risk and mitigation strategies employed. Over the years, pastoral sector has accumulated some longitudinal data capable of providing insights on the dynamics surrounding pastoral system and the impacts upon livelihoods. It is now possible to examine the etiology of pastoral poverty by examining assets dynamics and mitigation strategies from the available panel data using advanced software. For those with some kind of panel data, mostly generated through the memory recall data collection method (Angassa and Oba, 2007, Kassahun et al., 2008), the underlying research framework adopted is largely based on specific objectives of the interest group. Economists for instance have engaged in the study of poverty traps and safety nets using social capital and wealth dynamics framework (Mogues, 2004, Lybbert et al., 2004b). Environmentalists and ecologists, on the other hand, emphasise an equilibrium and non-equilibrium framework approach to studying pastoral risks. These frameworks do not incorporate the complexity and interdependence of pastoral systems as it should do, thereby failing to identify critical areas for sustainable development. The intense changes in land use and economic diversification have threatened pastoral equilibrium calling for evaluation of the pillars supporting it (Little et al., 2001b, Rutten, 1992). Economic and conservation conflicts are created by the common sharing of pastoral rangelands by wildlife, livestock and human population. Figure 1:2 summarises the issues addressed by different groups of researchers. The diagram describes how independent the past studies have approached the subject of pastoral systems and risks. It shows the various areas widely researched by conservationists, ecologists, demographers and economists.

Although socio-ecological systems are interlinked (Wolstenholme and Coyle, 1983) and vulnerability measurement cut across the sub-systems (Hope, 2009, Lybbert et al., 2004b), there is less integration on their objectives to the multiple and the knock-on effects. Different groups have different perception of risk management:- (1) In the actor-oriented approaches, Anthropologists studying pastoral communities argue that risk management strategies are the major influence on the dietary choices arising from hunting and gathering, and other food sharing behaviours (Kaplan et al., 1990, Kaplan and Hill, 2008). Agents are used to study and test some specific hypothesis set, such as the role of food sharing as a means of reducing food level among the community members. However, these strategies studied did not provide general applicability of these models, due to lack of consideration of other interrelated factors such as the economy and environmental complexity. (2) The ethnographic approaches: anthropological studies on the pastoral economic marginalisation and impoverishment have been undertaken (Hogg, 1986, Anderson and Grove, 1990) and found that rangelands degradation is caused by changes in the land use systems and other social factors (Galaty, 2005, McCabe, 1990, McCabe, 2003, Little et al., 2001b). Pastoral risk management is therefore an important aspect of building a sustainable utilisation of rangeland and maintaining appropriate living standards among the poor pastoral communities. These studies focus on grazing strategies and mobility (Dyson-Hudson and McCabe, 1985), appropriate stocking strategies (Campbell et al., 2006) and market research to stimulate livestock off-take (Barrett and Luseno, 2004). (3) In Interpretative approaches, social scientists have contributed towards pastoral risk management by evaluating risk perception among these communities (Douglas, 1992). This perspective of risks suggests that the frequency and impact of risk is relatively interpreted by different people depending on their perception and social institution.

Figure 1:2 Research Gap



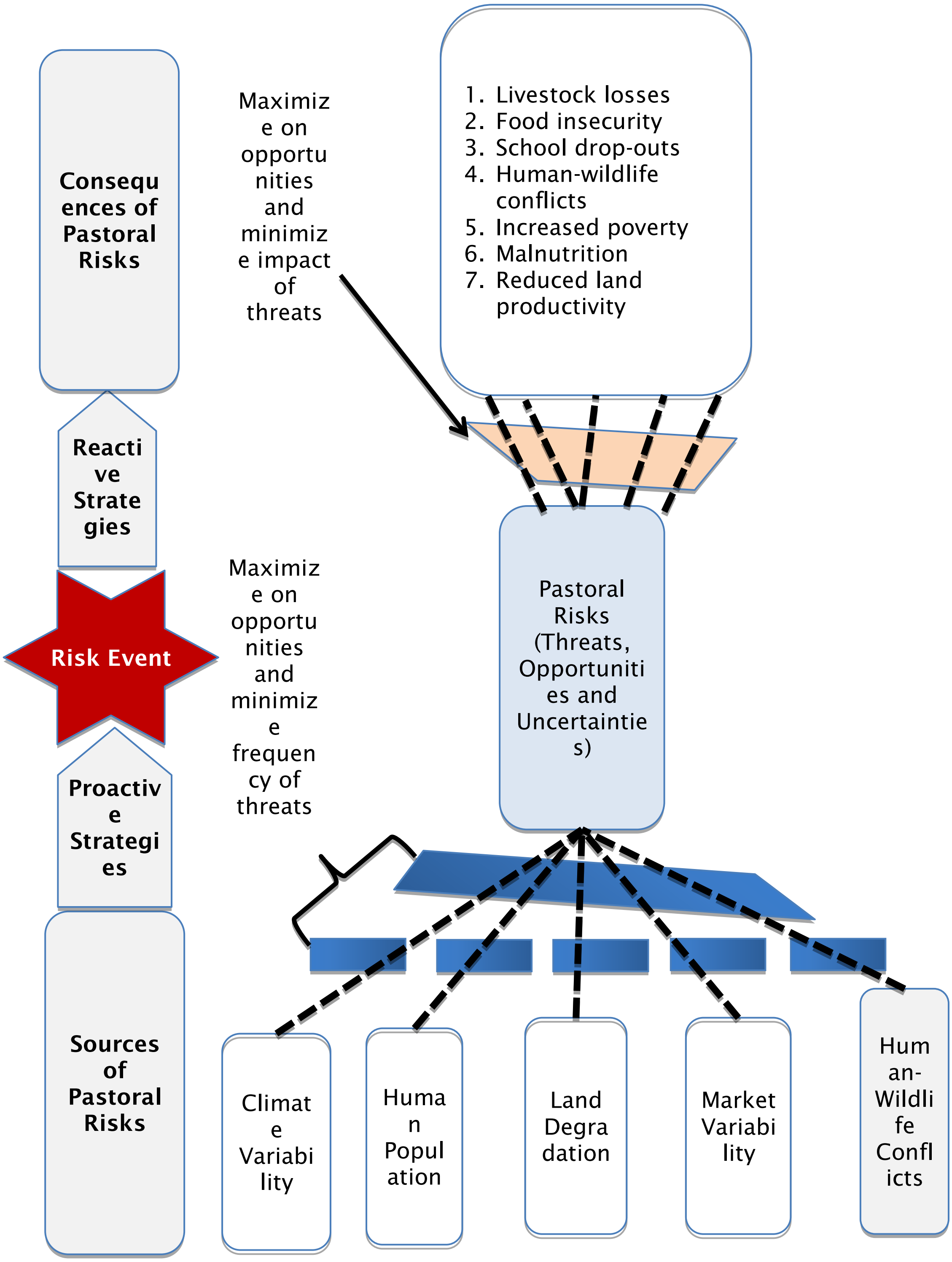
Understanding the multifaceted challenges facing pastoralists require a multidisciplinary approach and evaluation across time and space (Weichselgartner, 2001). There is a clear indication that the complexity of a pastoral system and the associated uncertainty, poses a risk to those dependent on it for livelihoods. The role of risk management is therefore paramount in identifying risks and mitigation strategies employed by the community at risk. Similarly, the complexity of this system can also be simplified using SD modelling. In doing so, the shortcomings of the past researches on pastoral system management are solved. Holistic understanding of the effects of the various exogenous factors relating to the individual elements in pastoral system is lacking. This lack of system integration has been indicated as a cause of the conflicting findings on pastoral rangeland theories of equilibrium and non-equilibrium (Coughenour, 2004, McCabe, 1987, Vetter, 2005) as well as the difference of opinion in economic benefits of stocking strategies (Sandford and Scoones, 2006, Campbell et al., 2000a). Introduction of a system dynamics methodology to evaluate the stochastic relationships established from the elements of the pastoral system enhances the integration of science, policy and practice (Campbell et al., 2006). This measure aims to evaluate not only the effect of individual pastoral risk on poverty levels but also its influence on the whole pastoral system. This study aims to incorporate the multidimensional approach towards pastoral systems. It endeavours to evaluate the consequences of both up and down sides of uncertainties affecting the pastoral economy.

1.7 Research Framework

1.7.1 Risk Management Framework

The first phase of the research, dealing with identification of pastoral risks and mitigation strategies, adopts a simple but reliable bow-tie framework (Crerand, 2005). Managing both exogenous and consequential risks in the pastoral economy using the "bow-tie" approach, and dealing with sources and consequences helps to reduce the impact and frequency of risk events. Although this approach was initially used in the engineering field to assess the downside of risk effects, the same is applicable for pastoral uncertainties assessment. The method incorporates both proactive and reactive measures of risk management, to assess causal and consequential risks respectively and incorporate management controls. Described on figure 1:3 is a modified Bow-Tie model for the purposes of assessing pastoral risks. The sources and consequences of risks were generated from a review of literature. This framework was chosen to achieve the first objective of the study dealing with identification of risks and mitigation strategies.

Figure 1:3 Risk Management Framework



1.7.2 Sustainable Livelihood Framework

The second phase of the research deals with evaluation of vulnerability arising from identifiable pastoral risks. In this phase, we adopt Sustainable Livelihoods (SL) framework to understand pastoral well-being; sources of livelihoods, environmental variability, processes, and livelihood outcomes (figure 1.4). Livelihood approaches are important in developing response strategies to fight against poverty (DFID, 1999). Department for International Development (DFID have in the past years adopted livelihood principles to address poverty. The principles require clear objectives, scope and priorities for development, especially those directed towards reducing poverty. They include understanding the holistic system by identifying causes of poverty and evaluate opportunities for development. SL approaches are desirable in many ways: they inform the process and content of policy formulation, allow cross-disciplinary analysis, and helps in monitoring holistic impacts of new and existing policies on well-being. SL endeavours to evaluate the impact of policies on the proxies selected to measure community vulnerability at both micro and macro levels, with people being the central focus. Development, based on SL approaches, allows policy makers to focus on the primary unit of a society (household) in the development agenda.

SL framework is developed from basic principles requiring the process to be people-focus, sustainable, multi-dimensional and dynamic. Areas of greater priorities are selected as proxies to represent indicators of well-being for sustainable development, likely to bring upon the desired goal of minimising people living in abject poverty. The framework encompasses the understanding of the priorities that people identify as important, institutions that help develop strategies to access various forms of capitals, and the context in which the community live. The use of SL approaches has gained momentum, especially in the areas of research, planning, and project management (Ellis and Mdoe, 2003, Scoones, 1998). DFID, for instance has used the SL framework to evaluate development projects around the world including Zambia, India, Pakistan and Kenya (DFID, 1999). Livelihood analysis, using SL framework helps in developing areas for priority in mitigating the adverse effects of the environment, both internal and external. It provides a checklist of important issues and processes, in addition to drawing attention to the interaction between factors affecting livelihoods.

The analysis of the SL framework commences with the appraisal of the people's assets, identify livelihood objectives and the strategies to achieve them (DFID, 1999). This process involves interlinked feedback causing further effects on the assets, processes and livelihood outcomes. The impacts are more severe when the vulnerability context, represented by trends, shocks, and seasonality is adversely affected. Carter and Barrett (2006) defined vulnerability as the residual of impact against adaptation, and the ability to cope with the current situation and adapt to future uncertainty. In pastoral systems, the vulnerability context relates to the occurrence of droughts, growth in human population trends, and variability in market prices (Galvin et al., 2004, Little et al., 2008, Swift, 1989). They directly influence the quality of the pastoral wellbeing, depending on the direction of the trends and seasonal shifts. Desired policies need to enhance people's resilience towards shocks and capitalise on the opportunities caused by positive trends. The approach focuses on people's vulnerability by assessing livelihood assets based on five forms of capital assets, baptized 5 C's for sustainable development. It provides a set of principles which help in measuring the impact of policies in the various livelihood categories, classified here as forms of capitals. These are human, natural, financial, physical, and social capitals. These forms of capital are interlinked and none of them can be treated independently without influencing the other. They are influenced by the external and internal environments ultimately influencing the livelihood outcomes.

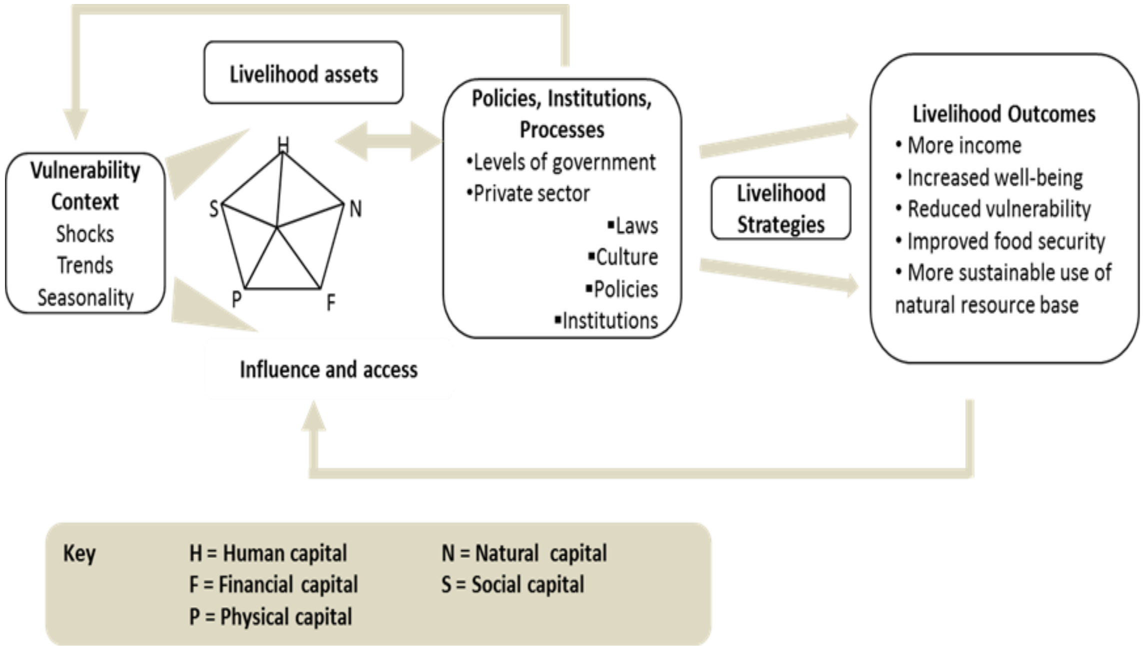
Human capital represents the knowledge and skills, ability to labour, and good health. It allows households to diversify to other sources of livelihoods such as employment and trade (Soini, 2005). The health of the population indicates the ability of the community to make use of the other forms of capital. Studies on pastoral systems have indicated a consistent and strong influence of livelihood sources on malnutrition among children below 5 years old (Mude et al., 2009a, Roth et al., 2005, Sellen, 2003). In the current study, anthropometric measure of Mid-Upper Arm Circumference (MUAC) was used to monitor child malnutrition. Other measurable human capital indicators include literacy rates, life expectancy, and employment of knowledge in productivity. Social capital represents the existence or absence of the society's social resources as indicated by social networks, membership to groups and trusts, and access to other institutions. Such memberships and groupings allow the society to respond to the effects of vulnerability as well as shape the policy decisions. There is an observed decline in the effectiveness of the traditional kinships among pastoral communities arising from modern education system and reduced livestock ownership (Lesorogol, 2009, McPeak and Little, 2005). Local NGOs and government institutions have more often responded to social distress by offering food reliefs. The outcome of the strategy is reduced food insecurity, as indicated by reduction in child malnutrition (Mude et al., 2009a). This study uses the proportion of households receiving relief food as a proxy for measuring the extent of social resources. This does not take away the fact that government plays a major role in provision and distribution of relief food. The result shows the extent of the institutional role in responding towards food shortages in pastoral areas.

Natural capital comprises of the availability and access of quality natural resources, such as forests, land, and lakes etc., which contribute towards livelihoods. Rangeland in pastoral system forms the bedrock for building resilience towards shocks, in ensuring access to quality pasture and water resources (Niamir, 1991). The quality and access of pasture resources is affected by expansion of human settlement (Lamprey and Reid, 2004), rainfall (Leggett et al., 2003, Pickup, 1995), and the stocking rates (Sandford and Scoones, 2006, Campbell et al., 2006). Based on the strong linkages between rangeland productivity and pastoral wellbeing, the current study utilised pasture quality and availability as a proxy to measure the strength of natural capital. Normalised Differenced Vegetation Index (NDVI) was used in this case to measure quality and quantity of pasture in the study area. NDVI, measured using satellite-based optical sensors, has gained worldwide popularity as a tracking tool for drought existence and severity (Tucker et al., 2005).

Basic infrastructure and producer goods represent the strength of physical capital in SL framework. Infrastructure analyses include transport, markets, shelter, water and sanitation, affordable energy, and access to information. Pastoral areas in Kenya are characterised by poor infrastructure and lack of information flow mechanisms (Luseno et al., 2003) making them to depend on their local knowledge (Lybbert et al., 2007). Lack of early warning information coupled with seasonal rainfall variability affect market prices (Khan et al., 1992, Barrett et al., 2003). The government of Kenya, through Arid Lands Resource Management Project (ALRMP) has for a very long time used livestock and food prices to indicate the state of market stability (ALRMP, 2007). The relationship between prevailing livestock and food prices in pastoral areas indicate to some extent how the available information is absorbed in the market. The outcome of the interaction measures the purchasing power for the households and is used in this research as a proxy for physical capital.

Finally, financial capital comprises of all the economic resources that people use to acquire and utilise the other forms of capitals. They include livestock assets and other streams of income enabling people to meet livelihood needs. Livestock assets are the most important financial capital in pastoral systems. Livestock are kept as both fixed and working capital, with households often convert livestock to access market products (Aklilu and Catley, 2010, McPeak, 2004). Studies have often recommended for pastoral strategies likely to household's herd size by minimising losses, such as livestock insurance (Chantarat et al., 2009b) and appropriate stocking rates (Campbell et al., 2006, Sandford and Scoones, 2006). In this study, Tropical Livestock Unit (TLU) was used to measure the quantity of the financial capital available at the household level. This is a standardised index that brings together the quality of every livestock species based on their metabolic and economic factors (see table 3.5 for computation). Households, when deprived of livestock assets, fall into a poverty trap characterized by high level malnutrition and low per capita assets (Khan et al., 1992). Social status among pastoral communities therefore revolves around livestock asset ownership, hence wealth determination (Kassahun et al., 2008, Mogues, 2004).

Figure 1:4: Vulnerability Framework



Source: DFID (1999-2005) Sustainable Livelihood Guidance Sheet 2.1

The guidelines on sustainable livelihoods described by figure 1:3 demonstrate the effects of institutional policies and processes on the frequency and impacts of shocks on the livelihood assets. Since the second and third objectives were geared towards identifying the impact of pastoral shocks on wellbeing and evaluation of suitable policies respectively, the outcome variables were aligned to the 5 C's. Pastoral community's vulnerability, and hence sustainability, is linked to the variability of access to the different forms of capital. This study examines variability in human capital proxy by the percentage of children at risk of malnutrition, natural capital measured by the amount of pasture available for the livestock, Financial capital in the form of total livestock owned, physical capital assessed in the purchase power variability, and finally social capital proxy by the percentage of poorer households among the pastoral community.

1.7.3 Vulnerability Measurements

Financial capital variability, measured by livestock assets, was estimated based on their accumulation, herd structure (species) and related processes. Livestock numbers were converted into a standardised index, TLU, for ease of comparison over time in addition to transforming the data. Further, goats and sheep were clustered into a single measure, Small Stock Unit (SSU), to allow analysis of the variability of stock species in measuring financial assets. The main livestock processes examined in this study were sales, births, and mortalities. These processes are arguably the main channels through which herd size is affected (McPeak, 2005, Osterloh et al., 2003, Desta and Coppock, 2002b). The choice of the predictor variables for financial capital was based on objective to assess the major drivers of livestock assets. Studies have also argued that households are diversifying livestock ownership by increasing small stock (King et al., 1984) because of their lower mortality rates during droughts (McCabe, 1987). Pastoral communities have also adopted small stock herding as a strategy to build their herd size quicker than cattle, following drought events (McPeak and Little, 2005). Although many studies have indicated minimal role played by market off-take (Lybbert et al., 2004b), this study assesses the influence that sales rates between small stock and cattle have on the herd size. In addition, we also measured the effects of pasture condition, proxy by NDVI, on the herd size. A healthy rangeland, characterised by absence of droughts, has been found to provide favourable environment to rebuild herd size (Oba, 2001, Angassa and Oba, 2007).

Human capital, which was denoted by child malnutrition indicate wellbeing responses towards livelihood stressors. Malnutrition among children below 5 years is an indicator of chronic food insecurity and measures respond rapidly to nutritional stressors. Both local and international organisations respond towards wellbeing vulnerability by monitoring the percentage of children below 5 years of age with MUAC readings below 135 mm. MUAC is a commonly used anthropometric index in assessing the extent of the effects of disaster (Mude et al., 2009a, Khan et al., 1992). In the current study, monthly MUAC readings are recorded for children below 5 years of age and the proportion of those below the cut-off line (135mm) is reported in the monthly bulletins at the district level. This proportion is referred as the children at risk of acute malnutrition (ALRMP, 2007).This study has however, recalculated percentage of children at risk of malnutrition for every community for the period under consideration. The choice of the covariates affecting malnutrition were generated from past studies which suggested that availability of livestock products, such as milk and meat, provide the most needed nutritional requirement for a pastoral community (Galvin, 1992). Livestock birth rates and mortality rates denoted the availability of milk and meat respectively in this study. Sellen (2000) noted that malnutrition among women and children in pastoral communities of Tanzania increases during drought period associated with drier ecological conditions. Consideration of pasture condition therefore becomes important in our study both in short and long term. The study made an assumption of time frames for 3 and 6 months to represent mid and long term in our pastoral cycle. This assumption is sensible because the study area receives a bimodal rainfall, suggesting that taking period longer than 7 months overrides seasonal patterns. Households respond to food shortages by engaging themselves in market-based economies, involving sale of livestock to purchase market products (Little et al., 2008). Sales rates explain part of the influence that the households respond towards food shortage. The contribution of sales towards meeting livelihoods can also be explained by the value of sales measured by the strength of purchasing power affected by biotic and abiotic factors (Barrett and Luseno, 2004).

This study also included the effects of purchase power on child malnutrition. Improved purchase power for the households means that fewer sales are required to meet food shortages. Purchase power is described as Meat-Cereals Price (MCP) ratio, also used as proxy for physical capital. Small Stock Unit (SSU) prices were standardised to reflect the cost of a single kilogram of meat for comparison with same weight of cereals (see Eq. 18 & 19). The rationale is that an increase in this ratio suggests a superior purchasing power for the pastoral households, an indication of more market products for fewer livestock sales. Households in such improved purchase power are therefore able to respond towards food shortages, hence reducing malnutrition. Market volatility, indicated by MCP ratio, was assessed for purposes of measuring physical capital vulnerability. Efficient pastoral market is characterised by stable livestock and food prices, resulting from sufficient flow of information (Luseno et al., 2003, Lybbert et al., 2007), good road networks (Osterloh et al., 2003), and absence of insecurity and conflicts (Haro et al., 2005). Market prices therefore respond to the forces of supply and demand dictated by the level of the infrastructure in place. MCP used in this study is a standardised measure of the interaction between market products and livestock prices. MCP variability could then be explained by the local demand and supply. The availability of milk and meat reduces demand for market products while increased supply, indicated by sales rates and malnutrition levels adversely affect the purchasing power. The availability of milk and meat was denoted by birth rates and mortality rates respectively. Holtzman (2007) noted that the demand for market products for the Samburu community reduces with increase in livestock productivity. It then suggest that herd size (TLU) affects the purchase power, by reducing the need to either buy market products or sell livestock. This study examines the effects of livestock birth rates, mortality rates, pasture condition, herd size, malnutrition rates, and percentage of households receiving food aid on MCP. Provision of food relief is intended to meet food shortages during famine, hence reduces demand for market products. Natural capital described earlier, as denoted by NDVI, was tested for significance with monthly rainfall. The aim of this analysis was to establish the extent to which pasture condition respond towards rainfall.

Finally, the measure of the total interaction between financial, human physical, social, and natural capital indicate the general vulnerability of the pastoral community. Poverty reduction is at the centre of the SL framework adopted as the analysis tool for the study. ALRMP dataset included a question for wealth ranking where households are classified into poorer or better-off. Monthly percentages of poorer households were then calculated to provide us with the dependent variable useful in measuring the ultimate pastoral vulnerability. The study examined the effects of variables representing natural capital (NDVI), financial capital (TLU), physical capital (MCP), and human capital (MUAC) on the percentage of poorer households. The analysis is based on the fundamentals of poverty reduction strategies among pastoral system, which in the past seek to recommend for increased herd size through social systems (Lesorogol, 2009, McPeak, 2004). Other strategies aimed at mitigating rising poverty level in pastoral system included land reclamation to improve pasture conditions (Kassahun et al., 2008, Puigdefábregas, 1998) and provision of food aid to cushion herders from rising food prices and declining livestock prices during droughts (Lybbert et al., 2004b). Pastoral households hard hit by droughts and food insecurity, indicated by high percentage of malnourished children (Khan et al., 1992), usually respond by selling off their assets, leaving them further impoverished.

It is based on these two frameworks that the third objective is achieved. The risks identified and their associated mitigation strategies are linked together. Finally, the established relationships are used to parameterise the simulation model. The severity of pastoral shocks is then examined based on these proxy variables and effective policies assessed on the outcome variables from the baseline scenario.

1.8 Outline of the Thesis

There are 9 chapters in this thesis described as follows:

Chapter 1 (this chapter) introduces the subject of the study by broadly explaining the roles played by the pastoral system and the main risks (mainly droughts). The chapter sets out the objectives of the study and their importance in meeting the research gaps identified. To achieve the objectives of the study, the chapter provides an in-depth description of the research framework adopted in the study.

Chapter 2 (literature review) provides an extensive discussion on the previous research relating to the pastoral risks and mitigation strategies, and vulnerability measurements. Drivers of pastoral systems are discussed and pastoral risks and mitigation strategies classified into environmental, economic, and socio-cultural depending on the causes and impacts. Past and current policy making criteria are discussed and the need for System Dynamics (SD) modelling in pastoral policy making process is introduced.

Chapter 3 (methodology) while building on chapters 1 and 2, sets out the strategies and approaches of the current study. The chapter provides a justification of the methods used to select the samples, collect data and analyse to achieve the objectives earlier set out in chapter 1.

Chapter 4 reviews the SD modelling techniques, development and parameterisation looking at the building blocks of the STELLA© modelling software. Building from chapter 1 to 3, the chapter discusses a conceptual pastoral system SD model. General causal relationships are identified and categorised into livestock, rangeland and human sub-systems. The impacts of the mitigation strategies discussed in chapter 2 are linked to the respective sub-systems.

Chapters 5, 6 and 7 highlights the results of the study structured around the three aims set out in chapter 1. Chapter 5 provides descriptive statistics on the sources of pastoral risks and mitigation strategies using cross-section data. Chapter 6 details both descriptive and inferential statistics of a 5-year pseudo-panel data collected during the period between January 2006 and March 2010 (secondary data). Chapter 7 on the other hand descriptively assesses baseline results against the policy options discussed in chapter 4.

Chapter 8 discusses the descriptive, inferential and simulation results highlighted in chapter 5-7.The chapter is structured into discussions on sources of pastoral risks, impacts of droughts on wellbeing and pastoral policy evaluation from the SD simulation results.

Chapter 9 finally draws conclusions from the key findings highlighted in chapter 5-7 and discussed in chapter 8. The chapter also discusses the recommended policies, highlighting the contribution of the study. The chapter also briefly explains the limitations of the study and possible future work arising from the study.

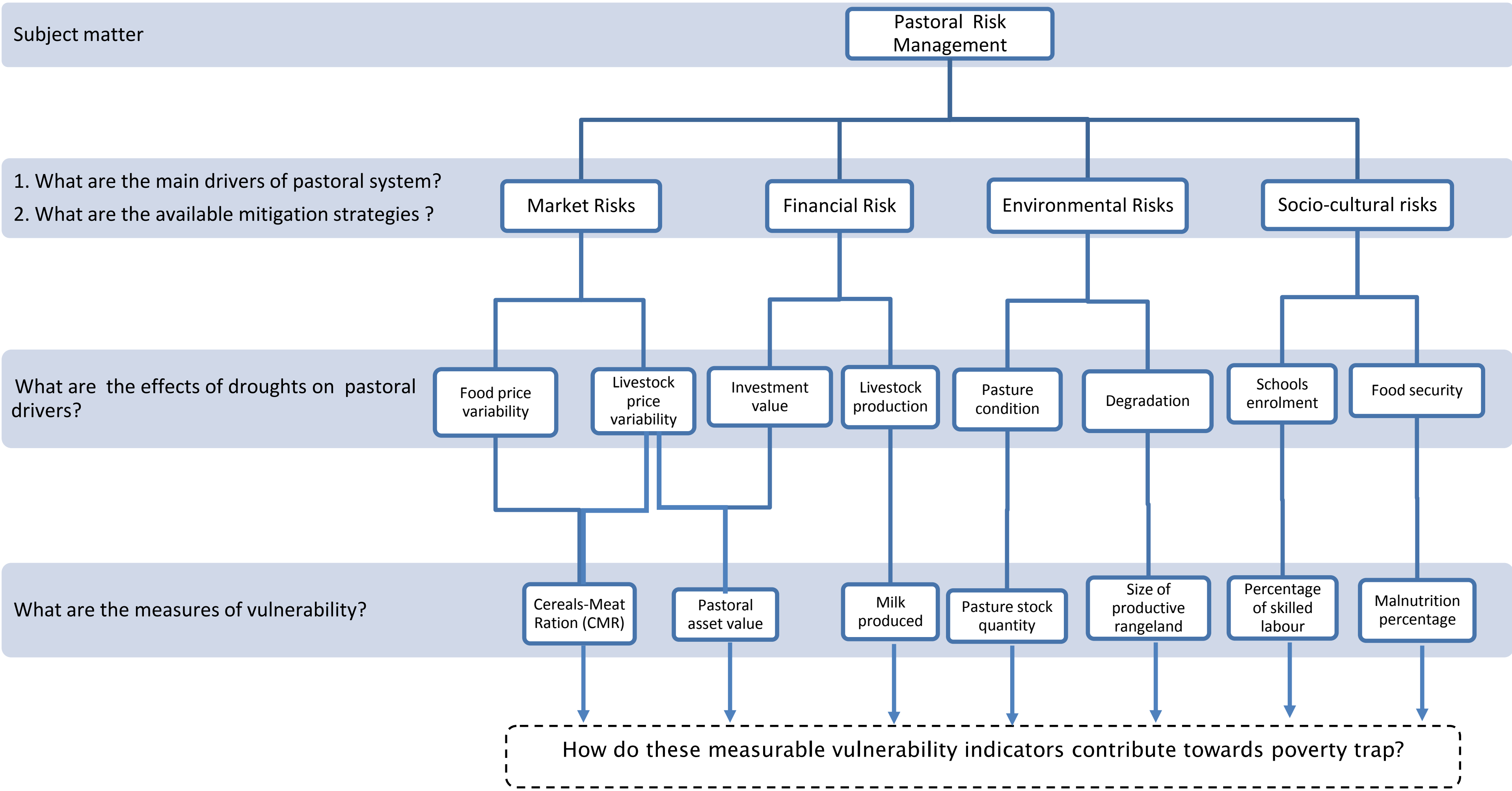
2 Literature Review

2.1 Introduction

Sustainable development of any nation depends on the strength of its own economic activities (IMF, 2010). Kenya, just like many of the African countries is classified as developing nation with competing needs within its economic sectors. To measure the level of success or otherwise, Kenya has set national and regional targets based on the resource availability and international guidelines. The recent effort by the government to design vision 2030 is aimed at improving economic growth alongside achieving Millennium Development Goals (MDGs) as mid-term objectives (IMF, 2012). This grand vision is subdivided into various mid-term plans establishing the primary sectors for development (IMF, 2010). However, these primary sectors are faced with various challenges likely to reverse the gains on meeting MDGs and the Vision 2030. This vision has a twin agenda of economic development and poverty reduction at the micro and macro level structured into Poverty Reduction and Strategy Papers (PRSPs) processes (Freeman et al., 2004). One important sector in the Kenyan economy is agriculture which account directly for more than a quarter of the GDP and support majority of households in Kenya. Agriculture is however classified into crop and livestock farming as the main practices with the latter often are being referred as pastoral farming. These livestock farmers are however vulnerable to the variability of rangeland productivity caused by bio-physical factors. To keep up with both the short and long term targets, management of uncertainties affecting pastoral system is inevitable.

The understanding of pastoral risks by households and to a larger extent by the organizations engaging in development and managing uncertainties in ASAL is that pastoral risks are linear in cause and effects. Such understanding has in the past led to development of risk management policies directed at some specific sector without necessarily evaluating the overall impact on the total pastoral system. However, studies have shown that the system is a complex “web” of cause and effects and the cumulative impact on the sector is immense (Thornton et al., 2004, Boone et al., 2006). The complexity involved in identification and quantification of these risks make mitigation strategies development and implementation ineffective. The structure to this chapter follows a representation of a tree diagram shown in figure 2:1. The subject matter of pastoral risk management being investigated is broadly classified into the four risk areas widely researched, namely; pastoral markets, financial, environmental and socio-cultural risks. The structure is adopted based on the objective of the study which is to investigate the uncertainties in these areas and the impact on pastoral vulnerability. It is further motivated by the identified research gap which noted that past studies by economists, environmentalists, sociologists and conservationists have identified risks relating to these individual sub-systems without interacting them in view of high level of pastoral system dependence.

Figure 2:1: Literature Map



2.2 Pastoral Systems and Vulnerability

2.2.1 Introduction

Pastoralism is an agricultural practice involving keeping of livestock and it is a dominant form of land use in Sub-Saharan Africa (Abule et al., 2005). They referred to pastoralists as the community owning different animal types. Boone et al. (2006) on the other hand used the term pastoral to refer to the rangeland and the lifestyle of the society that is dependent on livestock. The system itself is the total of the interactive components between pastoralists, livestock and rangeland. Pastoral systems therefore include all the variables that support livestock productivity such as the land, markets, wildlife conservation and households (Begzsuren et al., 2004, Boone et al., 2006). Research focus on pastoral risks have therefore suggested consideration of the uncertainties associated with the multifaceted components likely to affect the equilibrium condition of the system (Bollig, 2006). Livestock Production Systems (LPS) are broadly categorised as pastoral and agro-pastoral areas based on the land use by livestock (Steinfeld et al., 2006). The choice of the LPS is dictated by the prevailing biophysical and socio-cultural environments. Studies on human-environment interaction define vulnerability as propensity to “a higher risk of negative outcomes as a result of climatic events that overwhelm the adaptations they have in place” (Galvin et al., 2004). Further adverse effects on socio-economic status of the society reduce their ability to respond to it and ultimately pushing them into a poverty trap (Hope, 2009). Livestock income and asset variability is an important measure of vulnerability among pastoral communities in arid northern Kenya (McPeak, 2004). Understanding holistic pastoral system vulnerability therefore involves the examination of environmental, social and economic indicators. The quality of pastoral policy formulation and implementation is measured on its ability to reduce vulnerability on household assets which ultimately translate to food security (Swift, 1989).

2.2.2 Drivers of Pastoral System

The quality of rangeland and productivity is influenced by the “tragedy of the commons”, where resources communally owned are over utilised (Hardin, 1998). Earlier studies on rangeland had suggested non-existence of the tragedy of the commons in arid areas in Kenya arguing that pastoralism does not destruct rangeland as the carrying capacity is never exceeded (McCabe, 1990). Some recent literature on pastoral system however have suggested the existence of “tragedy of the commons” where households accumulate livestock in a limited rangeland beyond the carrying capacity (Hardin, 1998, Lesorogol, 2008a). To investigate these hypotheses, researchers developed simulation models to determine the carrying capacity for arid rangelands

(Retzer and Reudenbach, 2005, Plumb et al., 2009). Their conclusions were derived from the evaluation of rangeland productivity which depends on precipitation and the available land use system in place (Deshmukh, 1984, Campbell et al., 2000b). They argued that accumulation of livestock beyond rangeland productivity creates a deficit on the available resource necessary for primary production.

Slow onset of disasters associated with decline in rangeland productivity is linked with several causes. First, accumulation of livestock in excess of the numbers sustainable by the rangeland reduces future rangeland productivity (Blaikie et al., 1987, Chen et al., 2007). Second, changes in land use is mainly caused by human population increase (Garedew et al., 2009, Jolly and Torrey, 1993) and changes in government regulations, including gazettement for private ownership (Thornton et al., 2006, Kimani and Pickard, 1998). Other causes such as diseases, droughts, insecurity and market fluctuations are often classified as abrupt despite their frequent and repeated occurrences (Barrett and Luseno, 2004, Doss et al., 2005). These factors influence both the assets and income available for pastoral households.

Major risks affecting pastoral households vary in time and space depending on environmental condition. Seasonality in rainfall highly influences poverty levels among pastoral communities in East Africa (Barrett and McPeak, 2006). There are indications that rainfall causes substantial dynamics in pastoral system directly influencing the wellbeing of those dependent on livestock (Angassa and Oba, 2007). Sufficient rainfall distributed in the greater expansive rangeland ensures constant growth of livestock causing excess capacity (Doss et al., 2005, Angassa and Oba, 2009). Severe droughts occurring due to lack of sufficient rainfall more often cause a high rate of livestock mortality denying farmers income (Aklilu and Wekesa, 2002, Begzsuren et al., 2004, Homewood and Lewis, 1987). Inter-year seasonal variability also contributes immensely towards short term income variability and food insecurity (Barrett and McPeak, 2006, Hogg, 1986). Pastoral system in the arid areas of Kenya is highly dependent on a rain-fed primary productivity (Barrett and McPeak, 2006). According to research on pastoral system, stochastic/transitory poverty occurs whenever household are unable to meet their daily need due to insufficient income for a short period of time (Boone and Wang, 2007, Birch and Grahn, 2007). Rainfall variability also affects livestock and food prices contributing towards transitory poverty (Barrett and Luseno, 2004, Osterloh et al., 2003). Other causes of transitory poverty among the pastoralists are clustered as losses arising from insecurity, diseases and wildlife predation (Lamprey and Reid, 2004, Peden, 1987, Bekure and de Leeuw, 1991).

2.2.3 Changing Pastoral Systems in Kenya

Over the past few years, pastoral systems have undergone rapid economic, social, political, and environmental changes (Campbell, 1999). Livestock farming which is a major economic and social capital among the pastoral communities is threatened by the emerging market, socio-political and environmental risks. Economically, livelihood sources have increasingly been diversified from absolute dependence on livestock to sources such as eco-tourisms, agriculture and trade (McCabe, 2003). In some instances, pastoral farmers are slowly changing their income sources from livestock to small-scale crop farming, a system called agro-pastoralism. This system of crop farming alongside livestock keeping is common in areas around southern Kenya which receive a relatively sufficient rainfall to allow growth and harvesting of short period crops. Socio-political changes have also occurred especially in property ownership and utilisation. Constitutionally, most pastoral districts in Kenya are communally owned and the management entrusted to the local councils (Lesorogol, 2008a). Utilisation of these areas in the past was in the hands of the elders and the rules on using the rangelands were under their strict directive (Fratkin, 2004). However, there is a shift of responsibility of rangeland utilisation from the elders to board of trustees elected from every group ranch to represent the interest of the community (NRT, 2009). The decision making process involves consultation between the community elders and these elected board members (Lesorogol, 2008a). This land ownership structure and the implications on the land use is detailed in the work of Lesorogol (2008a) showing the process of privatising communal pastoral land in Samburu district. The administrative decision making process however has changed impacting on the rangeland access and utilization.

Environmental changes are evident ranging from changing land use to degradation of the ecosystem (Garedew et al., 2009). The shift from pastoral to agro pastoral system has attracted many immigrants into these areas. This High population growth in rural areas is overstretching the productivity of the rangelands (Schwartz, 2005). It is also associated with changing land ecosystem and increased human-wildlife conflicts. The main land use changes in most pastoral areas in Kenya include privatising land into commercial ranches, crop production, and gazettement of rangeland into game parks limited to wildlife conservation (Schwartz, 2005). Mobility strategy which has played a major role in mitigating most of pastoral risks for many years is being rendered inapplicable (Schwartz, 2005). Developing countries in Africa are still registering high growth in human population of about 2.8% annually (Steinfeld et al., 2006) and Kenya recording 2.6% during the period 2007-2010 (World Bank, 2011). Human population pressure and associated land use changes is limiting the freedom of shifting during poor rainfall years. Similarly high population is spreading over to areas previously used as buffer zones limiting accumulation of pasture reserves to be used during drought years.

2.3 The Concept of Pastoral Risk

Hazard was defined by Smith (2004) as "naturally occurring or human-induced process(es) or event(s) with the potential to create loss". Some of the environmental, social and economic processes may not however result into a noticeable loss but instead increases vulnerability and future impacts of subsequent events (Bollig, 2006). The resultant damages caused by hazardous events in these environments are spread among the dependent population. The anthropological approach to environmental risk management focuses on the sources of hazards, the frequency and impact, individual's mental constructs, and strategies to minimize the frequency and impact of these hazards aimed at reducing vulnerability (Bollig, 2006). Studies on risks and disasters in the mid and late twentieth century focused on the frequencies and effects of natural hazards (Smith, 2001). Models were developed to predict the occurrences of disasters and the social response strategies. The approaches used to develop risk management models were in the form of formalistic, ethnographic or interpretative (Bollig, 2006). Studies relying on formalistic approaches argue that risk management is best understood by testing hypothesis on the influence of adverse events on the society and mitigation strategies evaluated by the impact on the outcome. Ethnographic researchers on the other hand derived lessons from community participation and experiences to define risks, hazards and develop mitigation strategies (Ellis and Swift, 1988, Dyson-Hudson and McCabe, 1985, McCabe, 1997). They argue that understanding of risk management for theory building is best understood at the individual and institutional level. Interpretative researchers on the other hand argue that "risk perception is encoded in the social institutions" (Douglas, 1992).

System theory helps to understand the causes and effect of risks. Systems interact to produce a phenomenon which may cause further risk or mitigate the consequences of changes in their initial status (Turner and Pidgeon, 1978). The operation of the organizational system dictates its success or failure in meeting short and long term objectives. Although the frequencies and the impacts of pastoral risk have continued to increase, institutions need to apply the isomorphic learning over the whole pastoral system (Toft and Reynolds, 1994, Turner and Pidgeon, 1978). Despite these frequent disasters, most affected communities never seem to learn and get prepared for future events (Walsh and Healy, 1987). It is under these assumptions of system and isomorphic learning that it is argued that risks can be reduced or completely eliminated (Wilde, 1976). Risk homeostasis applies in pastoral system where the desired socio-economic condition is maintained against internally and externally generated risks. Identified risks are then mitigated by choosing the appropriate strategy ranging from avoidance, transfer, retention and reduction. Risk avoidance strategy involves complete removal of risk causing event(s) while transfer calls for the absorption of the risks by third party. Insurance is one major strategy of transferring risk where premiums are paid to cover uncertainties threatening the existence and the values of assets thereof. Some organizations however retain part or whole of risk exposure and deal with their consequences by financing recovery. Finally, risk reduction is applied by altering the frequency and/or impact of the risky event to minimise losses. Pastoral risks are interpreted by the extent to which future consumption is assured and stream of income is stabilised depending on livestock assets. Livestock provide high returns while at the same time face myriad of risks driving their number up and downwards depending on the conditions of the rangelands as dictated by the climatic conditions. Policy development and implementation is critical to evaluate the level of these assets and the potential risks they face. Studies on pastoral risks have suggested prevention of the downward risk by suggesting safety nets to prevent absolute poverty (Barrett and McPeak, 2006).

Pastoral risks are the uncertainties affecting herders from achieving their main goal of herd accumulation in order to supply the basic needs. Pastoralists in sub-Saharan Africa have identified overgrazing, droughts, human population pressure, expansion of urban settlements and land degradation as major risks facing pastoral economies (Desta and Coppock, 2002b, Angassa and Oba, 2007). These are broadly classified into (1) natural disasters such as droughts, diseases, and floods (2) human population pressures and (3) permanent loss of pastoral rangelands or (4) socio-cultural practices such as theft/raids (Schwartz, 2005). Little et al.(2008) also identified gazettement of pastoral lands into national parks, stagnant livestock prices as compared to the prices of primary products, conflicts and political marginalization as the major pastoral drivers. Historical marginalisation of the arid lands of northern Kenya has tied these communities to the old days practices (Reynolds et al., 2007) even though the change is slowly evolving (Lesorogol, 2009). This has therefore made it hard for the pastoral communities to adapt to the changing environment to reduce their vulnerability. These risks emanate from within or from outside the system and their effects may be isolated or systematically influence the whole sector. Some pastoral risks are temporal and change with time therefore influencing decision making processes depending on the circumstances and the risk preferences among the households (Chantarat et al., 2009b).

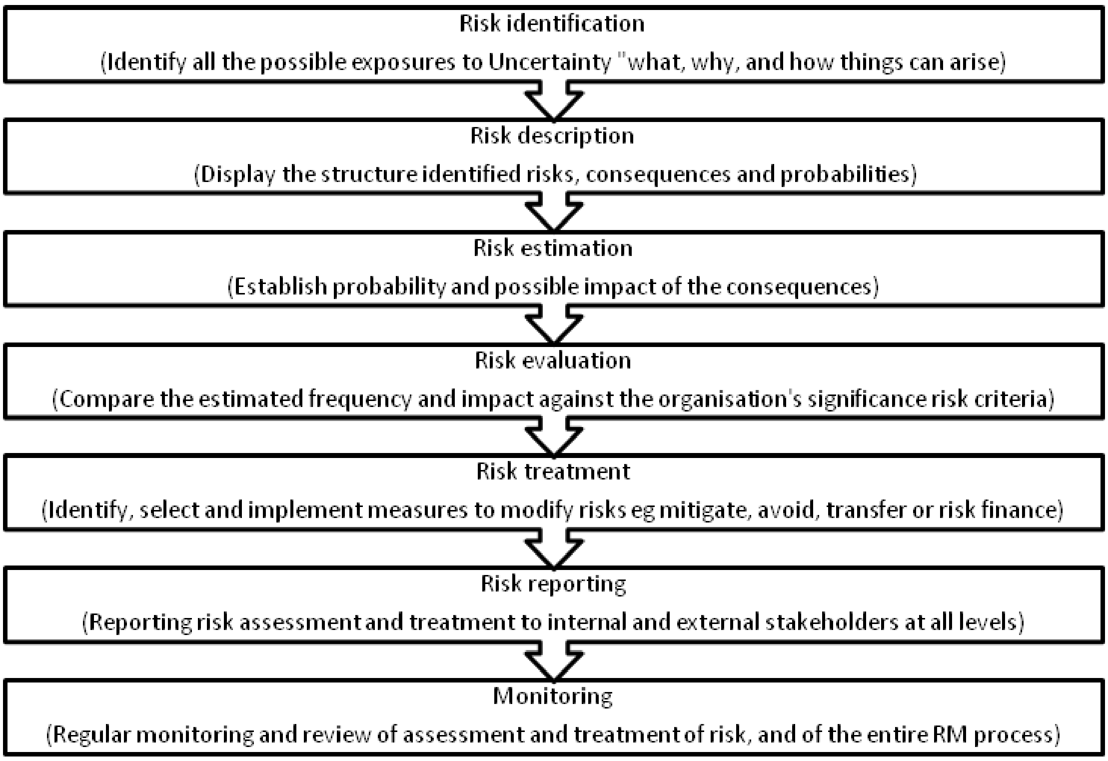
Pastoral risks arise from series of factors which include covariate risks of adverse rainfall and overgrazing causing range degradation (Lybbert et al., 2004a), information asymmetry and market instability (Fafchamps and Gavian, 1996, Barrett and Luseno, 2004). Pastoral rangelands are common to adverse shocks such as drought, floods and diseases causing humanitarian crisis. Majority of households living in these rangelands derive their livelihoods from pastoral practices due to unsuitability of the land for cropping. Livestock assets which provide income source (McPeak, 2004, Lybbert et al., 2004a) are highly affected by climate variability (Coppock et al., 1986, Ellis et al., 1993, Ellis and Swift, 1988). These shocks not only deprive households of their livelihood but also increase their vulnerability to future occurrence. The impacts of these risks are unbearable and little seems to be learnt from the past experiences of similar events locally and regionally as indicated by continuous losses arising from multiple droughts (Oba, 2001).

2.4 Risk Management Framework

Risk management is a continuous process of identifying, assessing and communicating threats, opportunities and other uncertainties (Ward, 1999). Managing risk is dependent on the environment where the organization exists and the perspective of what is being managed. Risk can be viewed in different management perspectives taking into consideration aspects of the corporate, asset, people, project, and system perspectives. The sources of corporate risks are categorised into strategic, economic, legal, organisation management, political, environmental and technical (OGC 2002). The asset perspective focuses on tangible and non-tangible assets employed by the organisations to respond to operation shocks. Asset risk management limits its focus on threats to preserve or sustain its productivity (Ward, 2005). Project specific focus perspective considers major organisational activities as independent projects. Identification and management of the associated uncertainties involves critical evaluation of the project life cycle from inception to completion. On the other hand, system perspective looks at both individual as well as collective effect of component parts making the whole system. Figure 2:2 below summarises the process of risk management and possible criteria for step-wise approach published by Institute of Risk Management (IRM), the Association of Insurance and Risk Managers (AIRMIC) and The Public Risk Management Association (ALARM) in 2002.

Risk identification and assessment is at the heart of risk management processes and the effectiveness of decisions taken largely depends on how these processes are undertaken. Comprehensive risk management involves not only the process but also consideration of the context uncertainty. Several methods have been implemented to determine sound risk management practices. One way is to treat the pastoral system, policy formulation and implementation as a project where the 6 W's (what, when, why, which way, who and wherewithal) are examined for the possibility of uncertainty (Ward and Chapman, 2003). Similarly, the pastoral system variables can also be assessed for risks using the “bow-tie” approach where the uncertainty causes and consequences are controlled (Crerand, 2005). Although this approach was initially used in the engineering field to assess the downside of risk effects, the same is applicable for pastoral uncertainties assessment. The method incorporates both proactive and reactive measures of risk management to assess causal and consequential risks respectively and incorporate management controls.

Figure 2:2: Standard risk management process

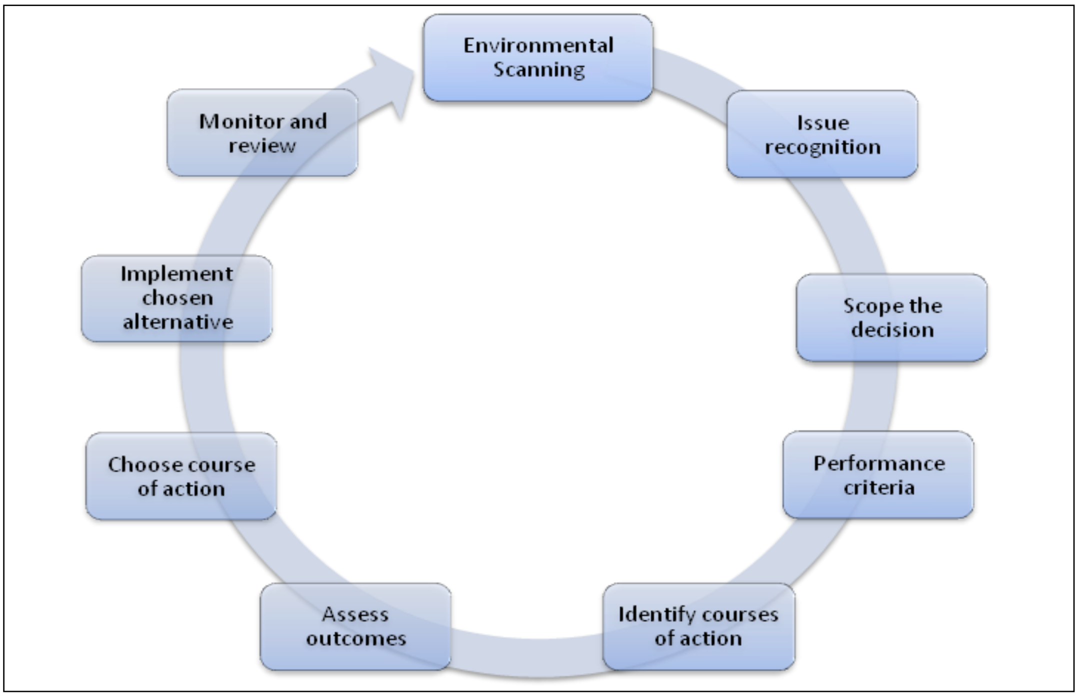


Source: The AIRMIC, ALARM, IRM (2002)

Risk management is fundamental for enhanced quality of organisation decision making processes. The onset of a decision making process, thereby policy formulation is the environmental scanning stage where threats and opportunities are identified. This stage is followed by identifying the scope and measurement criteria for effective monitoring and evaluation. All possible causes of actions are identified and measured against the target criteria for assessment purposes. The choice for the effective strategy is made based on the level of achievement of the desired outcome. The final stage involves monitoring the strategies over time while evaluating the feedback to make appropriate amendments (Chapman and Ward, 2002). Figure 2:3 illustrates the decision making process cycle indicating the similarity in activities with the risk management process framework.

The objective of Risk Management (RM) in pastoral system is crucial in managing the outcome of events (reactive measures) and planning for appropriate measures to manage future uncertainties (proactive measures). Crisis management, business continuity and proactive control are the three major RM objective levels (Ward, 2005). Crisis management deals with response strategy to the outcome of adverse event. Business continuity on the other hand focuses on influencing both the probability and impact of risk on an on-going basis while the highest level RM deals with policy formulation to achieve desired targets. The role of RM in improving short and long term performance is enhanced by appropriate objectives formulation and continuous control of any deviations from the targets. In pastoral system, the objective of a good RM is crucial in evaluating sustainability of livelihood sources and formulating policies to maximise efficient use of available resources.

Figure 2:3: Stages in the decision making process cycle



Source: Adopted from Chapman and Ward (2002)

2.5 Pastoral Risk Management

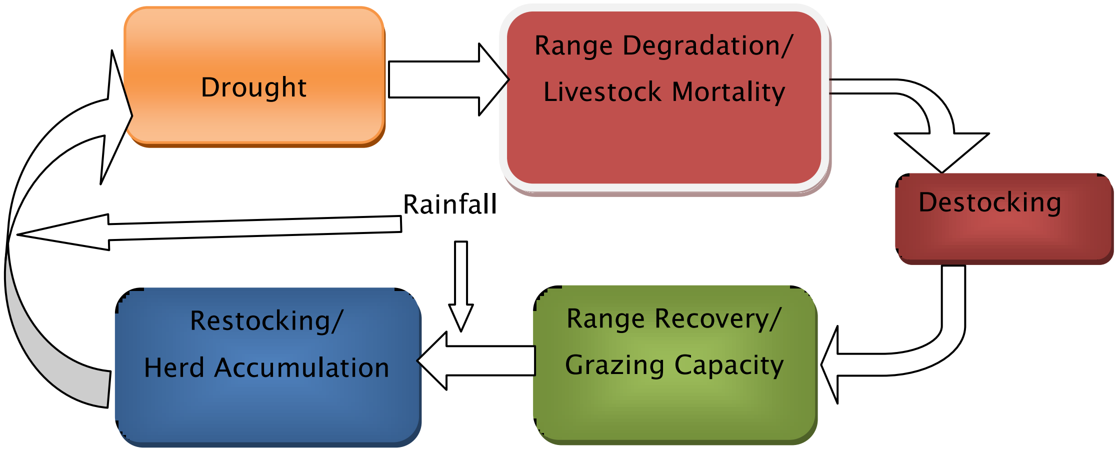
2.5.1 Introduction

The risks involved in pastoral system relates to the uncertainties faced by the factors of production in a pastoral rangeland. It is highly driven by the external and internal factors affecting pastoral system supply chain. The trade-off between pastoral wellbeing and the livestock population is one balancing act that helps policy makers to manage these risks. The existence of complexity is a crucial element of managing pastoral risks (Bollig, 2006). Appropriate pastoral risk management therefore include risk identification, evaluation and assessment, mitigation and control at both individual and aggregate level. Pastoral societies are susceptible to risks and uncertainties facing livestock which occur through, livestock diseases, droughts, conflicts and market variability (Little et al., 2001a). Widely researched area is the drought component found to limit availability of water and pasture and sometimes exacerbate losses arising from disease and predation (Mizutani et al., 2005).

Pastoral perceptions to risk factor differ in space and time. Campbell (1999) in his study on the response strategies towards drought by the Maasai pastoralists noted changes in ranking of problems associated with pastoralism. Drought, animal diseases, food insecurity, livestock mortality and poor health ranked the top 5 problems in 1977 (Campbell, 1999). However, in a similar study in 1996, the same pastoral community had reviewed its perception ranking food insecurity, drought and poor health as the top three while others include lack of pasture, animal diseases, wildlife conflicts and lack of land. There are no formal risk management structures in most pastoral rangelands in Sub-Saharan Africa (Doss et al., 2005, McPeak and Barrett, 2001). However, the recent institutional restructuring and government effort to develop arid areas in Kenya has focused on various strategies aimed at managing risks and vulnerability (ALRMP, 2007). Traditionally, the government has responded to major pastoral crises, mainly droughts, by destocking some of the livestock and restocking during rainy years (figure 2:4)(Aklilu and Wekesa, 2002). The government's effort to destock during drought seasons is motivated by the desire to reduce livestock losses hence rangeland degradation. Severe drought period is usually followed by restocking programs either between the community members (McPeak and Little, 2005) or aided by government or development partners (Lesorogol, 2009) leading to a high accumulation of livestock during periods with favourable fodder resources (Angassa and Oba, 2007). This cycle of herd rebuilding and rangeland recovery continuously exist depending on rainfall variability.

Studies have also identified and documented other forms of pastoral risk management. The common strategies applied by pastoral communities to minimise or cope with pastoral risks include diversification, building food reserves, creating social networks, enhancing mobility, and improve market stability (Colson, 1979, Browman, 1987, Campbell, 1999, Nkedianye et al., 2011). These strategies are directed to deal with the major categories of pastoral risks: environmental, economic and socio-cultural risks. However, some response strategies have far reaching implications across the pastoral system. Livestock off-take program for instance during drought events helps households to dispose weak livestock, gain cash and reduce the risk of children being malnourished (Sellen, 2003).

Figure 2:4: Government responses on droughts in pastoral rangelands.



2.5.2 Environmental Risks

United Nations Environment Program (UNEP) recognised the threat of expanding deserts in Africa following the Nairobi's conference held in 1977. The conference led to the creation of the Integrated Project in Arid Lands (IPAL) to research on practical rangeland policies to combat degradation leading to desertification (Lusigi, 1984). Degradation has been defined in various ways depending on the causes and effects. For the purpose of this study, degradation represents loss of rangeland ability to produce quality pasture (Puigdefábregas, 1998). Although widely agreed that degradation is man-made, other natural phenomenon such as droughts exacerbate its intensity. The reduction of productive rangelands ultimately reduces critical areas traditionally used as drought reserves (Homewood, 2004). Other causes of land loss include overstocking of livestock, deforestation, and human population pressure (Lusigi, 1984). Severe forms of degradation could lead to desertification which makes the rangeland productivity irreversible (Pickup, 1996, Pickup et al., 1998). The studies further argued that there is a strong link between rangeland degradation and pastoralism where pastoral vulnerability is driven by the quality of rangeland. Local communities have however developed measures to mitigate degradation by restricting access to areas used during the drought (Fratkin and Roth, 2005). Studies on management of rangeland degradation have centred on management of stocking rates. Increased frequency of droughts exacerbate livestock mortality suggesting an excessive grazing pressure caused by overstocking (McCabe, 1987). However, there is a long standing debate on the appropriate stocking rates for a sustainable pastoral economy (Campbell et al., 2006, Sandford and Scoones, 2006). They argued that the stocking strategy choice needs to be made based on economic, social and ecological outcomes. These decisions are however driven by the rangeland productivity and utilisation.

Rangeland productivity and utilisation has attracted a number of researchers from the fields of ecology, economics and social sciences. Among the major propositions developed from these studies is the idea of "new rangeland science" (Scoones, 1995, Sandford, 1983, Behnke et al., 1993). This science proposes that pastoral households should adopt an opportunistic strategy during good rainfall years to maximise on the excess forage resource while scale the herd size during low rain seasons. It does in a way provide with plenty of the necessary animal products such as milk and meat while at the same time allows pastoralists to provide security for drought seasons. However, failure to destock the herd at the appropriate time may lead to huge financial losses and could further exacerbate the impact of the drought due to high labour requirement and competition for pasture. Similarly, the supply and demand during and after drought drives prices up and down diminishing the expected benefits from this strategy. The other strategy is the conservative stocking rate where livestock numbers are maintained at some constant level at all time as a precautionary measure to unexpected pasture shortage. Biomass production and preservation requires a more conservative stocking rates to allow forage production and cushion pastoralists from adverse rainfall variability (Sandford and Scoones, 2006).

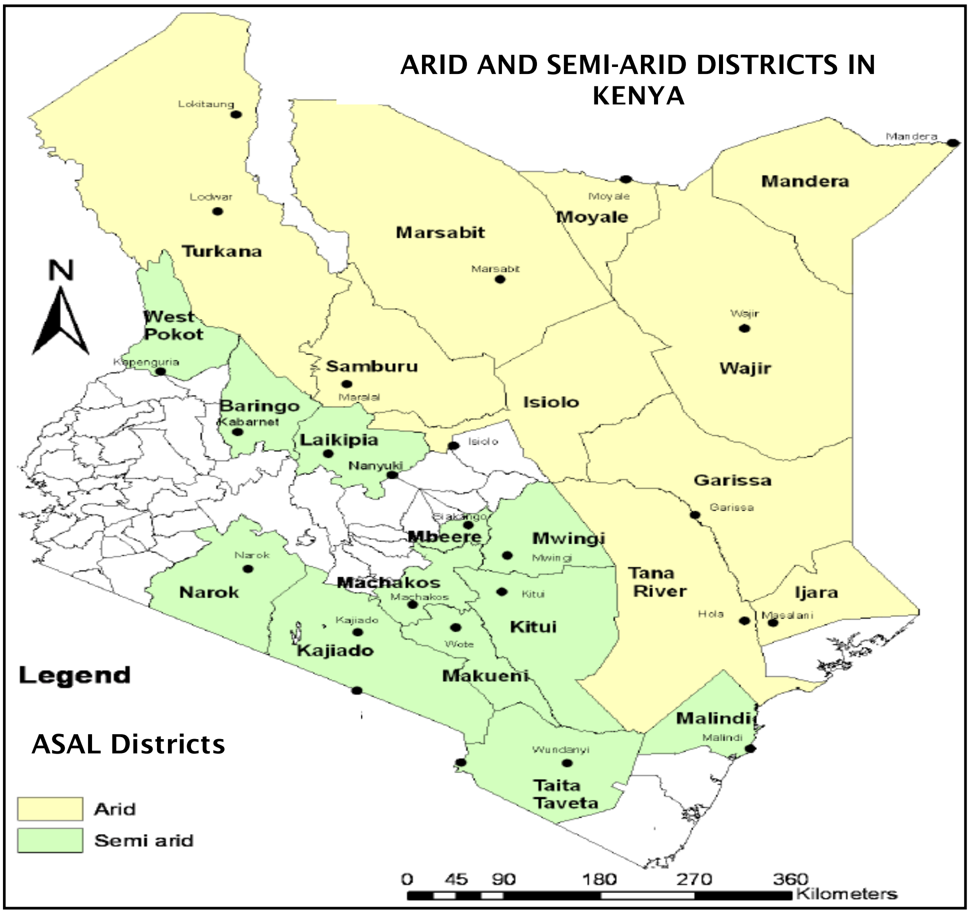
The underlying rangeland theory also plays an important role in making stocking rates choices. The theory of rangeland equilibrium and dis-equilibrium has generated wide range of debate. The proponents of equilibrium theory suggest that livestock dynamics is strongly determined by the pasture resource and livestock density drives mortality rates (Illius and O'Connor, 2000, Cowling, 2000, Campbell et al., 2000a). On the other hand the opponents note independence of livestock mortality, hence dynamics on the rangeland's carrying capacity (Behnke et al., 1993, Scoones and Graham, 1994). The latter group termed their argument "the new" paradigm on rangeland policy development suggesting diversion from the traditional stocking rates and carrying capacity evaluation. Opponents of the stocking rate induced degradation however argue that most pastoralists practice livestock mobility which allows the environment to recover during the good rain years because pastoral system is resilient to degradation (Ellis and Swift, 1988, Sullivan and Rohde, 2002). They argue that abiotic factor such as rainfall determines the rangelands productivity and carrying capacity causing degradation is never reached in semi-arid rangelands where droughts regulate livestock population.

Land degradation is non-linear and gradual although a threshold exist where the environment is able to support the livestock but only to the level determined by the environmental dynamics (Westoby et al., 1989, Friedel, 1991). The stocking strategies should therefore consider both threshold and the continuous changes in the environment. The safety net for land carrying capacity is maintained by observing the actual stocking rates (A) against the maximum land carrying capacity (S) and $A/S \leq 1$ otherwise the rangeland is at risk of depletion. These studies on rangeland productivity and livestock dynamics utilised system dynamics model to examine appropriate strategies. Sandford and Scoones (2006) for instance used 50% and 12.5% calving and annual growth rate respectively for the conservative strategy and 45% calving for opportunistic strategy. Variability in rangeland quality is a major influence on livestock dynamics in a density dependent rangeland (Baars et al., 1997, Snelder and Bryan, 1995, Abule et al., 2007). Sufficient rainfall provides appropriate replenishment of pasture consumed or otherwise destroyed by long duration of insufficient rainfall. To monitor rangeland response to rainfall and assess land cover changes, researchers have utilised Normalised Differenced Vegetation Index (NDVI). They have been particularly and reliably used to monitor rangeland conditions, desertification and changes in land use systems (Wittemyer et al., 2007, Tucker et al., 2005). Rangeland condition respond towards temporal rainfall variability suggesting that NDVI and forage condition are important factors in forecasting droughts hence livestock mortality.

Pastoral economy is driven by two major variables comprising of the primary (forage) and secondary (livestock) production (Bekure and de Leeuw, 1991). In most of the northern part of Kenya, Samburu lowlands included, the system is classified as livestock only, rangeland based, arid/semi-arid according to Sere et al. (1995). Pastoral policy development therefore needs to focus on the threats to the sustainability of the rangeland. Figure 2:5 shows the climatic zones in Kenya. The map classifies Samburu among other 28 districts as a wholly arid land implying that the rangeland is suitable only for pastoral farming (Oyugi, 2008, ALRMP, 2007). These pastoral areas are prone to climatic variation which significantly influences the vulnerability of the livestock dependent population (Ellis and Swift, 1988, Galvin et al., 2001, Desta and Coppock, 2002b). A cycle of both good and bad rainfall years each exists creating a pattern of “boom and crush” among the pastoral systems in East Africa (Angassa and Oba, 2007). Rainfall shortage causing droughts regulates livestock dynamics in arid rangelands (Homewood and Lewis, 1987, Oba, 2001). Studies have indicated that a 25% decline in the normal precipitation causes savannah drought; such a decline reduced grass productivity by about 90% in the Sahel region in Sub-Saharan Africa (Ridder and Breman, 1993).

Average rainfall is evaluated from the past period performance and the years in which the amount exceeds the average are regarded as good rainfall years (Desta and Coppock, 2002b). The economic assets, mainly comprised of livestock are favourably multiplied during this above average rainfall (McCabe, 1987) due to improved fertility, calving and reduced mortality rates. The annual calving rates during good rainfall years was between 52-55% in Southern Ethiopia (Angassa and Oba, 2007) 56-61% among the Maasai of Kenya (De Leeuw et al., 1991). This increased herd size during period of sufficient forage resource generated periodically enhances livestock body conditions. As a result, healthy and well fed lactating herds produce more milk for the household consumption and generate income from sale of the excess in the market (McPeak, 2004).

Figure 2:5: Climatic zones in Kenya



Sufficient rainfall which allows sustained forage supply positively influence livestock pricing, *ceteris paribus*. Livestock prices during these ‘good’ rainfall years are usually high (Kere et al., 2008, ALRMP, 2007). This is partly explained by the equilibrium theory of supply and demand. Sufficient supply of dietary requirements during this period reduces the need to supplement with grains from the markets lowering supply of sales (Barrett et al., 2003). Similarly, there is high demand by many households to maximise on this period by accumulating herds (McPeak, 2004). They do so by buying heifers to increase accumulation rates driving up their prices as well as increasing livestock populations due to marginal increase in natural stocking over mortalities (Angassa and Oba, 2007). Food prices on the other hand are inversely related to the level of rainfall depending on whether the shortage is local, regional or global (ALRMP, 2007, Kere et al., 2008). The low demand for grains during high milk and meat production season at the same time increased supply due to flourishing agricultural production in the region drives down the food prices to the suppliers' operating efficiency levels[1]. Similarly, milk prices during this period drop and sometimes free supply of these products are made depending on the level of relationship developed between businessmen and herders (Abule et al., 2005).

Rangelands' fodder quantity increases linearly with the average rainfall (Deshmukh, 2008). The uncertainty of rainfall directly affect fodder resource and by extension the quality of pastoral economy (Dahl and Hjort, 1976). Rangeland recovery occurs during period of above average rainfall (Desta and Coppock, 2002b). NDVI is a widely used indicator for vegetation condition and famine forecasting (Tucker et al., 2005). The Z-values of the NDVI are computed against the long term average and the negative values ($Z< 0$) are used as indicators of diminishing vegetation cover caused by lack of precipitation or overstocking depicting a 'bad rainfall year'(Chantarat et al., 2009b). The quantity of forage declines during drought seasons, especially where the population of herbivores exceeds the capacity and the level of precipitation to replenish, does not match out-take (Deshmukh, 1986).

Rainfall shortage is found to have a close association with livestock mortalities (Desta and Coppock, 2002b) and prolonged dry period further intensifies mortalities (Angassa and Oba, 2007). Livestock dynamics is therefore highly regulated by the drought related mortalities as opposed to household sales (Cossins and Upton, 1988, Angassa and Oba, 2007). Although droughts related mortalities vary between locations and regions, it is still generally agreed that severe droughts causes huge livestock losses. Chantarat et al. (2009b) noted that there is a 33% probability of severe drought occurrence causing livestock mortalities exceeding 10%. Failure in both short and long rains in the Eastern Africa region are the major indicators of impending droughts causing livestock losses (Desta and Coppock, 2002b). The mortality rate is higher when the stocking rates exceed the ability of the rangeland to sustain suggesting high competition for fodder resource (Rutten, 1992). Reduced livestock population not only

[1] Suppliers' objectives may differ as some would sell at the prices below their costs to remain in business, others would set their minimum price at the Break Even Point (BEP).

reduce the capital worth but also the income stream of their products such as milk and meat which forms the main livelihood income source (Dahl and Hjort, 1976).

Livestock prices during drought season are low and tend to discourage herders from disposing off their livestock. The overburdened supply to the market during later stages of drought largely drive prices downwards (Bekure and de Leeuw, 1991). This is followed by high post-drought prices arising from increased demand to accumulate stock for good rainfall years as compared with low supply to the market (Lesorogol, 2008a, p. 156). Livestock prices sometimes drop by more than half the pre-drought prices (Swift et al., 2002). The resulting effect of this holding back by the herders is more labour requirement raising students drop-outs while at the same time intensifying competition for an already minimum resources rangeland (ALRMP, 2007). The prices further deepen due to deterioration of the livestock body conditions causing herders to sell livestock at very low prices to avoid total losses (Barrett and Luseno, 2004). Price variability caused by the high supply and low demand of livestock during drought years as well as the poor body conditions of the animals make the return from pastoralism relatively low (Barrett et al., 2003). Market shocks invariably affect the stability of livestock prices because the local pastoral economy is not linked to the country's macro economy making it vulnerable to such shocks (Barrett and Luseno, 2004). Drought therefore remains a major driving force on pastoral economy and it regulates the wealth levels for most pastoral households. Pastoral system is self-regulating but highly dependent on rainfall and other climatic conditions. The climatic conditions not only affect the primary production but also influence on the strategies adopted by the farmers in the system.

2.5.3 Economic Risks

Studies on livestock herd dynamics have centred their focus on effects of rainfall conditions on livestock mortality and recovery rates (McCabe, 1987, Swift et al., 2002). Droughts have been noted as the main factor regulating livestock population in ASAL of Northern Kenya and by extension the driving force for poverty in the area (Lesorogol, 2009, Fratkin and Roth, 1990). Existence or lack of livestock asset plays an important role in determining whether the household is facing chronic or structural poverty (Ellis and Mdoe, 2003, Mburu and Kiriti-Nganga, 2007). To establish poverty levels among these livestock dependent population, livestock birth and mortality rates are considered. The birth rate provides a measure for assessing the herd rebuilding process to replace the ones that are either sold or dying from various causes. Similarly, livestock births also provide households milk for consumption and nutritional requirements (Mude et al., 2009a). Mortality on the other hand deprives household with not only the capital asset but also eliminates the source of income and food stream. Mortality of lactating cows for instance disrupts milk supply and potential for future production due to lack of breeding stock.

Droughts account for the highest livestock mortalities among the pastoral communities, some of which cause pastoralists to exit from pastoral system (McPeak and Little, 2005). The 2000/2001 drought for instance caused vulnerability among the pastoral communities in the northern Kenya raising stockless households from 7% to 12% (McPeak and Little, 2005). Severe droughts such as the one for 1984 resulted to over 95% livestock mortalities in Sudan (Hjort and Dahl, 1991). The associated economic loss is evident; for instance, between 1980 and 1997, the Borana community of southern Ethiopia lost about $300 million of livestock worth arising from the major droughts of 1984 and 1991/2 (Coppock, 1994, Desta and Coppock, 2002b). In northern Kenya alone, the financial loss resulting from livestock mortality caused by the drought in the years 1999/2001 was valued at US$ 77.3 million (Swift et al., 2002).

In pastoral economy, livestock represents both stock in trade as well as liquid savings for the pastoral farmers (Campbell et al., 2006). Livestock products are valued by the stream of income or dietary provision. In accounting terms, it is capital employed to produce stream of income in terms of livestock produce. Households derive their nutritional requirements from livestock products or trade them to supplements with cereals (Homewood and Lewis, 1987). However, livestock capital produces subsequent replenishment through reproduction and exchanges. Pastoral systems in good rainfall years yield more to the herders and their return on investment is always high during favourable conditions. The major livestock products are meat, milk and milk products although most famine crisis forces people to depend on other products such as blood and sale of livestock's hides and skins (Dahl and Hjort, 1976). Livestock markets convert livestock assets into non-livestock food items to satisfy other necessities such as clothing and medical services (King et al., 1984).

Herd dynamics provide an important insight as to the stability or susceptibility of pastoral households and their vulnerability. Continued decline in pastoral herd size observed and reported in pastoral studies (Little et al., 2001b, Fratkin et al., 1999) is noted as the main cause of sedentarization among the pastoralists. In good years for example, pastoralists deprived off their livestock by droughts settle around trading centres and practice subsistence agriculture in areas with some reliable rainfall (McPeak and Little, 2005). High livestock population per household ensures a constant supply of the economic value to its members (Fratkin and Roth, 1990). They argued that a pure pastoral household requires between 4.5 and 6 Tropical Livestock Unit (TLU) per capita to provide with the necessary nutritional and other welfare requirements. A TLU is computed as equal to one cattle, 0.7 camels or 0.1 small stocks (sheep and goats). Stocking rates above the optimal level only suggests the desired individual wealth upon which the social insurance is based (Lybbert et al., 2004a). This desired high stocking rates is however checked by the labour force and the land capacity which exacerbate the effects of droughts. Where the population grows faster than the pastoral production, the optimal per capita is reduced to a mere ‘Malthusian subsistence’ level, especially with the influence of climate and conflicts (Nordås and Gleditsch, 2007).

Livestock play an important financial role in pastoral system both in short and long term (Grandin et al., 1991). Livestock assets account for more than two-third of their average income (Fratkin and Roth, 1990, Desta and Coppock, 2002a). Uncertainty to these assets greatly influence the vulnerability of the pastoral community driving them into a poverty trap (Chantarat et al., 2009b). Livestock provides the basis for both material and social wellbeing (Bekure, 1991). The emergence of the market economy has also significantly influenced the financial role played by the livestock through sales to acquire primary inputs and purchase of goods and services (Grandin, 1988, Dyson Hudson, 1991). Primarily, livestock are kept as a source of food (milk, blood and meat), capital reserves, sign of prestige and status and provide services such as transport and ploughing (Lybbert et al., 2004a, Holtzman, 2007). Milk, for instance provides between 62% and 66% of dietary requirement to the pastoral households in Kenya while meat account for 10% (Sellen, 1996, Galvin, 1992). To maximise on milk production, households accumulate their herd size (Fratkin and Roth, 1990).

In the long term, livestock are accumulated to cushion pastoralists from covariate shocks thereby acting as a form of social insurance by spreading production risks (Lybbert et al., 2004a). Livestock accumulation implies wealth accumulation which is used as a major investment. Any threat to the livestock directly affects pastoral household wellbeing by influencing both income and investment capital. However, financial return from livestock is highly variable depending on the primary productivity of the rangelands and other factors such as insecurity, market structure and diseases (Osterloh et al., 2003, McPeak, 2003, Barrett et al., 2003). McPeak (2005) for instance arrived at rate of growth in investment ranging between 6-15% for the pastoral communities in northern Kenya for the period 1990-1997 with 12-28% of households registering negative returns. Despite rangeland variability, livestock still play an important role is providing net income to the households and was estimated annually at between $ 141-155 for households in Laikipia and Amboseli regions in Kenya (Mizutani et al., 2005). Net annual income per TLU was estimated at $ 21 in Amboseli area with a range of between $-8-$61 in the same study.

Tourism is another major source of income to the pastoral communities and to the local governments (NRT, 2010). Wildlife game reserves and the rich traditional culture coupled with the natural sceneries are the attraction for the tourists. The major attraction however is the presence of the 'big five' wildlife species within the pastoral rangelands (De Leeuw et al., 2001). The local community directly or indirectly benefit from tourism. Firstly, they directly conduct business with the game park hotels by selling livestock products and employment for both skilled and unskilled labour (NRT, 2009). Secondly, the fees charged for the entry and safaris (game drives) are utilised for current and development budgets by the local council. Some conservation institutions in the area offer educational bursaries for bright students from poor families and improvement of schools within the district. The game rangers also boost security within the district borders to prevent intrusion of livestock raiders thereby reducing the risk of banditry related livestock losses (NRT, 2009). However, both human and wildlife conservation activities are creating conflicting interests. Expansion of human populations and changing livelihoods is threatening the future of pastoralism and wildlife alike (Lamprey and Reid, 2004). The future of tourism related income is therefore largely dependent on the level of security, presence of wildlife and other attraction activities.

Livelihood sources in most pastoral areas are classified into three broad categories; all influenced by market conditions. Table 2:1 shows the main components of pastoral livelihood and their respective contribution. The main livelihood source, especially in the dry lowlands of Samburu district is pastoral activities which entirely rely on livestock productivity (Wambua et al., 2009). The other sources of livelihood, which comprise a little but stable component of income, include trade, tourism, formal and informal employment. Pkalya et al. (2003) also noted that animal husbandry accounts for over 90% of the economic activities in the pastoral areas of Samburu.

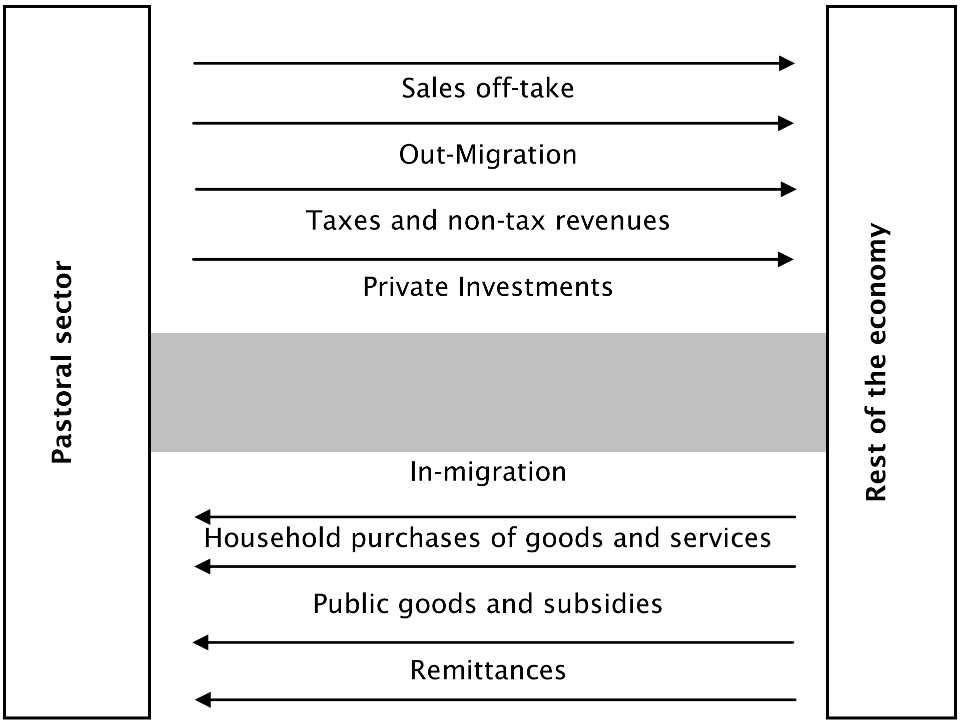
Table 2:1: Samburu District livelihood sources

Economic activities	***Population supported***	***Percentage***
Pastoral Sources	97,996	57%
Agro-pastoral (Subsistence farming)	64,109	37%
Trade/Wages/Other	11,194	6%
Total	***173,299***	***100%***

Source: Regional assessment team (Wambua et al., 2009).

Droughts affect GDP as well as causing inflation. The drought which affected Australia in the period 1982/3 brought to knees the economy which led to change of governments (Coenraads, 2006 p. 378). Some countries faced with regular droughts have developed appropriate policies to respond to the adverse economic effects. India for instance which is affected by regular droughts have developed response mechanism such as maintaining food reserves, planting of drought resistant crops, and fiscal policies in addition to devoting research into prediction of harsh climatic years. The drought of 2002, despite being widespread across the country, had little effect on GDP and inflation as compared to the 1930's to 1960's due to planning made for impending future droughts (Coenraads, 2006 p. 372). Pastoral economy exists within the broader economy and it contributes towards the provision of the common good of the national government (Konczacki, 1978). Agriculture plays an important role in the Kenyan national economy accounting for over 21% of the GDP with livestock sector contributing half of it (Aklilu and Catley, 2010, DFID, 1999). Aklilu and Catley (2010) noted that majority of livestock distribution is located in arid and semi-arid areas exposing risks to both the community and the national economy. The interaction between local pastoral economies to the rest of the national economy is important especially in an agricultural based economy such is Kenya. Pastoral sector is therefore an important sector not only to the GDP of the country but also helps to reduce poverty in the poor rural households.

Figure 2:6: Relationship between pastoral and the national economy



Source: Adopted from Konczacki (1978).

The flow of goods and services between pastoral sector and the rest of the economy implies that changes in one sector affects the other. The framework shown by figure

2:6 indicates that pastoral economy is an open system allowing transfer of resources in and out of the sector. Migration in the model reflects movement in and out of the system by human, livestock and wildlife caused by resource imbalance as well as resulting from changes in the ecosystem. The inflow and outflow of these populations depends on the cause for the migration and most of the time, they end up counter balancing leaving the system unaffected (ALRMP, 2007, Konczacki, 1978). The purchasing power comes from sales of livestock and their products. The spending to acquire other food supplements comes along with boosting government taxes in the forms of Value Added Taxes (VAT) as well as other forms of sales tax (cess) paid to the local governments for the sale of livestock. The common goods provided by the governments to the pastoralists include transport and communication infrastructure, water points, veterinary services and other general public goods (Konczacki, 1978).

Herders' reaction towards harsh droughts has been to sell livestock even though the existing market offers minimal prices (Osterloh et al., 2003). During regional droughts, there are usually less buyers in the market other than those buying to slaughter in both local and regional market (Fratkin et al., 1999). Further, the associated low production of milk by the livestock faced by shortage of pasture forces people to supplement dietary from cereal bought in the market. Literature on livestock supply and demand have not produced a direct relationship between the quantity of livestock sold and the prevailing livestock prices (McPeak, 2005, Osterloh et al., 2003). However, pastoral households sell their livestock assets during the time of stress such as famine. During drought seasons, milk production is reduced and households generate cash to buy cereals from the sale of livestock (Little, 1992). Similarly, movement of livestock away from household settlements to satellite camps far from the market centres result into reduced livestock prices (Barrett et al., 2003). Livestock trek for long distances to the nearest market and pastoralists are often faced with the risk of not selling them and would be willing to sell them at the best available price (Barrett and Luseno, 2004). During drought years, costs associated with transportation of livestock to better markets are high and sometimes account to about 60% of the selling price (Osterloh et al., 2003). Livestock price movement depends on both the supply and demand but takes into consideration other intervening factors such as droughts, diseases and access to markets (Barrett et al., 2003). In the year 2009, the general livestock trend steadily reduced from the source (pastoral) areas raising both local and national prices (Burra et al., 2009). Khan et al. (1992) noted a high correlation between rangeland productivity, market items and livestock prices and pastoral wellbeing.

Livestock prices respond positively towards availability of sufficient rainfall while food prices drop. Inversely, livestock prices significantly drop as a response towards existence of droughts while food prices rise. Households derive income and food from livestock and livestock products. Good rainfall years are associated with sufficient livestock production, with milk being the main product is produced in large quantities (Fratkin and Roth, 1990). Households supplement consumption of milk with minimal purchase of market dry cereals reducing their demand from the local market (Smith, 2005). Similarly, good rainfall years are associated with large scale food production in highlands thereby distributing the benefits in the whole country (Stewart and Hash, 1982). Variability of livestock and food prices exposes pastoral households into financial risk. The inverse trend in these set of prices creates consumption deficit where the existing assets are unable to secure sufficient household requirements. In some cases, increase in the global food prices especially agricultural products has been associated with the increased demand for bio fuels and the rise in oil prices and improved economic development populous nations such as India and China (FAO, 2009).

Studies have indicated that low livestock prices are caused by the poor livestock body conditions arising from starvation (James and Carles, 1996). During drought seasons, there is limited pasture for livestock causing them to lose body fats and eventually fetch low prices in the market. Osterloh et al. (2003) noted that pastoral households hold their herds even during harsh climatic periods instead of offloading them in the market. Continued accumulation eventually cause higher competition for pasture resources. Studies however indicate that volatility of the terminal market prices caused by supply and demand forces have very little impact on the producers' price variability (Barrett and Luseno, 2004). Terminal market prices are affected by the prices of the adjacent markets regardless of the stability in the terminal markets (Fafchamps and Gavian, 1996). Other factors contributing to price variability are (i) animal characteristics (ii) seasonal events affecting supply and demand especially rainfall and diseases quarantine (iii) distance to the market (Barrett et al., 2003).

Livestock asset, hence economic value of pastoral communities, is affected by diseases outbreak. In the early years of the twentieth century, pastoral rangelands in East Africa were infested by tsetse-flies causing trypanosomiasis disease among livestock (Lamprey and Reid, 2004). Successive governments have however played a big role to minimise livestock losses by implementing disease control programs. In Samburu district, the government has continuously organised seasonal vaccination and deworming programs aimed at reducing livestock's susceptibility to common diseases (GoK, 2010a). This exercise has improved the health conditions in many pastoral areas boosting household wellbeing in many ways. Economically, healthy livestock not only fetch high market prices when sold but they also help reduce instances of quarantines which affect livestock markets (Barrett et al., 2003). It also reduces the economic losses arising from livestock mortalities which affect herd structure and size thereby affecting their productivity (Bebe et al., 2003). The outbreak of Rift valley Fever (RVF) in 2007/2008 caused pastoralists huge financial losses which arose from treatment expenses and actual loss of livestock affected by the disease (Munyua et al., 2010). They noted that many people in Kenya were affected and by extension, livestock prices dropped in hot-spot areas. In some cases, control of livestock diseases helps reduce its transmission to other wildlife, attracting even wildlife experts in livestock disease control (Mizutani et al., 2005). Diseases such as Anthrax were found by Muoria et al. (2007) to affect wildlife especially Gravy's zebra, which are considered endangered species and are at risk of extinction. Healthy livestock are therefore vital for socio-economic and conservation purposes.

2.5.4 Socio-Cultural Risks

Sustainable development in pastoral areas has been threatened by the high level of insecurity, political and geographical marginalisation (Haro et al., 2005). They found that interethnic conflicts in the northern Kenya cause both human and livestock losses. These conflicts have been contributed by the diminishing levels of resources caused by competition and its management. The scenario is further complicated by the droughts which reduces pasture and water resources and confine pastoral communities and wildlife in limited areas (NRT, 2010). Pastoral communities migrating from areas deficient of livestock resources have in some instances aggravated conflicts. The fragile arid rangeland is systematically affected by droughts forcing communities to coalesce around small patches of grazing lands where pasture and water is available. Local and regional droughts force people out of their settlements in search of pastures and water resources. Livestock movements have also caused seasonal tension between crop farmers and livestock herders despite their complimentary nature to each other (Van den Brink et al., 1995). During periods of severe droughts, pastoral communities shift their livestock from arid areas to the highlands where crop farmers are dominant. Despite the parties benefiting from each other, the destructive nature of livestock on crops raises conflicts.

The relationship between conflicts and droughts arises from scarce resource competition and the debate on climate change has also introduced the potential effects on conflicts (Nordås and Gleditsch, 2007). Rainfall determines the availability and distribution of water and pasture and absence of these causes pasture degradation, ethnic conflicts and human-wildlife conflicts. Productive rangelands become inaccessible where insecurity is high causing competition in areas with relative safety (ILRI, 2010, Haro et al., 2005). The indirect effect of droughts to conflicts is mainly brought about by the migration behaviour of pastoral communities to look for pasture in other regions and competing for water points (GoK, 2010a). Cattle rustling is a major factor causing displacement and destabilises livelihoods for about 17% of the

Samburu district population (Pkalya et al., 2003). Conflicts also disrupt education in the area as parents discontinue their school-going children from school as they move to safer areas and in other cases teachers withdrawing teaching services. To a greater extent, these conflicts have caused loss of human life, schools closure, loss of livestock and generally increasing poverty by slowing development in the region (Haro et al., 2005). The government has responded to the recurring pastoral insecurity by publishing a draft on National Policy on Peace building and Conflict Management (NPPCM) to address the issue of resource management and conflict (GoK, 2009). The policy is aimed at understanding causes of these conflicts and proposes measures to mitigate them by establishing institutional framework.

Pastoral system is rangeland size and productivity dependent. Its success in the past has been linked to the availability of expansive tracks of land (Lamprey and Reid, 2004) and climate condition which does not favour other forms of agriculture (Bollig, 2006). These twin factors have since changed throwing doubts the initiatives for rural development and poverty reduction. Despite the slow pace of economic growth in most African nations, human population has continuously expanded (Konczacki, 1978). The rapid human population increase is not matched with the level of production as their main livestock resource is recording a drastic decline over time (Abule et al., 2005). It has resulted to lower per capita livestock among the pastoral communities raising fears of an impending poverty trap (Spencer, 1973, McCabe, 1997). In some pastoral areas in East Africa, per capita livestock ownership has seen a decrease of the ratio from 1:17 (person/TLU) in the 1950s to 1:1.9 in the late 1990s (Bollig, 2006) implying a harsh economic future for the households which depend on these highly variable environments. The levels of current livestock ownership by pastoralists are argued to be insufficient to support a purely pastoral system in many arid areas in East Africa (Thornton et al., 2006). There is therefore need for more diversified and sustainable income sources to support the growing population and diminishing rangeland productivity.

Expanding pastoral population is similarly contributing to pastoral risks by destabilising rangeland ecosystem and land use systems (Garedew et al., 2009). They argued that as population increases, the need for more space to generate livelihood increases. Further, the increase in human population is associated with rangeland degradation (Desta and Coppock, 2002b) arising mainly from some livelihood sources adopted such as charcoal production and logging (McPeak, 2003). Uncontrolled human activities may exacerbate the vulnerability of the rangeland ultimately affecting pastoral wellbeing. Most important in management of arid areas is the land tenure systems and its utilisation. Although Lesorogol (2008b) found no significant difference in wealth between private and communal land owners in Samburu, the expected increase in droughts (IPCC, 2007) will have negative impacts, especially to those private land owners practising crop farming. This form of agro-pastoralism is also only practiced in areas of sufficient rainfall. Arid lands sub-division aggravates degradation and ultimately affects wealth status of the pastoral community.

The expansion of human population also affects wildlife distribution (De Leeuw et al., 2001). There is increased population densities in rangelands shared between human settlement and forage production for domestic and wild herbivores (Grandin, 1988). However, the relationship between human and wildlife deteriorating by day as the resource base declines and competition intensifies. Human-wildlife conflict therefore creates another level of pastoral risk by threatening the existence of some of the tourist attraction and endangering the world's protected species commonly found in the area (NRT, 2010). Some studies carried out to assess appropriate models for wildlife conservation and pastoralism have indicated the adverse effects of human population growth on conservation and suggested institutional management of the rangeland (Boone et al., 2006). Measures to control access and utilisation of pastoral rangelands are therefore necessary to continuously support pastoral livelihoods and ensure co-existence with wildlife by ensuring a stable ecosystem.

There is an observed low enrolment and retention rates among many schools in pastoral communities in Kenya (Roth, 1991). Cultural practices, nomadic lifestyle and geographical marginalisation are some of the impediments accounting for the low rates of enrolment and high dropout rates. However, the Kenyan government's policies have in the past influenced the enrolment and dropout rates through some policy changes (Somerset, 2007). The recent policy measures include free and compulsory basic education, reduction in tuition fees paid by secondary-going students and school feeding programs. In line with the government's objectives, Somerset (2007) noted positive impact associated with free primary education and reduction of tuition fees for secondary school-going students.

Pastoral system is a labour intensive form of livelihood and it ties up some human capital in form of herders to look for pasture and water resource (Wilson, 2007). This argument was supported by a study by (Lesorogol, 2008b) which found an average of 50% enrolment rate for the pastoral Samburu people as compared to the national rate estimated at 74% (United Nations Children's Fund, 2010). This is an indication that pastoral areas are far behind the national averages when it comes to enrolment in schools. The need for appropriate care and supply of the required resources such as water and forage is constant (Roth et al., 2005). This need even increases whenever there is drought as livestock are moved to far distances in search of these resources (Nkedianye et al., 2011). Worse off is that school dropouts are experienced during drought seasons and some pupils outgrow their schooling age as they spend time looking after livestock (Roth, 1991). The long run effects of the reduced enrolments are tremendous and the region remains underdeveloped due to minimum human capital. Further, the future generations are tied to single source of livelihood with little to diversify on and minimal chances of stable formal employment not directly dependent on livestock (Adano and Witsenburg, 2005).

Increased occurrences of droughts, expansion of human population and shrinking rangelands have been considered as the main factors contributing towards food insecurity among many farmers, especially herders in northern Kenya (Khan et al., 1992). For instance the drought which occurred in Kenya during the years 1971 to 1973 and 1982 to 1984 impoverished many pastoral communities greatly damaging their food security (Fratkin and Roth, 1990). To mitigate the effects of reduced food security from declining herd sizes, pastoralists through the efforts of donors are resorting to supplementing small scale irrigated foodstuffs (Smith, 2005). Other benefits of irrigation include sedentarization which allows children to attend schools uninterrupted, creation of jobs as well as improved healthcare (Fratkin and Roth, 1990). Households exiting from the mainstream pastoral system are however finding themselves in a complex situation where climate is not favourable for crop farming. In this case, all those deprived of their livestock try other unsustainable livelihood sources such as borrowing from friends and families, government relief supply and miscellaneous trading (Little, 1992). The end result for shortfall in dietary supply is shown by unhealthy society measured in various ways. The main method of assessing the level of food security in arid areas is body wasting among children less than 5 years of age. This method has been used to indicate the level of malnutrition suggesting the society-wide level of food security and a proxy for forecasting impending famine (Khan et al., 1992, Mude et al., 2009a). Studies looking at the effects of food insecurity often use biometric measures to assess the extent of malnutrition in a certain region against a reference group (Sellen, 2000, Roth et al., 2005). The deviation below the mean for the reference group, measured by negative z-scores, indicates that the study group's malnutrition level is higher than the reference group.

Malnutrition caused by food insecurity in Kenya has since remained high with an average of a third of the population recording undernourished for the past two decades (FAO, 2009). The cause of this has been tied to low food productivity as compared to the nutritional requirements. In Kenya for instance, the average annual increase in dietary requirement for the period 1992-2006 was recorded at 20% as compared to 30% average increase in the average annual increase in dietary consumption in the same period (FAO, 2009). The shortfall in food productivity as compared to the needs affects food prices. The major evidence of food production shortfall as compared to the demand has been explained as a driving force of global food prices. Some studies have argued that pastoral households respond towards food shortages by cutting down on their daily consumptions (Sellen, 2003, Holtzman, 2001, Smith, 2005, Fratkin et al., 1999). Table 2:2 summarises the extent of population affected by the droughts of the past three decades in Kenya. The table shows that droughts frequency and the intensity of effects are increasing. Severe droughts, causing food insecurities are increasingly becoming frequent. The population affected is also increasing. This rise can be explained by two reasons; one, there is a general population increase in the country. Two, the frequent droughts are thinning-out the resource base used to mitigate the effects of the droughts. However, many of those affected populations are pastoral communities dependent mainly on livestock and livestock products (Campbell, 1999, Galvin et al., 2004).

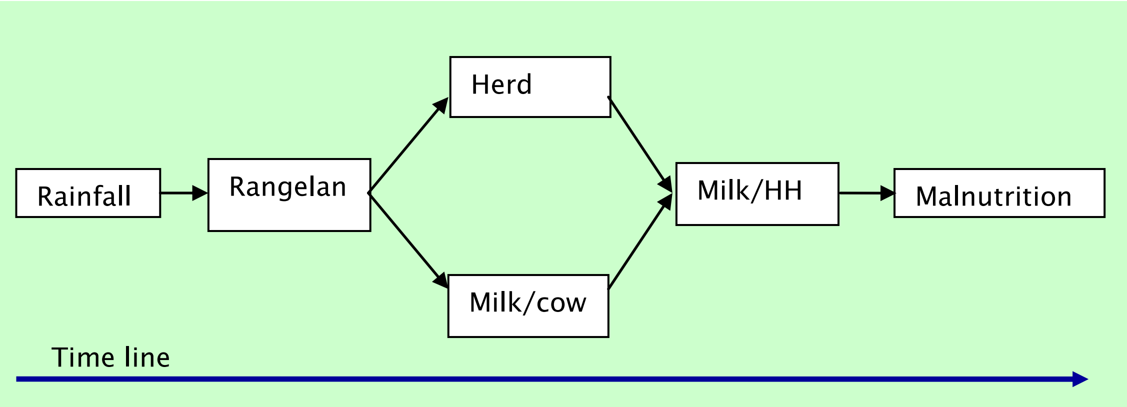
Table 2:2: Human population affected by droughts in Kenya, 1975-2006

Year	*Event*	*Declaration*	*Population affected*
1975	Severe drought	Food shortage	16,000 people
1977	Severe drought	Food shortage	20,000 people
1980	Severe drought	Food shortage	40,000 people
1984	Severe drought	Food shortage	200,000 people
1992	Severe drought	Food shortage	1.5 million people
1995-6	Severe drought	Food shortage	1.4 people
Jan-97	Severe drought	National disaster	2 million people
Dec-98	El-Niño rains	Floods	""
Dec-00	Worst in 37 years	Severe food shortage	4 million people
Jun-04	Severe drought	Severe food shortage	2.3 million people
Dec-05	Severe drought	National catastrophe	2.5 million people in N/Kenya
2006	Mild drought	Food insecurity	3.5 million people

Sources: National Disaster Management Policy, Republic of Kenya, 2004; and rapid food security assessments by the Kenya Food Security Steering Group.

Households derive substantial nutrition from their herds of livestock, such as milk, meat and blood (Holtzman, 2007). However, when these animals are subjected to seasonal risks such as droughts, diseases, raids or predation, the final effect is on the children dependent on them for dietary needs. Figure 2:7 demonstrates the indirect influence that rainfall condition has over livestock productivity and ultimately on human welfare (malnutrition) adopted from a project report on drought response strategies (ILRI, 2010). The framework acknowledges the delay of rainfall impact on households but the ultimate extent is dependent on herd size and conditions. Households respond to reduced livestock productivity such as milk and meat by acquiring market products through sale of livestock.

Figure 2:7: The effect of rainfall on rangeland and wellbeing



2.6 Pastoral Risks Mitigation Strategies

2.6.1 Introduction

Pastoral risks do not exist in isolation but arise and affect the whole system. Pastoral system includes human health, financial/capital assets, environmental productivity, and other economic parameters. Turner and Pidgeon (1978) argue that disasters arise due to man-made activities. In pastoral system, risks are caused by controllable and uncontrollable factors. External factors include rainfall, diseases, market dynamics and population expansion while internal factor are changes in land use and accumulation of livestock. Mitigating the frequency and extent of pastoral risks involves examining the causes and the causal relationships between the subsystems. Appropriate establishment of the linkages allows the pastoral households and the government bodies responsible to learn from frequently occurring disasters (Toft and Reynolds, 1994). Risk management involves a process of identification and evaluation of risk factors and designing strategies capable of minimising negative outcome or maximise the opportunity. Mitigating the impact of pastoral risks have been widely researched by anthropologists, ecologists and social scientists (Bollig, 2006:13-14). Some strategies proposed to reduce vulnerability include mobility, diversification, building food reserves, environmental and market information, conversion of surplus assets into durable forms and enhancement of social structures.

2.6.2 Livestock Migration

Pastoral lifestyle involving movement of livestock and households from one area to another in search of pasture and water resources is common in many pastoral areas in Kenya (ILRI, 2010). This lifestyle has been referred by many scientists as mobility allowing livestock to maximise resource which vary in time and space (Nkedianye et al., 2011). Pastoralists have for years practiced traditional risk management strategy of nomadism in response to the temporary variability in pasture and water resources (McPeak and Barrett, 2001, Dyson-Hudson and McCabe, 1985). Forage resource, which varies in space and time is fully utilised by nomadic households by shifting their livestock from one area to another (Coughenour, 2004) or sometimes move both livestock and households together (Thornton et al., 2007). Communities which practiced mobility in the lowland pastoral areas in Kenya reported lower livestock mortality rates during drought period as compared to those with little opportunity for mobility (McPeak and Little, 2005, Nkedianye et al., 2011). Migrating herders were argued by Little et al. (2008) as less likely to fall into a poverty trap than the sedentary pastoralists. Most of the arid rangelands in northern Kenya are still open to allow pastoralists to continuously migrate to utilise spatial and temporal forage resource (Butt, 2010). The study further argued that mobility allows livestock to cover a longer distance during dry period in search of pasture.

There is a debate surrounding mobility as a pastoral risk management strategy. The proponents of the strategy argue that mobility allows the range to recover from overexploitation during the drought years and reducing localised range degradation (Angassa and Oba, 2007). The ecologists favour mobility as an efficient and effective risk management strategy to conserve range productivity (Coughenour, 2004, Solomon et al., 2007). Wildlife conservationists too advocate for mobility as a way of reducing human-wildlife conflicts arising from resource imbalance such as permanent water source (De Leeuw et al., 2001). The opponents of mobility on the other hand argue that the tragedy of the commons arises where stocking rates exceed carrying capacity of the rangelands increasing the effects of droughts (Campbell et al., 2006, Sandford and Scoones, 2006). Regardless of the direction of the debate, the strategy remains one of the most employed by the pastoral communities in the ASAL (Nkedianye et al., 2011).

Mobility strategy is however hampered by the rangeland constraints relating to land use. The major constraint is land capacity which is continually reducing in productivity (Tefera et al., 2007b). Forage productivity for instance is declining and species changing due to overexploitation (Tefera et al., 2007a). Expansion in both human and livestock population is limiting the effectiveness of these practices due to widespread distribution all the year round, leaving no reserves for drought period (Kimani and Pickard, 1998, Kassahun et al., 2008). Further, changes in land ownership and land use system have significantly reduced grazing rangelands (Lesorogol, 2008b). There is a constant permanent loss of pastoral rangelands due to privatization, gazatement for conservation and a high settlement in addition to the consequential contraction of land productivity in space and time due to degradation (Thornton et al., 2006). The effectiveness of this strategy is therefore wholly dependent on the population pressure, degradation rate and changes in the land use.

2.6.3 Risk Planning; Early Warning System

Some important contributions made in dealing with pastoral risks in addition to the traditional mobility strategy (McPeak and Little, 2005, Angassa and Oba, 2007) is the development of efficient forecasting models (Luseno et al., 2003). Planning for mitigation strategies depend on the expected effects of the forecasted event, mostly the drought and the value of information. Forecasting and comparative evaluation of mitigation strategies is made possible by the frequency in which droughts seem to occur and the resultant impact (Abule et al., 2005, Desta and Coppock, 2002b). In Kenya, Arid Lands Resource Management Project (ALRMP) and Drought Management Initiative (DMI) were particularly established to develop Early Warning Signs (EWS) thresholds, report and monitor changes both in short and long run. They do this by publishing monthly bulletins indicating the state of environmental, market and human conditions as compared to the long term moving averages (ALRMP, 2007). The current EWS advanced by ALRMP is based on a composition of both qualitative as well as quantitative variables derived from the monthly household surveys. Depending on these outputs, the condition is classified as normal, alert or alarm stage. Alarm stage usually arises when the general economy exhibit adverse characteristics such as increasing food prices, lack of rainfall, poor forage condition or existence of conflicts.

Other institutions include Livestock Early Warning System (LEWS) which assesses the long term forage production, the effect on the livestock body conditions and productivity by incorporating both satellite data and the selected household variables. Rainfall and forage is an important input in planning tools such as vulnerability forecasting models and disseminated to the pastoral communities through radio, internet and monthly bulleting (Kaitho et al., 2003). Famine Early Warning Systems Network (FEWS-NET) sponsored by USAID also provides early signs on food insecurity. Livestock Information Network and Knowledge system (LINKS) provides advisory services to the pastoral communities in East Africa on the forage conditions and the impending famine for appropriate herd management (Kaitho et al., 2003).

Empirical models have been developed to provide the Early Warning Signs (EWS) and set basis for need assessment on the strength of the available response strategies (Campbell, 1999). However, Dewaal (1988) argued that such models fail to produce timely and accurate results hence inability to distinguish droughts based on severity. Drought related disasters is a major concern in many pastoral areas in Africa due to its devastating famine resulting from livestock deaths and environmental degradation (Kassahun et al., 2008). The extensive humanitarian effects of risks facing drylands globally require huge resource allocation for appropriate responses. In order to provide resource planning framework, several early warning systems have been devised especially to track climate and pasture resource variability in Sub-Saharan Africa. This is aimed at informing policy makers on the appropriate strategies to mitigate the consequences. Models have been developed to predict the human impact of climate variability some of which incorporate biophysical, socioeconomic and anthropometric variables (Mude et al., 2009a).

Pastoral systems have utilised forecasting models to predict the expected performance of the fodder in the ASAL with the objective of evaluating the state of food security (Kaitho et al., 2003). This is indicated as the point of preparedness in the pastoral risk management model (Swift et al., 2002). Mathematical forecasting methods used in east Africa include Autoregressive Integrated Moving Average (ARIMA) modelling used to predict the state of forage (Kaitho et al., 2003) and multiple regressions used in predicting the slow-onset of food insecurity (Mude et al., 2009a). The impact and severity of famine is also assessed using health and nutritional records, especially on the infant mortality, diseases, children's height and weight (Roth et al., 2005). Rainfall and availability of pastures provide a measure for prediction of the malnutrition status hence the wellbeing of the population (Mude et al., 2009a).

2.6.4 Livestock Insurance Scheme

Although livestock mortalities arising from droughts are idiosyncratic to households (Lybbert et al., 2004a), the common primary resource also influences the extent of the impact of drought. In most pastoral households the consequence of harsh droughts is absorbed through the social insurance systems relating to herd diversification and accumulation, livestock borrowing, transfers and loans recoveries (Lesorogol, 2009, Bekure, 1991, McPeak and Little, 2005). Herders have traditionally used their social networks to mitigate losses arising from droughts, conflicts, and diseases (Schwartz, 2005). They also accumulate livestock at all times as a social insurance to meet their smoothened feeding requirement and other daily needs. Pastoralists have managed to practice this strategy because of favourable conditions such as expansive rangelands to practice mobility. Households accumulate large herds to increase chances of a proportionate ex-post drought herd size to ensure recovery (Lybbert et al., 2004a, McPeak and Little, 2005). McPeak (2005) further noted that post drought herd sizes is influenced by the pre-drought herd holding. The users of a common resource are motivated to overexploit its productivity to maximize the marginal revenue utility while giving less consideration to the shared marginal cost (Hardin, 1998). The fact that pasture land is a common asset, it is likely to be overused and households accumulate livestock to the extent that they meet their subsistence requirements and fulfil the level of social insurance. The impact of overusing rangelands is borne by the whole society as a result of reduced pasture during drought seasons. There are costs and benefits of herd accumulation especially when the community make a choice between conservative and opportunistic stocking strategies (Campbell et al., 2006). This motivation to accumulate herd size also exacerbates the effects of droughts causing massive livestock losses (Tefera et al., 2007b, Vetter, 2005).

Insurance scheme cushions the policy holders against the impact from certain specified risks of which the assets are covered. The impact of risk can be minimised through (1) prevention which include dealing with the events causing the risks, (2) transfer to a second party such as the insurer or (3) by self-assumption where losses are absorbed by accumulating more assets. Preventing the risk from happening would be total avoidance or taking less risky ventures. The consequences could also be dealt with through a transfer to a third party, insurer, who accepts similar risks exposed to a large group of people. Climatic variability has remained uninsured risk in East Africa despite wide agreement that it is the highest cause of poverty trap in most pastoral areas (Chantarat et al., 2009b). They noted that some countries such as the USA provide insurance to farmers losing their assets from droughts. They do this by monitoring rainfall hence forage trends. It is based on the NDVI forecast models that the Kenyan government, through global partnership, is designing insurance schemes for livestock (The Guardian, 2010). Chantarat et al. (2009b) in designing the premiums and compensations, argued that the model monitors forage condition and predict drought with high level of accuracy. The inputs to the insurance compensation criteria include rainfall, average forage yields and livestock mortality in the area.

2.6.5 Carrying Capacity Control

Sustainable rangeland systems, hence livestock productivity, has attracted a wide range of researchers although consensus is still elusive (Vetter, 2005, Campbell et al., 2006, Sandford and Scoones, 2006). They argued for an appropriate utilisation of rangeland system aimed at maximising on the environmental, social and economic benefits. To do this, livestock and other herbivores need to be matched with the resource availability and the social and economic needs of the pastoral communities.

High level stocking rates have been found to affect productivity of perennial grasses causing pasture land degradation (O'Connor, 1995, Tainton, 1981, Tainton, 2007) while conservative stocking rates underutilises fodder during good rainfall years (Sandford, 1983). Economic and ecological equilibrium is maintained by constantly maintaining grazing pressure within the limit the environment can support without strain. Such artificially designed stocking rates helps in reducing ecological degradation while at the same time maximising on the economic benefits (Fynn and O'Connor, 2000).

There are four major livestock management strategies aimed at reducing the drought induced mortalities as well as rangeland degradation (Campbell et al., 2000b). First is the opportunistic strategy, employed by most pastoral communities, where good rainfall years allow natural increase in livestock population. This population is naturally regulated by the presence of droughts, diseases and shortfall in labour (Thornton et al., 2006). Second, the tight tracking scenario where forage produced is tightly matched with livestock population to maximize on high primary production during good rainfall years. In addition to the natural births, livestock herd is increased or reduced by buying and selling to match the stocking rates with the rangeland's carrying capacity (Behnke and Kerven, 1994). The risk with this strategy is that during poor rainfall years, there is no forage to support livestock and may exacerbate the effects of drought especially where markets are not stable (Barrett and Luseno, 2004). Third, conservative tracking strategy allows households to increase their livestock proportionately to the primary productivity. This rate fluctuates with variability of forage while maintaining some buffer stock for precautionary purposes. The fourth and the final strategy involve maintaining a low stable conservative rate for the livestock population. The rate required entirely depends on the stability of the rangeland; precipitation and forage productivity and livestock population growth.

In order to properly manage forage, water and biodiversity of these tracks of land communally owned, the government of Kenya set up group ranches in 1963 provide communal land ownership at a smaller scale than the previous system (Bekure and de Leeuw, 1991). The intention was to allocate grazing quotas with members regulating the stocking capacity. In Samburu district, controlled grazing dates back in the 1930s when the colonial government issued grazing scheme procedures to limit overgrazing. At the time of enforced livestock capacity between 1930s and 1950s in the district, there was no major drought reported (Lesorogol, 2008a pg. 39-42). These controls either through private or group ranching has however not been successful as expected and communal land ownership practices are still practiced (Thornton et al., 2006).

The government of Kenya and other development partners have employed the strategy of destocking weak livestock during drought seasons (Aklilu and Wekesa, 2002). Density influenced livestock mortality is managed through regulating livestock population prior to drought to balance fodder requirement with the resource, especially when it is predictable (Desta and Coppock, 2002b). These livestock are sometimes slaughtered and meat distributed to schools and hospitals as relief foods (Morton et al., 2006). The strategy provides both the purchasing power as well as reducing the financial loss that would otherwise have been caused by the drought. The process of destocking, when done at the appropriate time reduces the stocking rates hence lower forage and water competition as well as save on labour requirements. Continuous livestock off-take through the market channel not only provide household with the necessary financial resource but also allows conservation of forage for dry year's utilisation (Bekure and de Leeuw, 1991).

Although the Kenya Meat Commission (KMC) is charged with the responsibility of countrywide purchase, slaughter and refrigeration of livestock carcasses, its limited resource capacity implies that it does not offer the services effectively (Aklilu and Catley, 2010). This has left the responsibility to the local Non-Governmental Organisations (NGOs) working in arid areas. Livestock destocking has become a common activity among the pastoralists of Northern Kenya. Northern rangeland Trust (NRT) is a conservation body which oversee community conservancies in northern Kenya (NRT, 2011). Between the year 2006, when the program was initiated, and 2009, NRT has bought 1,965 head of cattle spending around US$ 0.5 million at an average of US$ 222 per head (Burra et al., 2009). Positive results have been observed in the area mainly in stabilising livestock prices and creating a constant sales rate regardless of the existing drought.

2.6.6 Rangeland Reclamation

Risks associated with declining rangeland productivity arising from overstocking and climate effects have been responded in various ways. Unproductive rangelands are reclaimed back to some level of productivity (Dregne, 1995, Solomon et al., 2007). Managing degradation risks involves identification of their causes and the possible response strategies. Increasing rangelands' vegetation cover is done by allowing sufficient time for pasture to grow shoot and roots through regulated land utilisation programs (Higgins et al., 2007). This aims at increasing land cover for those areas whose forage mass have been exhausted. Dependence on a few water sources for instance lead to rangeland degradation and subsequent lower forage production (Bekure and de Leeuw, 1991). Rehabilitation of water points for instance allows dispersion of livestock and wildlife to avoid localised degradation (Upton, 1986, McPeak and Little, 2003).

Traditionally, pastoral communities practice forage conservation by practising mobility to maximise spatial forage resource and mitigate diseases and other pastoral risks (McPeak and Little, 2003). This is where the productivity of the forage is improved and the existing one conserved for the use during dry seasons. Similar rotational grazing could be imposed to limit over exploitation of forage. Rapid human population growth (Kimani and Pickard, 1998), lack or ineffective national policies (Kassahun et al., 2008), frequent droughts and increased sedentarization (Angassa and Oba, 2007) have however reduced the effectiveness of this strategy in regaining its productivity.

The government of Kenya has therefore directly or through development partners initiated various programs directed at improving rangeland productivity. The Ministry of Livestock Development (MLD) for instance work with the communities in planting indigenous grass in areas prone to soil erosion (GoK, 2010a). They do this by targeting a proportion of degraded areas and reporting the same at the district level as part of deliverable annual targets. Similar programs have also been carried out by NRT, especially around conservation areas aimed at reducing human-wildlife conflicts (NRT, 2011). They provide grass seeds and employ casual employees to clear weedy plants likely to minimise pasture production. They also allow harvesting of hay from the reclaimed areas used to feed livestock during drought seasons. Other commercial means are also available to minimise livestock mortalities and range degradation during droughts. Supplementary calf pellets for instance reduces calf mortality by 50% during drought period (Bekure and de Leeuw, 1991). During the drought years of 1999 and 2000, commercial feeds were supplied by various organisations engaged in drought risk management (Aklilu and Wekesa, 2002). The outcome of this strategy was positively noted in ensuring continued milk supply and reduced livestock mortalities as well as reduced effects of livestock on the environment. Reclamation therefore focuses on production of forage, rehabilitation of water points to expand grazing areas and allow pastoral rangeland to recover from seasons of overexploitation and provision of supplementary feeds to reduce dependence on rangeland.

2.6.7 Diversification of Income Sources

Pastoral households respond to deteriorating wellbeing by adopting various income diversification strategies. Households for example make a decision to reduce reliance on direct livestock products through the traditional pastoral system by adopting mixed agriculture or trading on livestock (Little et al., 2001b, Lesorogol, 2008a, p.192). Livestock trading allows financial transformation from capital assets into stock in trade. Regular sales of livestock therefore reduces the risk of losing many livestock as they are kept for sale and one can temporarily avoid purchasing during harsh conditions. Similarly, formal employment and skills-based economic activities is a sustainable source of livelihood for most pastoral households (McPeak and Little, 2005). In pastoral areas of northern Kenya, the level and skills of education is associated with rate of employment, hence the proportion of non-pastoral sources (McPeak and Little, 2005). Employment income provides a reliable stream which is less affected by temporal climate variability thereby reducing their vulnerability.

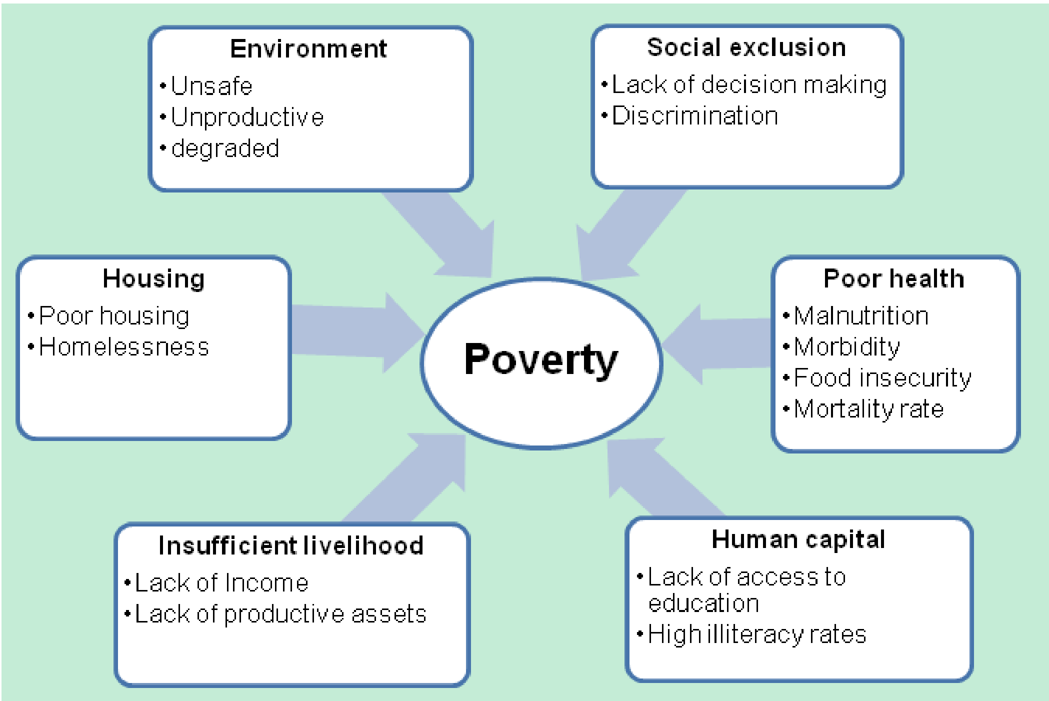
Agro-pastoralism is another diversification strategy where households supplement livelihoods by growing some subsistence food crops during rainy seasons (Thornton et al., 2006, McPeak and Little, 2005). Supplementing dietary with agricultural products reduces the need for the households to sell off their herds to acquire grains. Communities with higher non-livestock income are more sedentary and they practice pastoralism by way of satellite settlements (McPeak and Little, 2005, Fratkin and Roth, 2005). This category of agro-pastoralists are increasing in number with many people deprived of their livestock assets settling down for subsistent farming (Smith, 2005). They further noted that vulnerability risk exposed to less diversified communities is higher than those whose income sources are diversified. Eco-tourism also plays an important role in the economy of pastoral rangelands whose biodiversity relatively remained least disturbed (Boone et al., 2006). In the year 2008-2009, community conservation lodges under the umbrella of NRT generated an approximately US$273,373 suggesting the importance of the practice in income diversification (Burra et al., 2009). These tourist lodges are also source of employment, directly and indirectly to the local residents.

2.7 Pastoral Policy and Poverty Measurements

Poverty definition has taken a multidimensional approach due to the causal effects. Traditional methods focus on monetary measures examined by income or expenditure on basic needs. However, other non-monetary methods such as asset index have emerged to measure household wellbeing. This methodology is important especially in evaluating the wellbeing of pastoral households who derive substantial income from livestock which directly affect households' wellbeing. Baulch (1996) presented a pyramid of elements used to evaluate poverty progressing from a simple measure of consumption alone to a complex inclusion of common property resource, government public good, household assets, dignity and individual autonomy.

There are various measures of poverty and by extension interpretation of poverty line. This line is defined as the minimum economic welfare requirement to achieve basic human survival (Ravallion, 2010). People are deemed poor when their 'economic measure of welfare' is below some specific set of monetary minimum. The common measures of economic welfare are the household survey on income and consumption over a specified near past; with consumption being preferred for the developing countries due to inability to establish incomes. The absolute poverty lines is based on the cost of the minimum required to meet basic needs for human survival while the relative lines measures a “proportion of current mean income” (Ravallion, 2010). In measuring absolute poverty, the minimum standard of living dictated by the individual’s physiological needs (water, clothing and shelter) is pre-established while relative measures go beyond these needs to compare with acceptable standards. An international standard of measuring poverty set as US$1 a day although US$ 0.50/day per capita is used for the Kenyan rural households (Barrett and McPeak, 2006). These measures are aimed at identifying people living at absolute poverty and those with limited resources compared to other society members. Household welfare, hence consumption level, is proxy by expenditure or income depending on the data collection accuracy. Some of these methodologies have fallen short of measuring accurately due to bias, underreporting and imputation of internally generated goods (Mburu and Kiriti-Nganga, 2007). Generally, poverty definition takes different forms which include lack of income and/or productive resources, lack of food, malnutrition, and increased morbidity, lack of access to education, safe drinking water, medical services, and decent housing services (Mburu and Kiriti-Nganga, 2007). Figure 2:8 shows the multidimensional aspect of poverty based on the main socio-economic and environmental variables.

Figure 2:8: Poverty dimensions and measurements



Source: Adopted from Mburu and Kiriti-Nganga (2007).

Poverty further is described as either chronic or transitory depending on its impact and the extent of vulnerability (Carter and May, 2001, Little et al., 2008). Chronic poverty persists over time beyond the covariates and affects both household income and asset while transitory one affects income stream periodically and allow recovery at some point (Barrett and McPeak, 2006). The later suggest that households are temporarily deprived of sufficient resources to meet their basic needs during the periods of climatic shocks. Households tend to adjust to their normal consumptions after the covariates in the case of a transitory poverty. In the case of structural poverty, external intervention is highly necessary to reduce vulnerability. The difference between structural and transitory poverty is based on assets and income availability. Carter and May (2001) argued that structural poor lack sufficient assets to provide the required income while stochastic earn income below poverty line. As for the case most pastoral areas, relief food supply has become a common occurrence as many households are trapped into chronic poverty (Mude et al., 2009a).

Pastoral policies in the past are argued to have been insufficient in allowing sustainable development of the arid areas in Africa (Pratt et al., 1977, Ellis and Mdoe, 2003). While efforts have been put into projects towards revitalizing pastoral sector, little success has been reported; partially due to the marginalisation of these communities and the perceived inability of pastoral rangelands to support other major economic activities (Ellis, 2000). In the recent past decades, great involvement of the respective governments in managing livestock assets as well as improving the supporting environment has been noted (Behnke et al., 1993, Scoones, 1995, IMF, 2010). The "new range management" focused on the dynamics of the productive pastoral rangelands; with regard to carrying capacity, overgrazing, "tragedy of the commons" and desertification. Managing these dynamics calls for institutional responsibility to evaluate social, economic and environmental impacts of pastoral policies (Adger, 2006). Pastoral policy formulation in ASAL needs to be focused on the dynamics between the environment, economic and the social system (Burra et al., 2009, Abule et al., 2005).

Literature on pastoral system of East Africa has shown existence of poverty traps caused by livestock asset crash (Mogues, 2004, Lybbert et al., 2004b). Asset endowment inequality is evident among these households with relatively wealthy ones able to accumulate stock more easily than the poor. In pastoral communities, the interpretation of a dollar daily per person estimates over 8 million poor pastoralists in Eastern Africa (Thornton et al., 2003). Livestock sources being the major source of income therefore vary with the prevailing livestock and food prices (Little et al., 2008). Higher livestock prices indicate some boost to the pastoral income since the sale of a few heads generate more resource for the household. However, income and expenditure measure is incomplete for pastoral poverty evaluation without consideration of the underlying livestock assets (McPeak and Barrett, 2001). Measures to mitigate poverty therefore focus on asset accumulation in form of livestock and income diversification. Asset risks such as drought, diseases and insecurity causes vulnerability among the pastoral communities (McPeak, 2004).

In pastoral system, stochastic poverty is determined from the availability of milk, rise in food prices or drop in livestock prices. Structural poverty on the other hand could be evaluated from long period deprivation of livestock assets which create income stream. Loss of assets subsequently drive people to a stochastic poverty state and ultimately into a structural state (Carter and May, 2001). Table 2:3 broadly classify households into different categories to aid policy formulation and implementation. Cell 1 and 2 for instance would require risk management policies aimed at mitigating asset depletion and rebuilding the existing stock to the critical herd size. Cell 3 on the other hand would only call for emergency policies to support the households from temporary income and asset covariates.

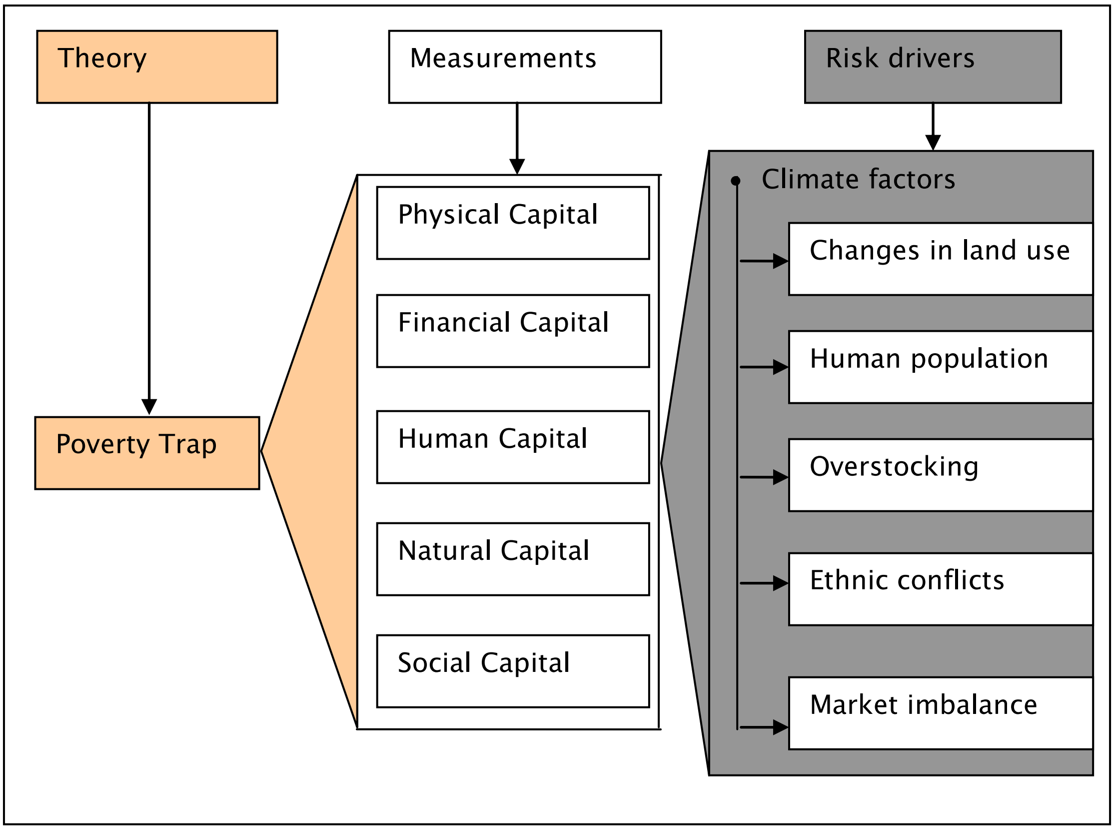
Table 2:3: Asset-based poverty classification

		Asset-Based Poverty Status	
		Poor	**Non-Poor**
Income-Based Poverty Status	**Poor**	1. Structural Poor	3. Stochastic/transitory poor structural non-poor
	Non-Poor	2. Transitory non-poor structural poor	4.structural non-poor

Source: Little et al. (2008)

Based on the summary of the wide range literature review and the research framework, it can then be concluded that poverty trap among the pastoral communities can be assessed by measuring the variability of the 5 C's discussed under section 1.7. The events leading to pastoral poverty trap is a long-term slow process which may take many years. However, the causes and effects can be measured using distinct measurable elements as observed from the study and relationship summarised (fig. 2.9). The theory of poverty trap among the pastoral communities is well discussed by Lybbert et al. (2004a) suggesting that households move in a continuum of wealth classes with lower classes predicting poverty trap. Mogues (2004) also observed the role played by social networks in providing means to financial asset growth and recovery from the potential of poverty trap. These studies have linked the variability of climate and traditions and customs as the cause driving forces towards pastoral poverty levels. Droughts affecting livestock market prices (Barrett et al., 2003), rangeland productivity (Deshmukh, 1984), stocking rates (Sandford and Scoones, 2006) and ethnic conflicts (Haro et al., 2005) is therefore an important input towards determination of pastoral poverty and the likelihood of existing poverty trap. To investigate poverty trap at the regional level, the average livestock ownership, level of malnutrition, market prices, productive rangeland size and the proportion of poor households can provide an avenue to determine the trend in pastoral system. Similarly, the directions of these forms of capital give an indication as to the policy development. However, the complexity involved in pastoral system does not allow evaluation for the direct linear outcome of policy options (Bollig, 2006, Campbell, 1999). Efficient methodology is required not only to measure the impact of the risk drivers on poverty trap but also to evaluate and appraise mitigation strategies. System Dynamics (SD) model, further discussed in detail in section 4.1, is a useful tool in dealing with such complex problems and compare the outcome of competing objectives (Forrester, 1994, Wolstenholme and Coyle, 1983).

Figure 2:9: Pastoral risk drivers, measurements and effects on poverty



2.8 Risk and Vulnerability

The concepts of risk and vulnerability, arising from social and natural system interaction, are widely researched in the field of social sciences (Adger, 2006, Walker et al., 2004). There are however multiple and divergent interpretation of vulnerability.

The cause of multiple understanding, they argued, is due to the differences of the research objectives and the context of interest. The research objectives and the context determines the angle in which vulnerability is considered, for instance development economists linking vulnerability with productive assets (Carter and Barrett, 2006, Swift, 1989). Adger (2006) argued that regardless of the objectives set and the context of the research problem, vulnerability parameters revolve around the understanding of the system drivers, its sensitivity to shocks, and the adaptive capacity. It thus imply that a comprehensive framework of vulnerability research adopts a methodology that identify critical risk drivers, establish their cause-effect links and evaluate the structural and behavioural adaptation of the system by proposing appropriate response strategies. The common characteristic of vulnerability is the loss of resilience to cope with existing and emerging challenges and susceptibility of the system to the effects of adverse shocks (McCarthy, 2001, Adger, 2006). The outcome associated with some slow-evolving changes such as the effects of climate change take time to manifest (Hope, 2009). Resilient systems can easily adapt to the changes by transforming their states to respond to the emerging shocks (Walker et al., 2004). The risks and vulnerability facing the pastoral system in East Africa have somewhat depicted short term resilience, indicated by the wealth and livestock dynamics (McCabe, 1987, Oba, 2001). The system however faces the risk of overexploitation by the pastoral communities, given the nature of the rangeland being a common property (Lesorogol, 2008b), and is likely to suffer from unsustainable utilisation (Agrawal, 2001).

The contemporary measures of vulnerability and risk, hence the resilience of the socio-ecological systems, have evolved from the traditional approaches, which view vulnerability as absence of entitlements causing food insecurity (Sen, 1981, McPeak, 2004), presence of natural hazards (Burton and White, 1993, Coenraads, 2006), and lack of governance structures (Ellis and Mdoe, 2003, Ellis, 2000, Olsson et al., 2004). Studies on the entitlements consider vulnerability as the deprivation of the asset endowment useful in responding to social-economic shocks and those with less assets and income are more vulnerable to risks (McPeak and Barrett, 2001). The level of asset endowment signifies not only the amount of the available resources at the individual or household level but also represent the strength to respond to shocks, such as famine (Swift, 1989). Hazards on the other hand have been argued as a major driver of vulnerability and the risk is measured based on the magnitude and frequency of hazards such as droughts, floods, hurricanes, conflicts among others (Burton and White, 1993, Smith, 2004, Bollig, 2006). The existence of droughts for instance affect the resilience of the rangeland causing degradation forcing the system to acquire another stable state different from the previous one (Kassahun et al., 2008). Droughts have been found to drive the pastoralists of east Africa into a poverty trap, where the livestock ownership fall below the safety nets (Barrett and McPeak, 2006, Carter and Barrett, 2006). Risk in this case is therefore considered as the hazards and the vulnerability is measured by their outcomes. The exposure, sensitivity and adaptive capacity of the system are dependent on the institutional structures in place helping those vulnerable to prepare and cope with socio-ecological shocks (Ellis, 2000, Ellis and Mdoe, 2003). A hybrid approach towards assessing vulnerability between hazards and institutional policy is detailed in the study by Blaikie (1994), who argued that occurrence of hazards and its accumulative impact on the internal structures of the system cause disasters. This theory, they called "Pressure and Release", considers risk and the eventual vulnerability as contributed by the initial impact of the hazards and the adverse effects within the system caused by the lack of adaptive capacity.

The recent advancement in vulnerability measures borrow from the antecedent theories relating to hazards and institutional policies (Adger, 2006). The variability in vulnerability measurement arises from challenges relating to measurements, perception of risk and institutional policies. Sustainable Livelihood (SL) approach, for instance, evolved from the shortcomings of the entitlement theory which suggest that the exposure and severity of an individual or community to vulnerability is dependent on the level of asset endowment (Adger, 2006, Mogues, 2004). SL approaches incorporates the elements of hazards, governance policies, and system processes to evaluate vulnerability, measured by variability in social, human, natural, physical and financial capitals (DFID, 1999). Holistic system approach, linking exposures, sensitivity and resilience, provides a far more understanding of the complexity of vulnerability and allows identification of key processes for policy development (Turner et al., 2003). This approach further allows treatment of non-linear causal-effects of system interaction, by incorporating endogenous and exogenous factors affecting vulnerability. Livestock market, for instance, contribute towards vulnerability of the pastoral communities in Sahel region (Turner and Williams, 2002). In pastoral systems, vulnerability research is widely spread between entitlements and hazard theories. Governments have a role in helping the poor and vulnerable rural communities to cope with rapidly changing socio-ecological environments (Ellis and Mdoe, 2003). Development of rural development policies by strengthening cultural traditions helps in building assets capable of responding to the future perturbations (Lesorogol, 2009). The complexity surrounding identification of key drivers and outcomes for measuring vulnerability necessitated a quest for multiple methodologies (Adger, 2006, Walker et al., 2004). The combined utilisation of socio-ecological drivers, mediated by policy measures, is likely to provide deeper understanding of the system's sensitivity hence build stronger resilience (Olsson et al., 2004). There is therefore the need for a framework that utilises statistical analysis of key development indicators to establish the direction and strength of non-linear relationships and the impact of management policies (Agrawal, 2001). Innovative use of system dynamics approaches have shown greater value in monitoring the identified key indicators used to measure vulnerability over time (Weichselgartner, 2001). The current study adopted the SL approach to vulnerability measurements and utilises SD methods to assess the effects of governance policies against the baseline scenario.

2.9 System Dynamics in Policy Development

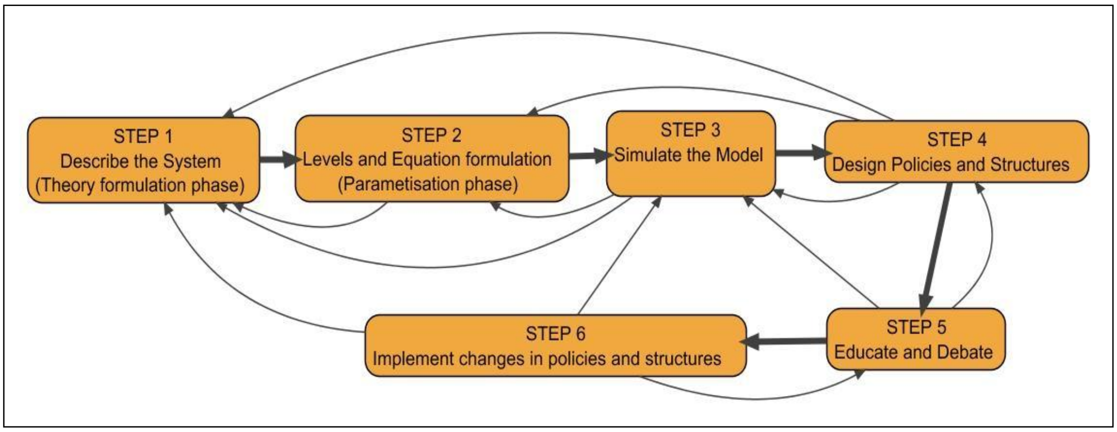
Policy development and implementation is an important process in understanding socio-ecological risks and establishment of a resilient system (Ellis, 2000). Many national and international policies have in the past been developed by various interest groups to suit different objectives (Wolstenholme and Coyle, 1983). These groups, in pastoral systems, include conservationists, rangeland specialists and economists. While the conservationists are working on increasing safety of flora and fauna by creating seclusion for protection (Georgiadis et al., 2003), rangeland specialists on the other hand are actively monitoring carrying capacity of the remaining rangeland (Abule et al., 2007, Boone et al., 2005). Pastoral management has for many years been synonymous with establishment of livestock carrying capacity and rangeland degradation (Scoones and Graham, 1994) but recent studies have called for holistic evaluation of pastoral system for sustainable development (Galvin et al., 2006, Homewood, 2004, Turner et al., 2003). The process of policy development in a dynamic environment requires a thorough understanding of the causal-effects links existing between the systems components (Adger, 2006) and the additive counter-effect of policy options (Blaikie, 1994). This literature therefore suggest that the methodological approach towards vulnerability policy development need to consider the complexity of the system arising from identification of key drivers, estimation of their links and the implications of the policies adopted.

In vulnerability literature, the role played by the institutions in policy development is vital, especially to strengthen the adaptive capacity of the system (Nkomo et al., 2006, McCarthy, 2001). Areas considered marginalised, lacking governance measures, are likely to suffer from disasters resulting from the initial impact of the hazards and the cumulative breakdown in the internal structures (Blaikie, 1994). The strength of System Dynamics (SD) approach in modelling non-linear, complex and competing objectives has attracted many researchers working on the socio-ecological systems (Picardi, 1976, Wolstenholme and Coyle, 1983). The use SD modelling has gained momentum, especially in understanding the knock-on effect in complex environmental systems, due to its ability to simplify the whole system into small manageable sub-systems (Nkomo et al., 2006, Forrester, 1994). Formulating an SD model structure replicates the logical flow of activities in the real world and allows simulation of different scenarios to test the outcome of policy options (Wolstenholme and Coyle, 1983, Xu et al., 2002). This methodology assumes that the knock-on interaction, informed by the feedback loops, has endogenous effects to the main problem under investigation. In considering holistic system interactions, SD methodology stresses the importance of events generated from the longitudinal patterns as crucial to decision making under complex circumstances. The approaches to SD involve qualitatively mapping the dynamic relationships in a system and establishing the quantitative rules (Wolstenholme and Coyle, 1983, Forrester, 1994). Causal Loops Diagrams (CLDs) are mapping tool used to visually represent the system interactions. This mapped structure is then parameterised based on the rules of interaction established quantitatively. It is based on this parameterised SD model that the outcomes of the targets and policies are evaluated against the desired objective(s) (Forrester and Senge, 1980). In planning and forecasting policies, SD has been used in natural resource planning including sustainable water use (Xu et al., 2002, Shiklomanov, 2000).

Research on vulnerability measurements have utilised SD to compare various strategies to maximise on the economic benefits (Sandford and Scoones, 2006), livestock assets dynamics (Boone and Wang, 2007), and land use systems (Garedew et al., 2009). The approach was used also to assess the socio-ecological consequences of the policies adopted following one of the worst droughts in Sahel region of Africa (Wolstenholme and Coyle, 1983). This method also provide basis from which competing theories are debated and assumptions clarified. The debate surrounding the economic values of stocking strategies, for instance, was highly discussed using SD models, with proposed strategies and the underlying assumptions used being at the centre of analysis (Sandford and Scoones, 2006, Campbell et al., 2000a). In pastoral systems, SD models have been used in different studies looking at the economics of pastoralism (Sandford and Scoones, 2006), livestock stocking rate (Campbell et al., 2006), land use systems (Yacouba et al., 2009) and in wildlife management (Ogutu, 2000). The Pastoral Household and Economic Welfare Simulator (PHEWS) was developed to investigate the effect of cultivation on wildlife conservation using SD (Boone et al., 2006). SD models have also contributed towards land-use policies (Yacouba et al., 2009, Garedew et al., 2009), given that rangeland forms and important resource in pastoral system driving livestock dynamics (Abule et al., 2007). The use of SD methods in policy development and evaluation in pastoral systems has also attracted many researchers in many arid areas of East Africa (Boone et al., 2006, Thornton et al., 2003, Galvin et al., 2004). Most arid areas, largely dominated by pastoral livelihoods, is arguably sensitive to socio-ecological risks (Solomon et al., 2007, Bollig, 2006), yet an important system supporting household livelihoods, wildlife and by extension the national economy (Little, 1992, Muriuki, 2001, Aklilu and Catley, 2010). To incorporate the complexity of this system and diverse objectives, SD models were used, for instance to determine policies on cultivation, settlements, and wildlife conservation (Boone et al., 2006).

Similar SD approaches are instrumental in the analysis of policy options available for wildlife management, such as spatial and temporal wildlife distribution (Ogutu, 2000), wildlife population control (Van Kooten et al., 1997), and the interaction between pastoralism and conservation agenda (Ogutu et al., 2005). The superiority of system dynamics in the analysis is its ability to incorporate complex non-linear relationships and the feedback loops which creates holistic system evaluation (Forrester, 1994). In addition to simplifying the complex environment, SD modelling is also preferred for analysis of non-linear systems and for problems with multiple stakeholders with varied proposals (Wolstenholme and Coyle, 1983, Picardi, 1976). The importance of a simulation model is its superiority in comparing competing strategic options and their expected results given some particular trade-offs (Thornton et al., 2006). Development of an efficient and effective SD model takes an iterative procedure as shown in figure 2:10 (Forrester, 1994). The current study aims at completing the first four steps and uses the findings to make recommendations for implementation. The system links are created through wide range consultation, focus group discussions, literature synthesis and expert opinion to establish the key pastoral drivers. Based on the understanding of vulnerability, as measured by SL framework, the theories of cause and effects are explored and tested to identify the drivers, their links, and adaptive strategies likely to create resilience in the system.

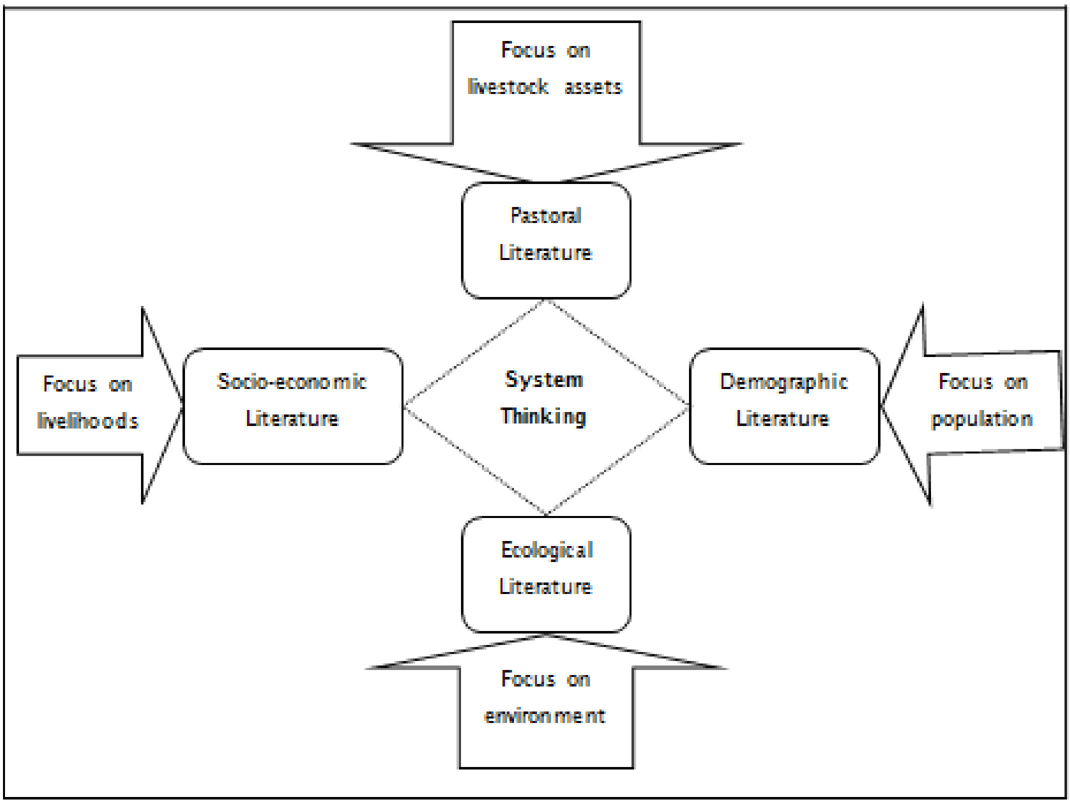
Figure 2:10: Iterative system dynamics steps



Source: Forrester (1994)

In the current study, four subsystems were developed and linked together to evaluate their feedback effects. First, the main subsystem is composed of livestock dynamics classified into cattle, small stock (sheep and goats) and camels. These are the primary assets of pastoral households and their dynamics represents the state of their wellbeing at that point in time (King et al., 1984, Desta and Coppock, 2002b, Lesorogol, 2009) . The Second subsystem of the model considers rangeland productivity driven by rainfall. Rainfall variability has indicated similar trends in rangeland productivity and pastoral socio-economic performance (Thornton et al., 2004, Angassa and Oba, 2007). The level of precipitation has also significantly been used to measure rangeland health (Deshmukh, 2008), although natural processes of degradation pose greater risk of reducing productive rangeland (Abule et al., 2005). Other competing land uses include land subdivision for wildlife conservation, settlements and crop farming (Lamprey and Reid, 2004, Ogutu et al., 2005, Boone et al., 2005). This subsystem involves land use changes resulting from multiple utilizations such as conservation, settlements, and urban development. The third subsystem considers human population dynamics, which have been found to be a major driver of pastoral system (Lamprey and Reid, 2004, Bilsborrow and Ogendo, 1992). The final subsystem incorporates the previous three subsystems and generates vulnerability outcomes, selected earlier for policy appraisal. There is a need to develop methods for evaluating pastoral policies which examine holistic effects of the entire system encompassing both equilibrium and dis-equilibrium conditions (Adger, 2006). An important method adopted in this study is the SD modelling for pastoral policy development and evaluation. The study reviews the evidence on pastoral household wellbeing on the current state of events and identifies patterns from various policy options for evaluation. In particular it examines the impact of rangeland rehabilitation programme, livestock supplementary feeding, provision of stable livestock markets, improving security to stem ethnic conflicts, and provision of veterinary services on pastoral wellbeing. A literature review was clustered based on livestock dynamics, livelihoods, human population and environmental variability as illustrated by figure 2:11. This approach helped in matching our objectives and research framework together. The framework also shows the importance of system thinking, using SD modelling in this case, for setting development policies in arid areas.

Figure 2:11: Conceptualization of the literature review



2.10 Literature Review Summary

Managing pastoral agricultural activities have taken a diverse interest approach. Policy research studies previously conducted are skewed depending on the sector of interest and their recommendations directed to a particular area without regarding the impact of recommended policies on the system as a whole. Identifying and managing pastoral risks in isolation does not provide sustainable solutions to this sector which is continually under threat. Recommendation for a particular strategy could offload risks into other sub-systems initiating potential systemic risk cycles.

A review of pastoral literature and risk management suggests the following conclusions:-

- Pastoral systems' livelihood source is largely comprised of livestock assets. There are however a myriad of risks affecting livestock both directly and indirectly thereby influencing the vulnerability of those dependent on them.
- The vulnerability of pastoral communities is highly affected by the wide range of risks. The major risks include rapid human growth, rainfall variability, unreliable market conditions and changes in land use. The ultimate impact

affects households economically and socially ultimately influencing the five forms of capital assets (economic, human, social, financial and physical).

- Past studies have dwelt on sector-specific topics by specialised anthropologists, sociologists, ecologists and economists. Recent researchers have however tried to incorporate the complex relationships between different pastoral systems in some cases but largely in conservation related studies.

- Pastoral risk mitigation strategies have evolved over time and their effectiveness are greatly affected by the drastic changes in the underlying elements of the systems. These include-:- changes in human population, variability in the bio-physical conditions and land use pressure. The choices of better strategies are made based on their impacts on the selected vulnerability indicators.

- The design of a risk management model which integrates the various sectors of pastoral economy and testing both the existing and proposed mitigation strategies is necessary. This study therefore aims to model major pastoral risks, incorporate identified mitigation strategies and make choices on suitable strategies.

3 Methodology

3.1 Introduction

Previous literature suggests that pastoral risks highly affect pastoral wellbeing and the response strategies adopted have counter effects on pastoral system as a whole. This chapter develops the methodology capable of identifying risks and their associated mitigation strategies, quantifying their effects on wellbeing of pastoral households and assess the impact of desired strategies. To achieve this, appropriate theoretical perspective, research strategy and data collection and analysis methods were required. Sections of this chapter are organised into research design, approach, and strategy and data analysis.

3.2 Research Design and Strategy

3.2.1 Research Paradigm and Philosophy

A research paradigm which entails peoples' opinion and intepretation of the real world is regarded as an important process in doing any research (Creswell, 2003, Saunders et al., 2009). Creswell (2003) conceptualised three main questions addressing the paradigm as to (1) the knowledge claims (2) the strategy of the enquiry and (3) the method of data collection and analysis. Collis and Hussey (2003) classified research based on the intended purpose, logic, process and the output. First, the current study's purpose is to describe and predict the impact of risk events on household wellbeing. The study describes wellbeing characteristics of the pastoral households and the drivers of wealth dynamics. Its main objective is to predict the effects of strategies applied in mitigating uncertainties faced in pastoral systems. This aim classifies the current study as a positivist one by seeking to explain and predict the phenomenon in the social world by establishing causal relationships and associated regularities. Secondly, the study utilises deductive logic to identify risk and examine their causal relationships. Deductive logic allows inference of the sample result obtained from large data set to represent the general trend in similar environments. This approach allows the current study to borrow arguments and conclusions made in the previous research. Thirdly, the output result of this study is applied in development of pastoral risk mitigation strategies. The results are generalised to represent the population in the focus area to measure the impact of region wise risk mitigation strategies as opposed to the idiosyncratic approaches.

The study adopts a positivistic philosophy where the social setting exhibits observable characteristics which can be reliably and validly generalised for explanation, prediction and control (Lee, 1991, Nagel 1989). The ontology of the study assumes that the characteristics of the study environment are independent of the researcher (Hofstede, 1991) and they are crucial than the community's experience (Sayer, 2000).The study measures the influence of certain variable propositions such as rainfall, pasture and other abiotic factors on wellbeing. Objectively, it is possible to measure the influence of pastoral risks, such as droughts to determine poverty levels using the hard data generated over time. The quantitative analysis of this data relating to simple measures of pastoral events helps to provide the understanding of the pastoral system. In a positivist philosophy, the causes determine the outcomes and appropriate identification and analysis of problem causes reliably allows the researcher to establish the outcomes. It involves reducing the size of the problem into small, manageable and testable hypothesis. The focus of a positivist study is aimed at verifying or falsifying a priory hypothesis (Guba and Lincoln, 1994). It is useful approach for prediction and evaluation of natural phenomenon (Guba and Lincoln, 1994). The choice of positivist paradigm in this study is supported by the aim of the inquiry, which is for prediction and control, by establishing causal linkages of the pastoral systems.

3.2.2 The Paradigm Adopted in the Current Study

The choice of paradigm places the researcher in the most appropriate assumptions and provides a clear design for the data collection and analysis (Creswell, 2003). Saunders et al.(2009) however argues that the choice of a paradigm over the rest is not based on their superiority but appropriateness of the research questions and hypothesis to be tested. It is based on these arguments that the current study adopted positivistic approach to explore pastoral risks, causes, effects and mitigation strategies. Positivism drives quantitative paradigm where empirical indicators are derived to represent a phenomenon. First, the ontological position of quantitative study assumes a single objective reality of knowledge independent of individual experiences and perception. There exist independence between the researcher and the study phenomenon thus none of the two influences the behaviour of the other. Pastoral system offers a "reality" external to any individual households and the researcher. This approach endeavours to examine between variables relationships within a value free framework. Questionnaires are administered to a larger representative sample generated from a random sampling technique for purposes of inference to the whole population. Borodzicz (2005) argued that psychologists view risk as both objective and real and quantitative measurement of risk perception is appropriate. Pastoral system is comprised of diverse stakeholders among them households, regulatory bodies in form of governmental and non-governmental organisations, and market players. The dynamics of the system is not dictated by behaviour of any single stakeholder operating singly when responding to risk events. It means therefore that pastoral system is highly objective and influenced by the interaction of the systems' players. Information collected from these large samples of households is used to test the hypothesis developed from past studies on risks, causes and mitigation strategies.

Second, the assumption as to the human behaviour and environment in which they live is an important consideration when positioning research design (Johnson and Gill, 1997, Creswell, 2003). In a positivist paradigm, human behaviour and actions are influenced by their environments (Robson, 2002). In this approach, pastoral risk is largely influenced by the strategies in place which influence the quantitative outcome. Empirical data on the causes and consequences of risk can be manipulated to test hypothesis relating to risk minimization. This is moreover useful approach given a wide knowledge and evidence of specific pastoral risks faced and the existing strategies. The actors of pastoral risks are quantifiable in regard to the impact and frequency (Fratkin and Roth, 2005). In pastoral agriculture, both prevailing and perceived risks influence the behaviour of households (Smith, 2005). The dynamics of pastoral rangelands therefore plays an important role in shaping the behaviour of these households depending on it for livelihood. The assumption of environmental influence positions the current study into a positivistic paradigm.

The aim of the study under this philosophy is to investigate the causes that influence the outcome. It involves reduction of various objective factors into a small representative elements capable of testing some hypothesis linked to the research questions. These individual behavioural elements are numerically represented to allow testing of the set hypothesis to ascertain the existing theory. The current study aims at exploring the causal relationships between pastoral variables which therefore fits a functional/positivist paradigm. The study involves repeated measures designs with multiple variables which influence the dependent variables under study. Survey strategy has been adopted in the study to collect longitudinal data from a sample households expected to be generalised to the population (Babbie, 1990).

Research studies adopt strategies consistent with the chosen philosophy and approach. The strategy allows the researcher to plan the whole process of data collection and further influence the nature of the analysis (Hussey and Hussey, 1997, Creswell, 2003). Research studies are further classified as exploratory, descriptive or explanatory depending on their objectives. Exploratory as the name suggest seek new insights of a phenomenon while descriptive study gives a clear picture of the data. Explanatory research provides the causal relationships between variables examined statistically (Hussey and Hussey, 1997). The current study aims at establishing causal relationships between pastoral variables. It is therefore an explanatory study that evaluates the causes and effects of pastoral risks on households' wellbeing.

Specifically, the study evaluates the impact of repeated disasters directed on the ecological, social, economic and demographic environments on pastoral vulnerability.

3.3 Research Approach

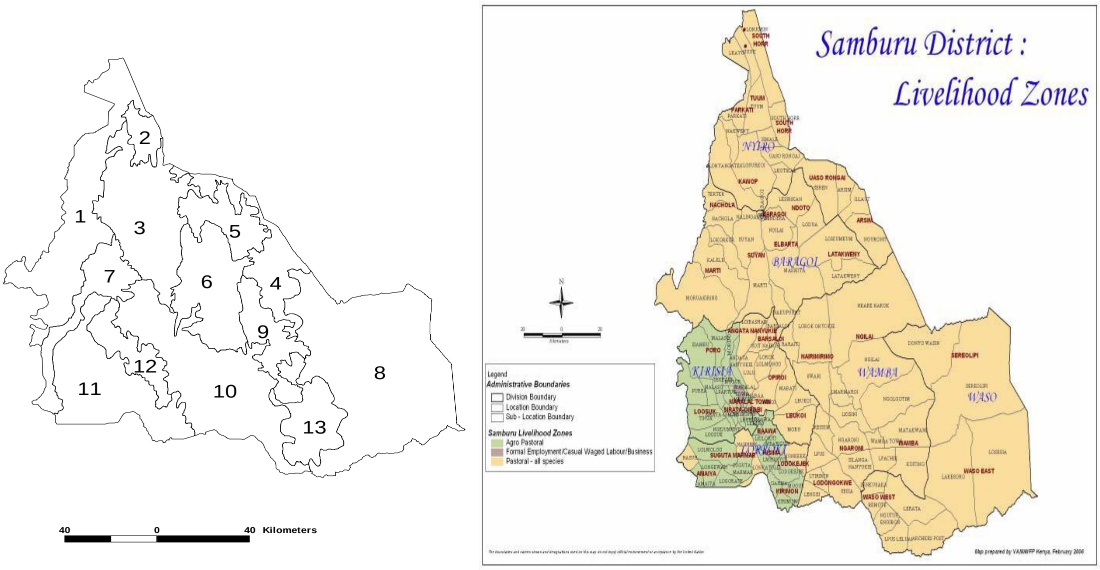
There are two main research approaches that a study may adopt based on whether or not theory are being developed and/or hypothesis are being tested. The approaches are classified as either inductive or deductive depending on how the data is collected, theory developed and hypothesis set. Researchers under inductive approach aim to explore the subject and may conduct a small case study to gain deeper insights as to "why" and "how" some phenomenon exist (Lincoln and Guba, 2000, Saunders et al., 2009). The aim of such study is to develop theories through analysis of data collected by observations and interviews of a small sample (Collis and Hussey, 2003). In a situation where there is no existing literature or a newly developing phenomenon, inductive approach becomes inevitable (Creswell, 2003). Inductive approach therefore fit into a description of qualitative research where theories are developed using small sample whose data is collected by way of observation and interviews. The current study fails to favour inductive approach by several ways. First, there is a readily available literature on pastoral risks, household strategies on risk mitigation and wellbeing dynamics. Several theories have been advanced as to what causes poverty in pastoral systems such as the tragedy of the commons (McCabe, 1990, Hardin, 1998) and poverty trap (Barrett and McPeak, 2006, McPeak and Barrett, 2001). Second, there is available data on pastoral dynamics that could help to test the hypothesis advanced under these theories.

The procedure in a deductive logic approach starts from theory, development of hypothesis, data collection and testing the hypothesis (Robson, 2002). Theoretical formal propositions will be developed and logically deduced to evaluate the causal effects of the model variables. A deductive approach will be employed to allow logical representation of the proposition on the subject of interest by examining the consequences of their relationships on pastoral poverty. Propositions are evaluated for their falsifiability, logical consistency, relative explanatory power and survival (Forrester, 1994). Research is therefore added value by proving or disapproving theories when the hypothesis are either accepted or rejected (Hussey and Hussey, 1997). Research hypothesis generated from the literature are tested against empirical data quantified to be represented as variables (Robson, 2002). This approach is appropriate when there is a readily available theoretical literature sufficient enough to logically link hypothesis. Similarly, deductive research requires sufficient data set to allow theory and hypothesis testing (Creswell, 2003). There are three sources of data for the current study. First, this study utilises secondary data collected ALRMP from monthly surveys on demographic, economic and social variables for the period between January 2006 and March 2010. This data is sufficient to allow testing seasonal variability as well as long term pastoral dynamics. Second, rangeland quality is examined from satellite data which produce modelled pasture and rainfall conditions and found to be highly accurate. Finally, primary data is collected to test the performance of the model developed. This data is subjected to statistical analysis controlled to examine the causal relationships to confirm or deny the proposed hypothesis.

3.4 Study Area

The study area was carried out in the Samburu County, bounded by $0^{0}36'$ and $2^{0}40'$ N latitudes and 36^{0} 20' and $38^{0}10'$ E longitudes. The County covers an area of 20,826 km^2 most of which is classified as either arid or semi-arid land (ALRMP, 2005). It is subdivided into three sub-counties (also referred as districts); East, Central, and North, with the current study focusing on Samburu East district only. Rainfall is erratic in time and space with normal bimodal pattern long rains falling in the period of March-May and short rains in October-December. Annual rainfall differs between the lowlands receiving 250-500mm and the highlands with 500-700mm (ALRMP, 2005). Temperatures range between 24-33 degrees centigrade with variation being driven by altitude. The most recent household census report of the year 2009 puts the Samburu East sub-county population at 59,094 (Republic of Kenya, 2010) indicating an annual growth rate of 4.5% for the county as compared with previous census estimates (ALRMP, 2005). This district presents a typical pastoral system, where households depend on rangeland productivity as influenced by climate variability (ALRMP, 2012). The district also has a more homogenous households' livelihood likely to offer suitable assumption for developing simulation model to generate scenarios. Socio-economic activities of the Samburu County is subdivided into two major livelihood zones; agro-pastoral and pastoral with over 90% of the total land mass being pure pastoral (ALRMP, 2012). Land is communally owned and is used for rearing cattle, sheep, goats, camels and donkeys (Lesorogol, 2008a). The majority of households are poor with the district poverty index of 84%, earning less than a dollar per day, and below 30% literacy rate (ALRMP, 2012). Over 60% of these households are entirely dependent on livestock products as livelihood source (ALRMP, 2005). The County is clustered into 13 range units with homogenous vegetation conditions and rainfall distribution (figure 3.1). The current study covered the range units 4, 6, 8, 9, 10 and 13, covering Samburu East district, a sub-county of the Samburu County. Detailed study area and the sampled regions are further shown on appendix I. The sample area was spread across economical and socio-ecological diversity as explained further in the subsequent section on study population and data collection.

Figure 3:1: The map of Samburu Country



The Samburu pastoral community has for years used its expansive rangeland to mitigate risks (Fratkin and Roth, 1990, McPeak and Barrett, 2001). The main livelihood come from livestock sources and like many pastoral communities around arid areas, few households have access to significant income diversification (Desta and Coppock, 2002b). Some of the strategies used in the past are facing challenges due to the changing environmental, economic and social factors (Lybbert et al., 2004b). These strategies served well especially during period of little ecological degradation and low population pressure (Abule et al., 2005). With the emergence of high population growth, causing pressure on pastoral rangelands, coupled with uncertain weather patterns, these pastoral groups live in a high risk of a poverty trap (Barrett and McPeak, 2006).

3.5 Study Population and Sample

Pastoral households living in Samburu East district forms the target population for this study. This population however is diverse in many ways including geographical, social and economic diverse characteristics (Fratkin and Roth, 1990). Despite these temporal and spatial differences, majority of these households derive livelihoods from pastoral system and are affected by common risks. The sample population for statistical analysis and further SD model development comprise of households chosen randomly from various communities. Communities were clustered based on proximity to markets, conservation areas, grazing rangelands and climatic conditions; and based on a combination of these factors five communities (Sereolipi, West gate, Lodung'okwe, Swaari and Laresoro) were selected to represent the pastoral population. Arid Lands Resource Management Programme (ALRMP) established in 1996 have since been collecting data on socio-economic variables in the same areas for purposes of monitoring vulnerability and plan for responses during drought periods (ALRMP, 2007). The reports of these repeated surveys are published in monthly bulletins stating the status of food prices, rangeland and rainfall condition and food insecurity. Appendix I shows the spread of the data collection points for both primary and secondary data utilised in this study. The key identifies only the estimated location of the study area. The data collection procedures and processing is detailed in the subsequent section, indicating the nature of data sourced and the methods applied in collecting.

3.6 Data Sources and Collection

Various approaches were followed in this study to gather data relevant to achieve objectives set earlier in this work (section 1.5). The structure of this section followed on the methods used to meet each of the three objectives. The first objective, identification of pastoral risks and mitigation strategies, was achieved by collecting primary data. The purpose of this study was to identify what pastoral communities consider as risk affecting them and the means to adapt or mitigate their effects. Risk management procedures use various tools to identify and quantify risks for purposes of developing mitigation strategies. One such approach is the assessment of frequency and impacts of such events likely to produce undesired results while considering the feasibility of the response strategies and timeliness (Ward, 1999). To identify pastoral risks, the area under investigation was clustered into four regions to maximize on variability arising from the geographical locations, access to markets, proximity to protected wildlife areas and dry period grazing lands. These areas were within Sera, Kalama, West gate and Meibai conservancies selected on the basis of socio-economic heterogeneity (see appendix I). Data collection commenced with focus group seminars targeting women, elders and warriors for every community, totalling to 12 focus group meetings. Each focus group was conducted separately to allow full participation and wide range contributions. These three groups of people are considered important in identification of risks and mitigation strategies as they are either directly engaged with confronting pastoral risks or the victims of its consequences. Elders are the top informal community decision makers in many pastoral communities regarding rangeland utilisation and livestock ownership (Kassahun et al., 2008). Warriors engage themselves in risk mitigation strategies by driving livestock around in search of pasture and water; secure them against raids and wildlife. This makes them more aware of the risks affecting their livelihoods and mostly would vividly remember worst case scenario which affected them. Women and children are normally left at home to look after weak animals, fetching water and looking for pasture feeds for them. They often feel the effects of pastoral stressors affecting their nutrition and are vital in shedding light on livelihoods adaptation strategies (Roth et al., 2005, Sellen, 2000).

The aims of these focus group seminars was to understand what community consider as risk and generate lists of the major events and processes that affect their livelihoods, hence contribute towards vulnerability. Further, the risks identified were then linked to mitigation strategy or strategies that they feel were necessary and possible. It is from these lists of risks and mitigation strategies that a questionnaire was developed to allow quantitative statistical analysis of household level responses on risks and their associated mitigation strategies. It was also meant to triangulate monthly data collected by the Arid Lands Resource Management Program (ALRMP) under the office of the prime minister for purposes of monitoring wellbeing variability. The questionnaires covered the four broad categories of risks identified during the group interviews. These are rangeland, asset, information, and market risk and their associated mitigation strategies.

Traditional African knowledge is important in assessing the risks and develop mitigation strategies based on past experiences (Niamir, 1991). Conservation organisations have recently intensified training and education of the communities through Community-Based Approaches (CBA) aimed at Disaster Risk Reduction (DRR) (NRT, 2011). This approach involves identification of uncertainties by the concerned community, their underlying vulnerability factors, and their ability to respond to such risks at the community level (Weichselgartner, 2001). There are several participatory tools/approaches available for CBA some of which include mental models, timelines and ranking. This study combined timelines to identify the frequency of occurrence for the major hazards and ranking of risks and response strategies. Pastoral communities are argued to have developed traditional measures of responding to disasters, by adopting reactive and proactive measures (Little et al., 2001b). The risks identified, in focus group stage of this study, were developed into a standard structured questionnaire for purposes of collecting household responses. Data collection process described on figure 3.2 is aimed at setting the centre stage for identification of the mitigation responses towards pastoral risks. Studies focusing on understanding pastoral vulnerability have largely utilised memory recall methods due to lack of longitudinal data and the dynamic nature of risk and vulnerability associated with socio-ecological systems (Angassa and Oba, 2007, Abule et al., 2005). Memory recall method of data collection was used in the current study to generate key system drivers, vulnerability measures, and the community response strategies to mitigate the impacts of the identified risks. The diversity of the responses during focus group interviews was important in the discussions leading to the understanding of pastoral risks from broader to more specific. The outcome of focus group was used to develop questionnaire used to collect data capable of statistical analysis and testing homogeneity of this pastoral system.

Figure 3:2: Steps followed to collect data

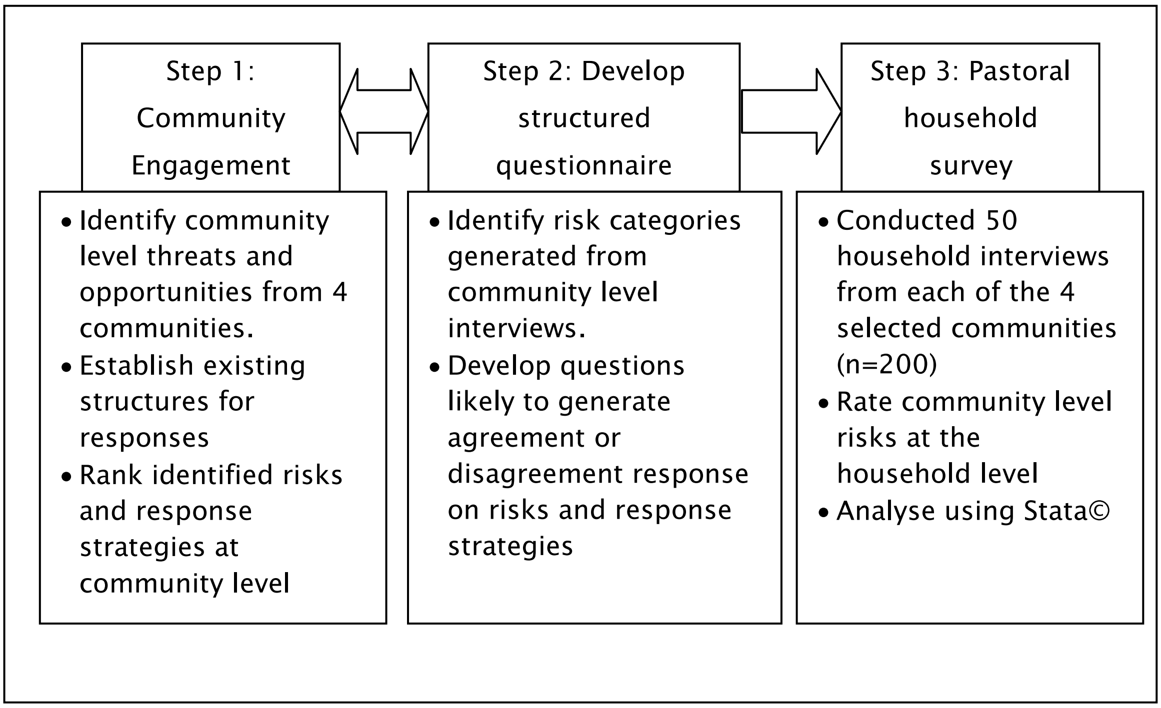


Figure 3.2 demonstrate the flow of the data collection process involved in achieving the first objective of the study. Step 1 (community engagement) seek to understand the major causes of pastoral vulnerability. The study therefore commenced with classification of the study area into 4 regions based on the socio-economic factors. Armed with the experience of the region, locations of the major markets, and core conservation areas, the clusters provided generally representative homogenous groups. Three focus group interviews conducted for every area was aimed at exploring possible differences in the risk perception among the women, elders and warriors, who play important roles in pastoral communities (Holtzman, 2001, Fratkin and Smith, 1995). The size of each group ranged between 8-10 members selected with the help of an informant picked from every region. The researcher guided the direction of the discussion based on the objective of understanding the major socio-ecological drivers and their related mitigation strategies. Caution was taken throughout the focus group sessions not to drop any possible opinion, however rare they are mentioned, and all key drivers and mitigation strategies were included in the questionnaire. The discussions were planned along the themes and theories of pastoral key drivers generated from literature and related mitigation strategies. The groups were also encouraged to highlight any possible emerging drivers, their causes, and their possible implications and coping strategies. These discussions provided this research with rich inputs, in terms of measuring risk and vulnerability perception and development of mitigation strategies. Step 2 of this objective (development of structured

questionnaires) utilised the responses from the focus group step to assess household level risk perceptions on socio-ecological system. The questionnaire developed from the inputs of the focus group is shown as appendix II. The third stage (households' survey) involved selecting 50 households at random from each of the 4 sample areas. The randomness was achieved by assessing the community settlements prior to commencement of data collection stage and allocating specific number of households for every identified settlement. The data collected was processed using STATA© statistical software to gain understanding of the risk perception, response strategies and other demographic characteristics that pose potential risks to the pastoral community under the study. Finally, the analysis also provided insights on the homogeneity or otherwise of the study area which ultimately help in the interpretation of the results of the SD analysis and policy development. Statistical analysis of this data helps the research to achieve the first objective of identifying key system drivers and their related mitigation strategies.

The second objective of the study was achieved using secondary data from two sources. First, ALRMP, under the office of the Prime Minister in the republic of Kenya, has been collecting monthly household data from 28 districts in Arid and Semi-Arid (ASAL) districts in Kenya since its inception in 1996. The objective of the data collection exercise was to provide information to the government and other policy-making institutions to assess drought early warning signs. It also allows the drought-disaster response institutions to mobilise resources when the selected indicators are showing signs of adverse social and economic trends. Samburu district is one of the 11 districts classified by ALRMP as arid districts whose main livelihood is pastoralism. Data has been collected from 14 communities selected within the district based on geographical, social and economic characteristics. The field monitors are asked to randomly select 30 households during the first selection and monitor them for a period of three years before they change their sample. However, due to data incompleteness and poor record keeping, it was not possible to trace single households for the period under review. The study therefore utilised community level (sentinel area) dynamics, by creating pseudo-panel, to investigate the effects of covariates on the selected livelihood assets. Problems with data storage made access to complete records since 1996 near impossible. However, ALRMP developed a database management system in early 2005 that allows the monitors to enter the data and generate basic statistics of the indicators. This provided us with more data points, although lacking some months' data, for the period between January 2005 and March 2010. This period provided us with sufficient data to assess livelihood assets under varying pastoral condition. In Kenya, nationwide droughts occurred in 2006 and 2009 allowing us to observe the state of the livelihood assets during drought and non-drought conditions. Since the study was designed to investigate the impact of droughts on pure pastoral households, the choice was made to utilise datasets for sentinel areas in the lowlands of Samburu district. The selected dataset had near complete entries for the period January 2006 to March 2010. It also represented the desired spatial and temporal variability in the variables under investigation.

Household heads are asked to fill in a structured questionnaire, with the help of trained research assistants about livestock assets, sources of income, morbidity cases, and MUAC taken for children below the age of 5 years[2]. The rangeland conditions, instances of conflicts, diseases, and other community-level decisions are recorded from the selected informants. These indicators are reported in monthly bulletins as is the case for other ASAL in the country (ALRMP, 2007). The deviations from the long term means are then reported as anomalies to trigger early warning signals for response planning. The current study reclassifies the Early Warning System (EWS) indicators, as previously reported by ALRMP, with the current study's dimensions designed to fit the SL framework. The justification for reclassification is explained earlier in section 1.7 (research framework) and expanded in section 2 (literature review) by providing more research grounding and justification for the choices of variables.

Table 3:1: Reclassification of EWS indicators Into DFID livelihood framework

<table>
<tr><th>Column (1)
Research Dimension</th><th>Column (2)
Early Warning System (EWS) indicator</th><th>Column (3)
Variables</th></tr>
<tr><td>Natural capital</td><td>Environmental indicators</td><td>Rainfall and NDVI</td></tr>
<tr><td>Physical capital</td><td rowspan="2">Economic indicators</td><td rowspan="2">Food and livestock prices</td></tr>
<tr><td rowspan="2">Financial capital</td></tr>
<tr><td rowspan="3">Livelihoods indicators</td><td>Livestock ownership, birth rates, Mortality rates</td></tr>
<tr><td>Human capital</td><td>Human nutritional status & Livelihood sources</td></tr>
<tr><td rowspan="2">Social capital</td><td>Wealth status</td></tr>
<tr><td>Mitigation strategies</td><td>Relief supply, copying strategies & migration</td></tr>
</table>

[2] In cases where the respondent does not have children below 5 years of age, other children within the same homestead are taken measurements.

Table 3.1 provides a summary of this process of reclassification. Column 3 lists all the variables of interest collected for the government reports. The second source of secondary data involved the use of NDVI, used as a proxy to measure the variability in rangeland productivity. In this study, NDVI was sourced to identify droughts years between 1983 and 2009 in the study area. Various models have been developed to monitor land cover at a global level. Tucker et al.(2005) described the advancement to the satellite data collection aimed at improving these models validity. Advanced Very High Resolution Radiometer (AVHRR) and meteosat are the instruments used to generate satellite data. Rangeland and ecological studies are increasingly depending on the satellite generated data for policy evaluation (Kaitho et al., 2003). The data has been used to monitor the environmental conditions in the Sahel region of Africa and develop Early Warning Signs (EWSs) (Justice, 1986). The satellite provides an estimation of vegetation biomass and is used by ecologists and conservationists to evaluate the condition of pastoral areas (Wittemyer et al., 2007). Such measurements allow quantitative analysis of forage production within some particular region and by extension the availability of forage resource capable of satisfying the existing livestock population. Satellite remote sensing data have supplemented ground data for accurate projection (Hutchinson, 1991). High resolution and frequency data on climate and forage conditions generated by the Famine Early Warning System Network (FEWS-NET) and the Livestock Early Warning System (LEWS) is used for the same period (Kaitho et al., 2003, Stuth et al., 2003). Recent studies have also utilised NDVI data to forecast the onset of slow evolving malnutrition among pastoral children (Mude et al., 2009a). Forage productivity has also been extended from modelling of NDVI and rainfall to provide the primary input required in pastoral system productivity. The details of the algorithms and mechanism of NDVI computation are explained in the work of Tucker et al (2005).

Table 3:2 shows the focus sentinel areas and the mean number of household interviewed every month for the period January 2006 to March 2010. The secondary data available represented the desired spatial and temporal variability in the regions being investigated. The average monthly samples for all regions were 30 households with a total of 6,630 interviews. The data has some missing values arising from poor database management and lack of data entry for some specific months during the data collection period. Ideally, data collections was aimed at following identified households for the first wave for a period of three years before they change to new set of households. The current practice and to a larger extent poor data storage does not allow us to link specific households to subsequent data collected. This research approached the challenges of the missing data and non-availability of the link in households over time in two ways. First, the available household dataset were all converted into community level averages giving rise to a pseudo-panel. By doing so, the relationships are examined at the community level as opposed to household level. This action does not affect our objective of establishing pastoral drivers at the community level. Second, to minimise the effects of missing data, the estimator chosen for the analysis, fixed-effects regression, fitted the model on existing data sets without dropping variables on the incomplete months (Baltagi and Song, 2006, Baltagi and Boozer, 1997). This is based on assumption that the missing values are at random and the dynamic estimators appropriately deals with unbalanced panels.

Table 3:2: ALRMP data for model estimation

Sample area	Description	Year					Total
		2006	2007	2008	2009	2010	
Laresoro	Interviews (households)	297	284	360	362	90	1,393
	Number of months	10	10	12	12	3	46
	Average households per month	30	28	30	30	30	30
Lodung'okwe	Interviews (households)	326	300	340	386	88	1,440
	Number of months	11	10	12	12	3	48
	Average households per month	30	30	28	32	29	30
Sereolipi	Interviews (households)	257	241	298	209	60	1,065
	Number of months	9	8	10	7	2	36
	Average households per month	29	30	30	30	30	30
Swaari	Interviews (households)	339	299	330	238	93	1,299
	Number of months	11	9	12	8	3	43
	Average households per month	31	33	28	30	31	30
Westgate	Interviews (households)	319	307	350	366	91	1,433
	Number of months	11	10	12	12	3	48
	Average households per month	29	31	29	31	30	30
Total	Interviews (households)	1,538	1,431	1,678	1,561	422	6,630
	Average households per month	30	30	29	31	30	30

Finally, literature synthesis was conducted to develop the qualitative SD Causal Loops Diagrams (CLDs) for various pastoral sub-systems to achieve third objective. The development and parameterisation of the model is detailed in chapter 4, with data sources, subsystem drivers and established links, and assumptions explained. The study utilises estimates from literature review and data analysis explained earlier aimed at achieving objectives 1 (primary survey data) and 2 (secondary panel data). The data collection process for the third objective commenced during the initial stages of this study and evolved throughout the research process. At the initial stages, identification of research gap, the literature drawn from multiple disciplines indicated relationships between subsystems (Mude et al., 2009a, Angassa and Oba, 2007), and some traditional mitigation strategies are reducing their effectiveness because of system sensitivity to the socio-ecological changes (Abule et al., 2005, Nkedianye et al., 2011). The process of drawing mental maps was shared with other experts in the various subsystems chosen to ensure that major drivers and processes were taken into account. Processes that minimise complexity of details, but still give similar results, were sought to reduce the possibility of overloading the SD model with too much details without necessarily adding value to the vulnerability measurement. The choice of SD model variables and vulnerability indicators was made based on the available variables and processes established from the data analysis for objectives 1 and 2. The other key variables included in the SD model, whose exact values were not established be either analysis or literature review were estimated. The process of making assumptions is considered plausible in SD modelling approach, for as long as the as it is reasonably estimated and applied across the competing scenarios (Wolstenholme and Coyle, 1983).

3.7 Data Analysis

The data analysis involved in this study was organised around the three objectives set out earlier (section 1.5) and data requirement explained (3.6). The data for the first objective was analysed by presenting simple descriptive statistics and explore the differences between groups of interest. To examine the sources and mitigation strategies for pastoral risks, descriptive data analysis was carried on the demographics, sources of livelihoods, risk and response strategies employed by households using STATA© software[3]. The descriptive statistics were presented for the various forms of vulnerabilities identified during the focus group discussions. The major point of focus for this analysis was to gain understanding on the major causes of risks and the main response strategies. Inferential analysis was conducted to examine the differences between households ranking on perceived risk and response strategies across regions, wealth and income classes. Wilcoxon-Mann-Whitney test is carried out to compare mitigations strategies adopted by households given presence or absence of drought information. This test is generally acceptable in assessing the differences between two groups without requiring the assumption that their differences are normally distributed (Fay and Proschan, 2010). The regions were purposely clustered into two based on their intensity of land use, including proximity to protected areas for conservation purposes (NRT, 2009). Westgate and Kalama sample areas are geographically closer to major towns and core conservation areas

[3] Copyright 1996–2011 Stata Corporation; Stata release 12.

providing them with possibility for livelihood diversification while Sera and Meibai are located in the interior rural areas (NRT, 2009, McPeak and Little, 2005). The strategies adopted by the group of people based on their regional location is important in this study showing the homogeneity or otherwise of the household level strategies. Information on impeding hazards, such as droughts, is vital to the pastoral households and they are found to update their traditional knowledge with emerging information to either prepare for the hazard or respond to the consequences (Luseno et al., 2003). Similarly, household perception to pastoral risks and mitigation strategies were tested using Kruskal-Wallis test. This test gives more consistent results than Wilcoxon-Mann-Whitney test when the dependent variable has more than two outcomes (Moore, 2009). It is a non-parametric measure which does not assume normality because it tests the null hypothesis of equal population medians (Breslow, 1970). In this study, the test is used to compare factors affecting livestock sales during drought period between income levels and regions. Similarly, Kruskal-Wallis test is also used in the current study to assess whether there are significant differences between strategies adopted by the households as drought coping strategies and the sources of income. The three most ranked strategies are compared with the top three sources of income (livestock, employment and casual labour), which supported over 75% of the sampled households. The ability of the households to respond to the socio-ecological shocks in pastoral systems is found to be dependent on their income streams (Lesorogol, 2009, Mogues, 2004). This study therefore uses one way analysis of variance (ANOVA) to assess whether livestock ownership determines the income level. Further, ANOVA is used to assess the coping strategies adopted by the households based on the TLU owned.

Several statistical analysis methods were used to achieve the second objective of the study (section 1.5), to assess the impact of drivers on pastoral wellbeing. Identification of drought is critical in this analysis, since it was identified as an important shock affecting virtually all forms of pastoral capitals (Homewood and Lewis, 1987, Fratkin and Roth, 1990, Begzsuren et al., 2004). Several approaches have been used to identify droughts, utilising temperature, precipitation, and vegetation growth (Ghulam et al., 2007, Wang and Li, 2004). In these methods, the current estimates of either temperature, vegetation, or precipitation is compared with the long-term average to identify periods with anomalies. The challenges facing some of the methods are the technicalities surrounding the input variables. Perpendicular Drought Index (PDI) and Modified Perpendicular Drought Index (MPDI), for instance require actual ground measurement points (Ghulam et al., 2007). Other methods used to determine drought status include Palmer Z Index (PZI), Palmer Drought Severity Index (PDSI) and Standardised Precipitation Index (SPI). The models are based on the deviations from the long term mean rainfall and temperature, hence moisture content (Ellis et al., 2010). Negative deviations indicate adverse condition, suggesting drought status.

There was no established study providing the use of these methods in the current study area. Comprehensive data on precipitation, temperature and vegetation growth is also lacking for most arid areas. An attempt to utilise varying proportions of the available data on temperature, precipitation, or vegetation was made to predict droughts in the horn of Africa (Balint and Mutua, 2011). CDI model was tested in various parts of the East Africa and found to be relatively efficient in identifying the current state of the ecological environment relative to the long term expected condition. This study relied on this latter model to identify drought years using exclusive data on vegetation. This is motivated by its ability to use any of the available data to predict drought situation. The model is also flexible and the choice of the period of interest can be manipulated to suit the objective of the study. In this case, it allows us to examine droughts quarterly, half-yearly or annually (Balint and Mutua, 2011). This model has also been adopted by the Food and Agriculture Organisation (FAO) Somalia to monitor drought conditions for Early Warning System (reports) and planning purposes.

The NDVI data for the study area was explored since 1984 to identify drought years. The NDVI analysis helps to identify mild and severe droughts which have occurred in the past nearly three decades and identify the extent of the 2006 and 2009 droughts. To achieve this, the study adopted a Combined Drought Index (CDI) model to classify the severity of drought in the sample area. The CDI is an index computed from anomalies arising from temperature, vegetation and precipitation with a zero minimum and infinite maximum value (Balint and Mutua, 2011). Values above 1 indicate absence of drought in the period of interest as compared with similar periods in the past years. Values closer to zero on the other hand indicate a worse drought condition in the current period of interest. Temperature, precipitation and NDVI and all used with subjective weights allocated to each item depending on the objective of the analysis (Eq. 1).

$$CDI = VDI.W_{ndvi} + PDI.W_{rain} + TDI.W_{temp} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots Eq.1$$

CDI represent the combined drought index generated from pasture condition (NDVI), hydrological state (rain) and the evapotranspiration rate (temperature). The Vegetation Drought Index (VDI) examines vegetation condition over the period of interest as compared to the previous similar period in the past years. Similar computations were made for Precipitation Drought Index (PDI) and Temperature Drought Index (TDI) with W_{ndvi}, W_{rain} and W_{temp} representing the percentage of weights allocated for NDVI, precipitation and temperature respectively. In this study, the weight of NDVI is given a 100% weighting based on two reasons. First, there was an incomplete dataset on temperature and rainfall available for this area. Second, the NDVI is strongly correlated with rain and temperature and the results using the vegetation proxy alone gives a similar or close outcome to that when using all 3 variables. Determining VDI is simply framing the research objective of identifying the period in which shortages of pasture cover occurred, causing socio-economic vulnerability. This is a proxy of measuring environmental health (Tucker et al., 2005) which then forms the driving force for pastoral economy (Khan et al., 1992). Once the drought years were identified during the period 2006-2010, wellbeing indicators are then descriptively analysed to assess the extent of which droughts have on pastoral livelihoods. The analysis will indicate the strength of rangeland, representing natural capital in the current study.

Drought phase classification in the past has been based on environmental, economic and social indicators at the district level. These are the indicators reported in the monthly bulletins prepared and disseminated by the office of ALRMP, in charge of drought monitoring. However, most of these indicators arise as impacts of an already occurring drought (ILRI, 2010). In this study, droughts were identified and classified based on NDVI data by comparing quarterly moving averages with the past performance. The rationale for quarterly divisions is appropriate as it matches the bimodal rainfall pattern for the district and the dry spells. It also allows for an adjustment for the number of months in which the study area has remained below normal relative to the same period in the long run. Due to lack of complete data on precipitation and temperature, our study utilises NDVI alone to compute Vegetation Drought Index (VDI) as described by Eq. 2. Analysis of NDVI alone is sufficient to give indications on the period and extent of forage below the long run means.

$$VDI_{i,m} = \frac{\frac{1}{PI}\sum_{j=0}^{PI-1} NDVI_{i,(m-j)}}{\frac{1}{(n*PI)}\sum_{k=1}^{n}\left[\sum_{j=0}^{PI-1} NDVI_{(m-j),k}\right]} * \sqrt{\left(\frac{RL_{m,i}^{NDVI}}{\frac{1}{n}\sum_{k=1}^{n} RL_{m,k}^{NDVI}}\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.2$$

In simple terms, the formula (Eq. 2) can be represented in the following expression (Eq.3) where LTM represent the long term means:-

$$VDI = \frac{Mean\ NDVI\ for\ PI}{LTM\ NDVI\ for\ PI} * \sqrt{\left(\frac{Actual\ continuous\ period\ of\ deficit\ in\ PI}{LTM\ continuous\ period\ of\ deficit\ in\ PI}\right)} \ldots\ldots\ldots\ldots\ldots\ldots Eq.\ 3$$

Equation 2 & 3 variables are explained in table 3.5 and the values derived from the model give indications on the severity of droughts. The thresholds for this model were classified as shown on table 3.4. In this study, extreme and severe droughts were combined such that any VDI below 0.6 was regarded as severe drought condition.

Table 3:3: Vegetation Drought Index (VDI) variables

Abbreviation	Explanation	Example
VDI	Vegetation Drought Index	The output index
PI	Period of Interest	Annually, semi-annually, quarterly or monthly.
RL^{NDVI}	Run Length	Max No. successive months whose NDVI is less than long term means in the PI
n	Number of years	Years whose data is being considered
j	Summation parameter for IP	Calculates the sum of NDVI for the IP
k	Summation parameter for n	Calculates the sum of years where data is available
i	Year	Represents the year of interest
m	Month	The month of interest

Table 3:4: Vegetation Drought Index (VDI) thresholds

Threshold	Drought Condition
VDI>=1.0	No drought
0.8=<VDI<1.0	Mild drought
0.6=<VDI<0.8	Moderate drought
0.4=<VDI<0.6	Severe drought
VDI<0.4	Extreme drought

Further, we assessed the effects of the major drivers of pastoral assets on TLU, MUAC, MCP, poverty, and NDVI classified as financial, human, physical, social and natural capitals respectively. The discussion in section 3.6 highlighted the challenge of missing data and lack of household level linkages. The use of pooled Ordinary Least Square (OLS) would therefore yield biased estimates given that the observations are not fully independent and are repeated (Baltagi and Song, 2006). Therefore, the study utilised a fixed-effect panel estimator which is efficient in dealing with an unbalanced panel to provide consistent results (Hansen, 2007). The estimator assumes that the sample areas are fixed (Baltagi and Song, 2006). Our interest is more focused on the "within-subject" variability than "between-subject" with variables changing over time being of prime importance. Setting fixed-effects model for this study helps to examine our aim of investigating the impacts of the identified covariates on the respective livelihood assets based on the underlying assumptions[4]. Further, a fixed effect model is useful when uncontrolled variables differ from the sample areas but are constant across time. Below, we summarise the general fixed-effect model (Eq. 4) and the variables used in the estimation further explained in table 3.5. For every category of capital asset under investigation, coefficients and their associated significance (p-values) were investigated to examine the most important drivers. Further, the coefficients of determination, r^2 values were reported to indicate how the variances of the dependent variable in the models are explained by the observed variables.

$$y_{i,t} = \alpha + X'_{i,t}\beta_t + v_i + \varepsilon_{it} \quad \begin{pmatrix} i = 1, \ldots., N \\ t = 1, \ldots., T \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 4$$

Where y_{it}=dependent variable (table 3.5) for regions *i* at time *t*., x_{it}= vector of observed variables (independent variables), ε_{it}=unobserved random error with a normal distribution with mean=0, variance σ^2, υ_i=subject specific residual and represents unmeasured individual factors which affects *y*.

[4] Fixed effects model assumes the entity's error term is correlated with predictor variables which are unique to individual entity

Table 3:5: Fixed effects model variables

Forms of capital (5 C's)	Dependent variable y_{it} =dependent variables	Independent variables $x'_{i,t}$ =Vector of independent variables
Financial	Tropical Livestock Unit (TLU) *TLU=C+0.7M+0.1S* Where C=cattle, M=Camel & S=Goats + sheep	• Livestock birth rate by species • Mortality rates by species • Sales rate by species • Pasture condition proxy by NDVI
Human	Malnutrition among children below 5-years. Percentage of children with MUAC<135	• Livestock birth rate by species • Mortality rates by species • Sales rates by species • Pasture condition proxy by NDVI • Herd size (TLU per household) • Market condition proxy by MCP • Food relief supply
Physical	Meat-Cereals Price (MCP) $MCP = (P_{meat} / P_{cereals})*100$ Where P_{meat} is the price per Kg of meat and $P_{cereals}$ is the price per Kg of cereals.	• Livestock birth rate by species • Mortality rates by species • Sales rates by species • Pasture condition proxy by NDVI • Herd size (TLU per household) • Malnutrition rate • Food relief supply
Social	Poverty rates. The proportion of poor households.	• Pasture condition proxy by NDVI • Herd size (TLU per household) • Malnutrition rate • Market condition proxy by MCP
Natural	Pasture condition. Measured based on the value of NDVI	• Monthly lagged rainfall measured in mm.

3.8 Chapter Summary

The methodology adopted for this research was based on the underlying paradigms and philosophies. The study adopted a positivistic paradigm which assumes that the reality is external to the individual being investigated and the knowledge can be acquired and shared through experiences. The choice is further strengthened based on the objective of the study looking at establishing relationships between pastoral systems. The approach therefore followed deductive logic where theory of study is primarily established and data collected to test the existing relationships between variables. To achieve this, pure pastoral community was chosen to identify risks, establish the effects of the main risks on wellbeing and develop simulation model to test the proposed policy options. Both primary and secondary data was collected to meet the objectives of the study. Data analysis for every objective was distinct. Cross-sectional data analysis for objective one was analysed descriptively to identify and rank pastoral risk drivers as well as assessing the differences existing between groups. The second objective, which included a pseudo-panel data, was analysed using fixed-effects regression model. The methodology for the final objective was achieved by linking the variables identified in the descriptive analysis of objective one, relationships established in objective two and supplement with proposed policies during focus group meetings and institutional targets. The approach for analysis is described in the subsequent chapter (chapter 4).

4 System Development and Parameterisation

4.1 System Development: Model Structure and Behaviour

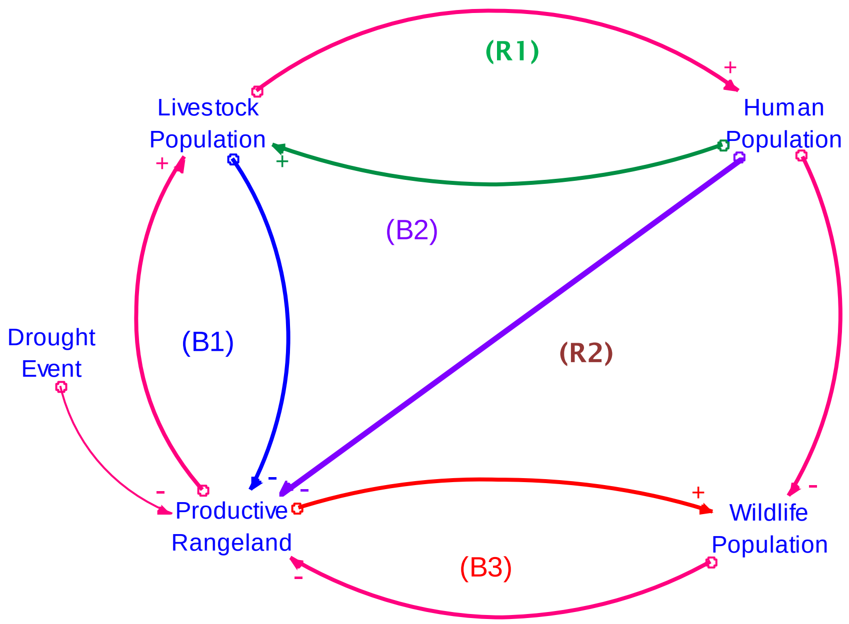
The principal aim of a SD model is to examine the forces influencing the system. This allows measurements of impact created by introducing changes in one or more drivers in the sub-systems and observing the overall system outcome. Changes with positive outcomes would then be considered potentially appropriate policies for the system under review. If proper structural and behavioural assumptions are made, SD models can allow management to predict outcomes useful for planning (Sterman, 2000). The output and subsequent performance of an SD model is dependent on the accuracy of the external structures as well as the internal estimates fed into the model. It is therefore clear that the success or otherwise failure of a SD model is dependent on the underlying structural and behavioural assumptions. The main structure of an SD model is comprised of stocks, connectors, converters and flows which allow the system to produce the knock-on effect and allows feedback behaviour to bring about endogenous as well as exogenous effects.

Stocks represent the levels of material or resources at a point in time. A stock can accumulate or reduce the amount of resources for the period under investigation. The level of resources available at a point in time provides an indicator as to the vulnerability of the system or the subsystem. If a specific level is set as the minimum/maximum requirement, the inputs or outputs are limited making the stock act as a constraint or buffer. The state of stock level is dependent on the inflows and the outflow rates. Flows are the active "taps" leading into or out of the stock. They regulate the amount of material in the stock. Performance of the flow is regulated by the rate assumed in the time-step for the simulation and it represents the process activities in time. Flows allow the SD model to produce time variant dynamics and the stocks indicate a snapshot time specific reality. Flows may be conserved or non-conserved depending on the source of the resources it transmits through the process. Non-conserved flows begin (end) from (with) "clouds" showing infinite sources (sinks). Conserved flows connect two or more stocks together to represent different steps in the process and derive its resources from the source stocks. For instance, the stock of finished goods is fed by the flow connected from finished goods warehouse. They may also be unidirectional or bi-directional depending on the causal relationship rules established. Unidirectional flow affects assumes non-negative values while bi-directional accepts both positive and negative values. Converters on the other hand are activities or events that transform inputs into outputs at every time step set for the simulation. They represent the variables and rules of the SD models.

4.2 Conceptual Model

System dynamics best begins with a theoretical framework commonly from the literature review and researcher's field experience (Forrester, 1994, Barlas, 1996). The cause and effect of the problem under investigation, in this case the influence of pastoral drivers on wellbeing and poverty reduction strategy is broadly categorised into subsystems. Literature on pastoral systems in sub-Saharan Africa suggests the conceptual model shown in figure 4:1. This study considers the pressure exerted by livestock population, wildlife conservation and human population on the common resource, rangeland. The occurrence of droughts introduces an imbalance in the whole rangeland system and finally to the entire pastoral economy which affects households' wellbeing. Various SD models developed for pastoral systems also suggested similar interaction between livestock assets, rangeland and land-use systems (Garedew et al., 2009, Boone et al., 2006). Other applications of SD models in pastoral socio-ecological analysis were elaborated in section 2.9 (literature review chapter). The main role of SD models is to help the multiple pastoral stakeholders to debate and propose strategies likely to produce desirable results to mitigate causes of vulnerability (Wolstenholme and Coyle, 1983).

Figure 4:1: System dynamics conceptual model



The conceptual model shows that the four main sectors in a pastoral system interract with each other to bring out an equilibrium condition. This conceptual model was expanded to include sub-systems described in chapter 4. The variables identified for the literature and cross-sectional data (chapter 2 and 5), and the relationship established on the basis of the panel data analysis (chapter 6) are summarised in appendix III (a) & (b). These relationships are graphically represented in each sector in appendix IV(a) to appendix IV(f). Figure 4.1 indicate the following general feedback relationships existing in pastoral system derived from the literature review, represented in these appendices as sectors:

1) Balancing loop 1 (B1), Increased extent of productive rangeland increases capacity hence capable of sustaining more livestock
2) Balancing loop 2 (B2), Increased productivity of rangeland raises the number of livestock it supports and ultimately reducing human morbidity driving up the human population. Increased human population is associated with more households which then increase the area they occupy for settlement, thereby reducing productive rangeland.
3) Balancing loop 3 (B3), Increase in productive rangeland, all factors held constant increases wildlife population due to reduced mortality associated with lack of pasture.
4) Reinforcing loop (R1) on the other hand exists in the model to indicate the relationship between the human population and the core asset (livestock). Increased human population as a result of minimised deaths arising from malnutrition, famine or reduced out-migration positively increases the total livestock population within the system.
5) Reinforcing loop (R2), Improved productive rangeland increases livestock population which then helps to boost the human population. High concentration of human population is however associated with reduced wildlife by direct means such as poaching. This reduced pressure on rangeland therefore increases its productivity.

4.3 System Parameterisation

4.3.1 Livestock Sub-System

Equations derived from the previous chapters based on statistical analysis were used in this study as constraints. The following equations (Eq. 5- Eq.8) are some of the main components of the livestock sub-system showing the species composition, growth and decline. TLU computation (eq. 5) was based on the proportions used in previous studies which considered the composite index as a function of livestock weight, 250 kg liveweight (Jahnke, 1982, Yacouba et al., 2009). This is a commonly used estimate to represent a single TLU by considering the metabolised energy of the livestock and social uses (Lesorogol, 2008b, Sieff, 1999). There are variation in the conversion rates depending on the species and economic values across cultures causing differences in the proportions (Jahnke, 1982). The variables are explained in details in table 4:1. Equations 5-8 show the processes through which the dynamics of livestock ownership is regulated in the system under review. The actual variables, parameters and rates used in the SD are provided in appendix III (a) and (b).

$$TLU = P_m + 0.7P_c + 0.1P_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 5$$

$$P_{c,t_n} = P_{c,t_{n-1}} + b_c \,.\, P_{c,t_{n-1}} - P_{c,t_{n-1}} \,.\, (m_c + s_c) \ldots\ldots\ldots\ldots\ldots Eq. 6$$

$$P_{s,t_n} = P_{s,t_{n-1}} + b_s \,.\, P_{s,t_{n-1}} - P_{s,t_{n-1}} \,.\, (m_s + s_s) \ldots\ldots\ldots\ldots\ldots Eq. 7$$

$$P_{m,t_n} = P_{m,t_{n-1}} + b_m \,.\, P_{m,t_{n-1}} - P_{m,t_{n-1}} \,.\, (m_m + s_m) \ldots\ldots\ldots\ldots\ldots Eq. 8$$

Table 4:1: Livestock dynamics variables

Variable	Variable explanation
TLU	Composite livestock ownership
P_{c,t_n} , P_{m,t_n} , P_{s,t_n}	Population for cattle, camel and small stock respectively in the current month.
$P_{c,t_{n-1}}$, $P_{m,t_{n-1}}$, $P_{s,t_{n-1}}$	Population for cattle, camel and small stock respectively in the previous month.
b_c , b_m , b_s	Birth rates for cattle, camel and small stock respectively
m_c , m_m , m_s	Mortality rate for cattle, camel and small stock respectively
s_c , s_m , s_s	Sales rate for cattle, camel and small stock respectively

Pastoralists keep livestock for purposes of milk, meat, sale and social status (Dahl and Hjort, 1976). The main livestock production estimated in this study is milk and sales revenue which are regarded as the most important reason for keeping livestock. Pastoralists adopt a milking strategy depending on their wealth status and the season of the year. Wealthy households milk 35-45% of their lactating herds while poor households milk 65-75% with only 5% of total daily production sold in the market, while the remainder is set aside for consumption (Upton, 1986, Sieff, 1999). The slaughter rate for livestock in the study area is minimal and quantification of such will not add much value to the objective of the study. The following equations (Eq. 9 and Eq. 10) therefore show the amount of milk produced and cash generated from pastoral system. Variables, signs and measurements, are described in details in table 4:2.

$$A = \left[\left(b_c \,.\, P_{c,t_n} \,.\, L_c\right) + \left(b_m \,.\, P_{m,t_n} \,.\, L_m\right) + \left(b_s \,.\, P_{s,t_n} \,.\, L_s\right) \right] \,.\, r \quad \ldots\ldots\ldots Eq. 9$$

$$R = \left(S_c \,.\, P_{c,t_n} \,.\, C_c\right) + \left(S_m \,.\, P_{m,t_n} \,.\, C_m\right) + \left(S_s \,.\, P_s, t_n \,.\, C_s\right) \ldots\ldots\ldots\ldots Eq. 10$$

Table 4:2: Livestock production variables

Variable (s)	***Variable explanataion***
A	Total amount of milk produced b(Dahl and Hjort, 1976)y catte,camels and small stock
R	Total revenue generated by livestock (Kshs)
L_c, L_m, L_s	Average daily milk produced by cattle, camel and small stock respectively
$(b_c.P_c.L_c)$	Total amount of milk produced by cattle in litres per day
$(b_m.P_m.L_m)$	Total amount of milk produced by camels in litres per day
$(b_s.P_s.L_s)$	Total amount of milk produced by small stock in litres per day
r	Milking strategy adopted (proportion of lactating animals milked)
C_c, C_m, C_s	Average selling price for cattle, camel and small stock.
$(S_c.P_c.C_c)$	Cash from cattle sold
$(S_m.P_m.C_m)$	Cash from camels sold
$(S_s.P_s.C_s)$	Cash from small stock sold

The costs of livestock production arise from direct and indirect means. The indirect cost of livestock production comes from the opportunity cost of labour. Some livestock resources such as communally owned land are freely utilised and do not attract any direct cost to the households. Pastoral system is labour intensive because of variation on the livestock species and ages requiring a dedicated caretaker for each of them. Livestock are often separated into different clusters comprised of similar ages and species during drought seasons so as to maximise on the scarce forage available and to allow convenient and sufficient supply of water and fodder (McPeak and Little, 2005). The direct costs arise from veterinary services where households treat their stock against common diseases. The main production costs in pastoral economy considered in this study are broadly categorised into labour requirements and veterinary expenses (Eq. 11 and Eq. 12). Labour requirements and veterinary expenses were derived from survey data analysis. Both equations were derived from the survey data analysis collected in this study to meet our first objective. Equation 11 was derived by regressing the labour required for herding livestock against TLU ownership.

Equation 12 on the other hand was derived from the descriptive statistics from the data collected indicating the expenses incurred on livestock treatment.

$$L_{tlu} = 0.69 + 0.07tlu \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.11$$

$$V = 10 . P_c + 22.25 . P_m + 4.4 . P_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.12$$

Where L_{tlu} represent TLU labour required and V accounts for the veterinary expenditure in Kenyan shillings per household. The veterinary costs are then converted into US$ by dividing it with base rate of Ksh 80=US$ 1.

Studies on rangeland resource utilization have highlighted various models indicating the pasture required by livestock. These models were developed based on the metabolized energy requirement by livestock. The international standard of dietary requirement for a TLU is 2.5% of their live weight daily (Yacouba et al., 2009, Minson and McDonald, 1987). TLU in this study is computed as equivalent to the weight of one cattle. The main breed of cattle kept by most pastoral communities living in the dry lowlands is zebu breed weighing average of 250kgs (Bollig, 2006, King et al., 1984) with lactation period ranging between 8-9 months (Dahl and Hjort, 1976, Coughenour, 2004). Therefore pasture required per month in sthe study is expressed mathematically as shown on Eq. 13 below:-

$$G_d = tlu * 250 * 2.5\% * 30 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.13$$

Where G_d is the amount of grass (biomass) required measured in Kgs per month. Research on animal dietary also proposes a safety requirement 10-12.5 kg DM/TLU daily for efficiency utilisation of 62.5% and 50% respectively to give cushion for healthy stock (Yacouba et al., 2009). This study adopts the higher daily requirement based on the assumption that free range animals consume as much as they can without restriction. Based on our statistical analysis of the occurrence of droughts, the SD model assumed a similar trend will remain unchanged. Regressing NDVI with drought, by creating binary values for drought years yielded a significant model with drought factor explaining 63% of variation in NDVI values (r^2=0.63, p-value<0.001). The mean NDVI and associated standard deviations for both drought and non-drought years are illustrated on table 4:3. NDVI values decline during drought years by a factor of 0.06 from the average normal pasture condition (Eq.14).

$$NDVI = 0.40 - 0.06d \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.14$$

Where d represents the binary value for the existence or absence of drought.

Table 4:3: NDVI measures for drought and non-drought conditions

Drought Status	Mean NDVI	Standard deviation NDVI
No drought	0.41	0.02
Drought exist	0.35	0.02
Grand Total	0.38	0.04

4.3.2 Rangeland Sub-System

Rangeland available for livestock grazing is influenced by ethnic conflicts, household settlements and expansion of wildlife conservation reserves. It is further affected by degradation through loss of vegetation cover (Eq. 15(a)).

$$Prod.\ Range = Land_{Total} - Land_{Conservation} - Land_{Settlement} - Land_{Degradation} \ldots\ldots Eq.\ 15(a)$$

Table 4:4: Restricted areas in Samburu East district

Conservation Area	Estimated Restricted Area (ha)
Samburu lodge	16,500
Kalama Conservancy	3,150
Namunyak Wildlife conservation Trust	2,000
Sera Conservancy Trust	33,325
West gate Community Conservancy	880
Total	55,855

The total land size in the study area is 10,142 km^2 (1,014,200 ha) used for settlement, pasture, and conservation (GoK, 2010b). Table 4:4 shows restricted pieces of rangeland dedicated for wildlife conservation in the area under review accounts for 6% of the total land size[5]. These core areas are assumed to increase in size as human population grows and threat to wildlife increases. An average household utilises 1-2 ha for settlement. This includes areas for constructing houses, kraals and compound fences. Further, a significant portion of the rangeland is degraded or inaccessible for grazing and not available for pastoral biomass production. The simulation considers only the productive rangeland in calculating the production of biomass to allow prediction of accurate pasture replenishment. Studies across the East African region found between 30% and 45% of the total rangeland to be either unproductive or

[5] Computed as 55,855/1,014,200=6%.

inaccessible for livestock grazing (Cossins and Upton, 1987, van Wijngaarden, 1985). The current study assumes that at least 30% of the total rangeland is degraded and would only be reclaimed back by adopting strategies likely to increase basal cover such as grass planting and prevention of soil erosion.

The sustainability of rangeland and continuous support of livestock depends on the capacity of the available resource compared with the current demand. To examine the susceptibility of rangeland to degradation, the current stocking rates are compared with the capability of rangeland to supply the resource. The number of TLU that rangeland can support, hence carrying capacity, is computed as follows (Eq. 15.b):-

$$N_{tlu} = \frac{T_{biomass}}{R_{biomass}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots Eq\ 15(b)$$

Where N_{tlu} represent the maximum number of TLU supported by rangeland biomass, $T_{biomass}$ is the total biomass available in productive rangelands per month and $R_{biomass}$ is the required amount of biomass by TLU per month. This equation is also important in determining the pasture shortages when making the decision to purchase supplementary feeds.

The rate of pasture production is dependent on rainfall amount, duration and distribution within the study area (Pickup, 1995). The quantity of pasture produced is affected by the degradation factor which reduces rangeland productivity. Studies have shown similar results of pasture production in East African (E.A) region with (Deshmukh, 1984) estimating grass productivity of 8kg Dry Matter (DM)/ha per mm in E.A grasslands. Other studies estimated 4-6 kg DM/ha per mm in Serengeti (Braun, 1973, Sinclair, 1975) and 4-7 kg DM/ha per mm in Athi plains (Potter, 1985), all within arid areas in Kenya. Established models for grass production per month (kgha^{-1} month^{-1}) in other regions such as Serengeti by Sinclair (1975) represented in Eq. 16 (a) and East African regional average by Braun (1973) shown by Eq. 16 (b). Regional biomas (Eq. 16.b) production is higher due to spatial variability than Eq. 16 (a) which represents a specific arid area.

*Peak Biomass= -201 + 7.67 * Rain...Eq. 16(a)*

*Peak Biomass= -196 + 8.49 * Rain...Eq. 16(b)*

Both models were used in the simulation to calculate forage resource. However, Sinclair's biomass production is used for examining grazing pressure and pasture stock. On the production side of the model, the biomass amount produced is dictated by rainfall and the available size of productive rangeland. The accuracy of the model prediction is also strengthened by setting rules on the consumption and decay. Not all biomass produced is consumed as some of it is either lost through animal activities such as trampling, consists of shrubs and weeds, or lost through bush burning (Hocking and Mattick, 1993). To avoid degradation of the rangeland, studies of ecological sustainability have proposed utilisation rates of between 45% and 50% of the biomass produced (van Wijngaarden, 1985, Mulindwa et al., 2011). The current study assumes that only 50% of the total biomass consists of palatable biomass available for livestock consumption. The composition of grass species in most of the rangelands in East Africa comprises of 70% perennial and 30% annual grass (Tefera et al., 2007a). While these rates appeared plausible, an interview with the local elders during the survey data collection confirmed that perennial grass has since declined and area dominated by annual grass. This required a further adjustment factor of decay loss for the previous season's biomass by 50% for the purpose of our simulations.

4.3.3 Human Sub-System

Kenya is among the world's developing countries with a fast growing human population and the projected population density in 2020 is expected to be double that of 1991 (Jolly and Torrey, 1993). This growth estimated at 2.8% puts the resource base under pressure especially with pastoralists whose per capita livestock is declining (Little et al., 2001b, GoK, 2005). Human population growth arises from in-migration and births and is reduced by deaths and out-migration. While the area under review is still under communal ownership, households still practice mobility within the district balancing the in-migration and out-migration, producing a minimal net migration effect (Galvin et al., 2006). The consequences arising from population pressure include reduced rangeland productivity (Campbell, 1999), reduced per capita livestock and general lower standards of living (Ellis and Swift, 1988). The sustainability of continuous human population growth requires a healthy society with sufficient food supply.

Most pastoral communities still maintain large household sizes mainly to provide livestock labour (Konczacki, 1978, Dahl and Hjort, 1976). The average pastoral household sizes are 7.23 members for Borana (Solomon et al., 2007), 7.7 for the Maasai (Galvin et al., 2006), and range between 5 and 9 members for Samburu (Lesorogol, 2008a). The land required for household settlement is estimated at 100 by 100 metres, equivalent to 1 hectare used in the current study. The building blocks to the population dynamics for this study utilised the demographic statistics in Kenya (table 4:5).

Table 4:5: Human population social indicators

Social Indicators	*Number*
Birth rate, crude (per 1,000 people) (2007)	39.2
Death rate, crude (per 1,000 people) (2007)	11.8
Mortality rate, infant (per 1,000 live births) (2007)	79.8
Mortality rate, under-5 (per 1,000) (2007)	121.2

Source: IFAD (2009).

Human population dynamics plays an important role in the pastoral economy. Increase or decrease in human population dictates rangeland stocking capacity. Further, intervention strategies are easily planned if the statistics of the affected household are known or estimated. In this study, a classical human population model, adopted from the work of Dewi and Chesson (2004), and applied in Yacouba et al. (2009) is used to test the accuracy of the SD model developed using the demographic estimates (Eq. 17).

$$H_p = H_0 * (1 + r)^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. 17$$

Where H_p is the human population at time *n*, H_0 is the population at time *0*, *r* is the rate of growth and *n* is the number of years under investigation. The results of the 2009 national population census reported an estimated total population of 59, 094 people in Samburu east district (Republic of Kenya, 2010). The national population growth rate is estimated at 2.8% with a rate as high as 4.4% among the rural households (Homewood et al., 2001). The census population estimate was used to work back the approximate population at time 0 (H_0). The SD model on human population once tested for accuracy is then used in this study to compare policy implications of growth and education policies on natural and human capitals respectively.

4.4 Mitigation Strategies

Studies have highlighted the need to evaluate interventions to reduce poverty through "integrated, multi-tiered and long term" pastoral risk management (Campbell et al., 2006). To do this, the study evaluates policy proposals for poverty mitigation strategies, including diversification of economic activities, efficient ecological utilization, and mitigation of drought losses through appropriate stocking rates and regulating the livestock population by improving marketing structures (Campbell et al., 2006, Behnke et al., 1993). McPeak and Little (2005) argued that households in pastoral areas, in northern Kenya, with more livestock and diversified income sources have a better welfare. They further noted that households with higher school enrolment rate had higher and more stable income sources. Various policy options were generated from structured interviews conducted from pastoral households and the officials from interested organisations operating in these areas. Some policies were also derived from the literature and previous programs such as those proposed by IPAL on the reduction of degradation in order to promote pastoral productivity (Lusigi, 1984). Table 4:6 provides a list of possible strategies used in this study as simulation scenarios. Policies were then evaluated based on the impact they had on the main forms of capital. A list of the proposed strategies and policy combinations is provided on appendix V. These strategies were parameterised, based on the justification described in the following discussions on every strategy (see appendix II (b)).

Degradation is evident in many parts of Sub-Saharan Africa, Kenya included causing both economic and social crisis (Baker, 1981). The primary causes of degradation are temporal variability in rainfall and herbivore abundance (Hambler et al., 2007). Minimal or complete lack of national policies to intervene has made natural resource vulnerable to irreversible conditions which could lead to a pastoral poverty trap (Kassahun et al., 2008). The mitigation strategies available for rangeland rehabilitation include, but are not limited to, planting vegetation (mainly grass) and preventing soil erosion to improve basal cover (although it is impossible to return severely degraded rangeland to its initial state (O'Connor, 1995). While it is possible for rangeland to partially recover its degraded parts during good and above average rainfall, it is however prevented from that by herbivore pressure and the continuing occurrence of droughts (Westoby et al., 1989). Based on these ecological studies, the current model assumes that under strategy 1, government and other development agencies can reclaim 5% of degraded rangeland every good rainfall year spread evenly for every month (GoK, 2010a). On the other hand, 1% of productive rangeland is lost through degradation annually for every event of overstocking. Since the time step for the simulation is monthly, a proportionate percentage is applied for every month where pasture demand exceeds supply. We also assumed that only half of the annual degradation rate applies where there exist a surplus in pasture signifying the natural causes such as soil erosion and natural loss of soil nutrients (Snyman and Du Preez, 2005). The Northern Rangeland Trust (NRT), the umbrella organisation bringing together many community development programs, has in the past few years endeavoured towards incorporating community development in conservation (NRT, 2011). They have come up with rangeland reclamation programs by clearing unpalatable shrubs and replace them with grass, planned settlement on less productive fields and creating buffer zones for rotational grazing to allow recovery of degraded range. This holistic model was then adopted as a possible strategy of reclaiming degraded rangeland (strategy 2). This strategy targets relocation of 50% of existing households at the beginning of the simulation in addition to settling all newly created households on the degraded rangeland spread evenly starting January 2013 for every month. This allows increase in the size of the productive rangeland pushing up pasture resources.

Pastoral communities do not harvest excess pasture during good or above rainfall years (Abule et al., 2005, GoK, 2010a). The costs of livestock feeds in other pastoral studies have either been quantified based on the labour hours spent on cutting grass or the actual cost spent on buying commercial feeds (Campbell et al., 2000a). Supplementary feeds come from both commercial as well as non-commercial means. Non-commercial includes collection of shrubs, pods, grass from areas inaccessible by livestock and leguminous fodder (Cossins and Upton, 1988). Commercial means on the other hand involve purchase of high energy, fat and protein formula produced by commercial food manufacturers such as Sigma feeds in Nairobi. Livestock supplementary feeding programs have been carried out by several Non-Governmental Organisations (NGOs) in many arid regions of northern Kenya in order to reduce livestock mortality rates. Aklilu and Wekesa (2002) noted from their review of the drought intervention programmes that households which participated in buying the supplementary feeds experienced reduced livestock mortalities. They noted that one bag weighing 22.5 Kgs (costing $5) is sufficient for one small stock for a period of three months when served daily in equal proportions. The current study uses two bags of the concentrates for a TLU for every drought month experiencing pasture shortage and one bag monthly for good rainfall years but insufficient supply causing shortages. Livestock are sold during pasture insufficient months to purchase feed supplements at the current prices. Both cattle and small stock are sold to acquire capital necessary to purchase these feeds. For the purposes of this analysis, the model assumes in strategy 3 that households sell cattle to finance 2/3 of the purchase of supplementary feeds if the cattle's proportionate contribution to household TLU is greater than 40% and the remaining by selling of SSUs. If the proportion of cattle is equal to or less than 40% and the camels' proportion is above 14%, then the SSUs are sold to finance 2/3 of the total cost of feeds and camels the remaining portion, otherwise SSU are sold to finance the total costs under any other condition. These computational assumptions were made after several runs were made to allow for all of the species to exist in the model for the simulation period. The simulation model further made an assumption that providing supplementary feeds during drought years reduces mortality rates by 1/3 and 1/2 for months experiencing pasture shortage and those with sufficient pasture reserves respectively. This assumption was motivated by the fact that a bag of supplementary feeds would only last 0.33 months for a TLU[6] (Aklilu and Wekesa, 2002) translating

[6] Computed as 1 bag of supplement can last for 3 months for SSU, 1 SSU= 0.1 TLU, Therefore it takes 0.3 months for 1 bag of supplement for TLU (0.1/1*3)=0.3

into three bags per TLU per month. Using these figures, 3 bags per TLU, is not only uneconomical but also unsustainable.

Livestock diseases expose households to some level of welfare uncertainty. Although mortalities arising from common diseases are at a lower risk, their persistent occurrence is worrying for pastoral communities. Campbell et al. (2000a) in their study on examining economic stocking rates among the Zimbabwean pastoral communities highlighted the role played by subsidised government veterinary services. Substantial reduction in disease related mortalities or a complete wipe-out of livestock diseases would therefore help herders to accumulate more stock which then would mean more wealth and food for them (Lusigi, 1984). However, pastoral communities incur minimum expenditure in prevention of livestock diseases (Scoones, 1995, Solomon et al., 2007). Survey data analysis in this study showed that households spent less than a dollar to treat livestock suggesting the reported losses arising from diseases. Aklilu and Wekesa (2002) noted in the report on intervention for 1999-2001 drought years that households which participated in general vaccination of livestock against common diseases reduced drought related mortality by 20%. In this study, cost and survival rates are affected under strategy 4. In terms of cost, households are given a base target of three times cost invested on control of livestock diseases from the current expenditure basket. To achieve this, SSUs (goats and sheep) are sold to purchase livestock medicine. The anticipated impact of this strategy is reduction of drought related mortalities by 20% and 50% of the current reported monthly mortality rates arising from diseases.

Restocking of livestock following droughts is widely written about and practically applied as a reactive measure to restore pastoral livelihoods. Various forms of restocking have been applied in the past by various governments and non-governmental organisations. Some of them involved livestock redistribution among the community members to bridge the gap between the very rich and the poor who are worse hit by the droughts (Lesorogol, 2009). However, emerging strategies based on economic models are highly regarded as an effective means of mitigating livestock risks. The Index Based Livestock Insurance (IBLI) is one product developed particularly to cover drought risk in Northern Kenya using NDVI and household idiosyncratic variables as important inputs on setting contract pricing (premiums). The operations of IBLI, regarding the timing of premiums and subsequent pay-out is highly elaborated in the works of Chantarat et al. (2009b) and Mude et al. (2009b). They proposed a model where pastoral households buy livestock insurance prior to the rainfall seasons and compensate them in cases where NDVI fall to a set critical value. Restocking strategies and insurance policies under the strict definition of principle of indemnity, where the insurer restores the position of the insured to that prior to the loss involve purchases of actual livestock lost during the drought season (strategy 5). The SD model developed for this analysis assumes that livestock are restocked during the first month of the years following drought from other regions which are not high hit by the drought. Prior to indemnity however, the insured are expected to pay a contract sum in form of premiums. The Guardian (2010) newspaper reported that the premium payment for livestock insurance contracts is between 3.25% and 5.5% of livestock value for full cover against drought in the year 2011. The cost involved in payment of premiums is high hence households require sale of either large number of small stock or cattle. Cattle are sold in this study for purposes of simplicity of the model, as the literature suggested that households sell large stocks to pay for large sums of expenses (Barrett et al., 2003).

Inter-ethnic conflicts are common among many pastoral communities in Eastern Africa, causing a reduction in pasture resource exacerbating drought induced mortalities or physical loss of livestock (Haro et al., 2005). Strategy 6 examines the effects of eliminating losses arising from insecurity by government providing security services. The assumption is vital because the model utilises pasture productivity from the whole rangeland under consideration. The impact of strategy 6 in the current study is the introduction of a binary variable of 0 and 1 suggesting non-existence and existence of insecurity hence conflict losses respectively. The baseline model utilised the variable of existence of insecurity and included conflict losses in the model. We then limited conflict losses to zero when the security of the area is improved.

Market infrastructure plays an important role in facilitating efficient and effective livestock off-take. Some institutions have used organised mobile markets during drought years to help households dispose of weak animals during drought years. The Northern Rangeland Trust (NRT) has played a role of ensuring existence and accessibility of livestock markets by many pastoral farmers in Samburu East district (NRT, 2011). These markets are created for four main reasons. First, there is need to establish markets accessible for emaciated livestock unable to trek for distant markets. Second, the availability of alternative institutional buyer supplements few individual livestock traders thereby helping in stabilising livestock prices during drought years. Third, the market allows the community to sell off more livestock to reduce stocking pressure. In so doing, the household would require less labour to provide water and pasture to larger herd size. It also allows smoother utilisation of common pasture by both livestock and wildlife. The outcome of a consistent livestock destocking program is increased sales during drought years and reduced drought induced mortalities. Fourth, income generated from the sale of livestock is used by households to meet dietary requirements and other household expenses. Strategy 7 of this study tests the impact of implementing a target policy likely to double sales rates for livestock during drought years. The percentage of livestock sold is then deducted from drought induced mortality by reducing the rate by the percentage of livestock sold assuming that drought mortality is driven by lack of pasture.

Wildlife conservation, which has grown as an emerging pastoral livelihood depends on the same rangeland. However, increased pressure from human activities has greatly affected distribution and sustainability of wildlife hence tourism (Lamprey and Reid, 2004, Ogutu et al., 2005). Organizations keen on promoting pastoral development through community conservation programmes have implemented several strategies likely to reduce resource competition. The Northern Rangeland Trust (NRT) for instance has engaged communities in reclamation of unproductive land by planting grass, clearing weedy shrubs, preventing soil erosion and organising planned grazing systems (NRT, 2011). The aims of these strategies are to expand productive rangelands to allow livestock and wildlife to continue using them without much resource conflicts. High numbers of wildlife are lost through human-wildlife conflicts such as poaching for trophies, providing households with food and creating space for livestock to enjoy pasture. To reduce these conflicts, many organisations have advocated the seclusion of wildlife in some protected areas to separate wildlife from livestock and human beings. Strategy 8 adopted in this study is allocation of 30% of productive rangeland between the period 2013 and 2030 for wildlife conservation in addition to the current core conservation areas accounting for only 8% of the total rangeland. To compensate the pastoral community for the change of land use, effort and funding is then directed into reclamation of land by targeting at least 50% of degraded land over the same period. Strategies 9 to 18 show combination of programs applied to the simulation following additive method of one program at a time. However, we made an assumption based on economic prudence that strategies 3 and 5 cannot be combined. One would not sell livestock to purchase supplementary feeds if they have already spent money for the insurance policy.

Table 4:6: System Dynamics (SD) policy options

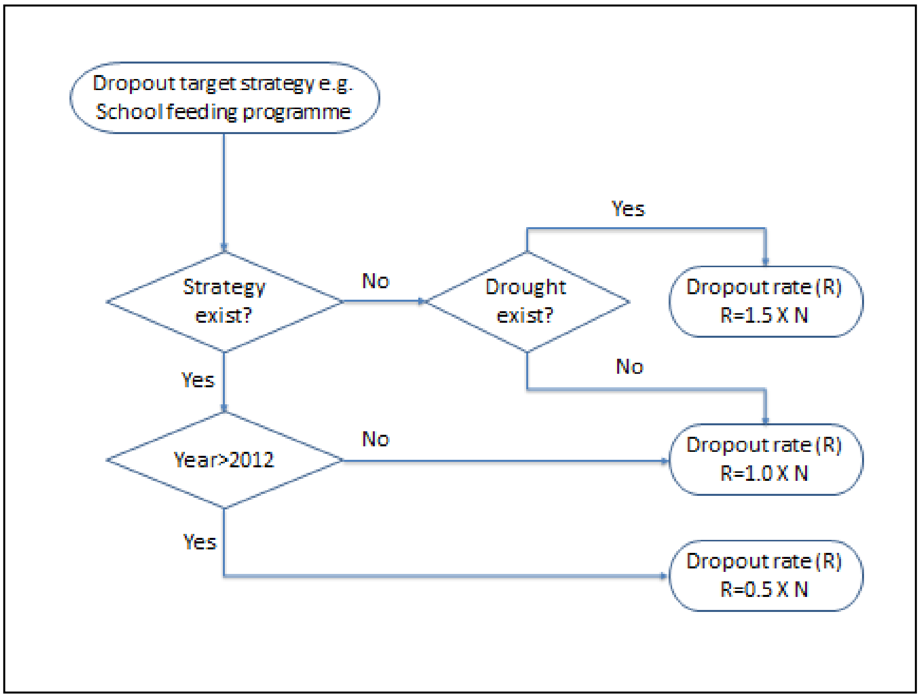
	Broad strategy	Implementation criteria	Impact
1	Land reclamation	Planting grass on degraded rangelands	Reclaim 5% of degraded rangeland annually for every good rainfall year
		Replacing weed and other shrubs by grass , preventing soil erosion	
2	Settlement planning	Give priority to settlement at degraded rangeland	Resettle 50% of all households Settle 100% of new households
3	Livestock feeding	Purchase supplementary feeds for livestock whenever there is a shortage of pasture	Sell livestock to purchase 2/3 of the feeds required and reduce drought mortality by 1/3
4	Veterinary services	Treating livestock through vaccination against common diseases	Reduce drought mortality by 20%; reduce average diseases caused deaths by 50%; sell SSU to finance 100% of veterinary costs.
5	Restocking	Livestock insurance	Sell cattle to finance 5.5% of livestock value as premiums; restock livestock lost through drought through compensation
6	Security	Rule out interethnic conflicts	Reduce livestock losses arising from insecurity by 100%
7	Market infrastructure	Encourage voluntary livestock off-take.	Double sales rate during drought years and reduce drought mortality rate proportionately. Repurchase 50% sold after the drought
8	Enhance conservation	Increase core conservation areas by 30% by the end of 2030	Reduce productive rangeland by 30% of core conservation
		Compensate with reclamation by recovering 50% of degraded land	Increase productive rangeland by 50% of degraded land
9	Reclamation and planned settlement		Effect of strategy 1 & 2 combined
10	Reclamation, planned settlement and supplementary feeding		Effect of strategy 1, 2 & 3 combined
11	Reclamation, planned settlement,		Effect of strategy 1, 2, 3 & 4

	supplementary feeding and veterinary services	combined
12	Reclamation, planned settlement, veterinary services and restocking programs	Effect of strategy 1, 2, 4 & 5 combined
13	Reclamation, planned settlement, veterinary services, restocking programs and bolster security	Effect of strategy 1, 2, 4, 5 & 6 combined
14	Reclamation, planned settlement, veterinary services, supplementary feeding and bolster security	Effect of strategy 1, 2, 3, 4, & 6 combined
15	Reclamation, planned settlement, veterinary services, supplementary feeding, bolster security and destocking	Effect of strategy 1, 2, 3, 4, 6 & 7 combined
16	Reclamation, planned settlement, veterinary services, restocking, bolster security and destocking	Effect of strategy 1, 2, 4, 5, 6 & 7 combined
17	Reclamation, planned settlement, veterinary services, supplementary feeding, bolster security, destocking and enhance conservation	Effect of strategy 1, 2, 3, 4, 6, 7 & 8 combined
18	Reclamation, planned settlement, veterinary services, restocking, bolster security, destocking and enhance conservation	Effect of strategy 1, 2, 4, 5, 6, 7 & 8 combined
19	Increase school retention rate e.g. School feeding programs	Reduce baseline dropout rate by 50%.
20	Increase school enrolment rate	Raise enrolment rate to the national level of 74%
21	Increase enrolment and reduce dropout rates	Raise enrolment rate to 74% and reduce baseline dropout rate by 50%.

Studies on pastoralism across sub-saharan Africa noted the need to diversify livelihoods to areas less prevalent to drivers of pastoral economy such as small scale trades, education, commercialisation of livestock and alternative investments of revenues (Desta and Coppock, 2002b, McPeak and Little, 2003). Provision of education facilities to pastoral households and mass enrolment is a policy tried by the government and private organisations in the past to allow pastoral communities to diversify their livelihoods. This involved using local administration government to force parents to take their children to school and maintain them until they finish their primary education, after all primary education is free. In Samburu district, Lesorogol

(2008b) reported primary enrolment rate of 50% for the age below 17 years. This rate is relatively lower than the national gross enrolment rate of 74% between the years 2005 and 2009 (United Nations Children's Fund, 2010). The current study examines the impact of both enrolment rates on the proportion of skilled labour on the total population (strategy 20). Similarly, the study also evaluates the impact of reducing primary and secondary school dropout rates, especially that proportion associated with droughts by 50% (strategy 19). Government and development partners have in the past responded to this problem by construction of boarding facilities and offering school feeding programmes to minimise the need for school-age children to drop out of school in order to look after livestock or move in search of pastures with the households. Many students at higher level studies drop out because of lack of school fees.

Figure 4:2: Human capital (skills base) scenarios



Several measures are available to mitigate the risk of drop out at the higher level of education starting from secondary school. These strategies are aimed at raising finances to allow the students complete their studies. The government through the Constituency Development Fund (CDF), Ministry of Education (MoE), Samburu County Council (SCC) and Northern Rangeland are some of the donors awarding scholarships to students from poor families in the areas. Targets therefore can give indications as to the impacts of reduced dropout rates on the human skills base in the region. Simulation runs for this sub-system includes the baseline scenario with a 50% enrolment rate derived from the literature from the same pastoral community.

Completion rates for primary and secondary schools stand at 60% and 77.5% for primary and secondary schools respectively, suggesting higher dropout rates in lower education levels. The study assumed evenly distributed dropout rates for the years spent in schools. An interview with education officers in schools within the area suggested that drought increases dropout rates by 50% and 30% for primary and secondary schools respectively. Although there is no direct linkage established for this model on livelihoods, the proportion of skilled labour to total population is monitored and reported as a measure of impact of pastoral policies on human capital. The population dynamics developed is tested against a classical growth model to validate population growth and the ultimate distribution of population categories into schooling and non-schooling. The model used the following criteria on strategies aimed at reducing drop-out rates as shown in figure 4.2.

4.5 Measure of validity

Content validity of the model was evaluated by individually examining causal relationships with logical constructs (Barlas, 1996). This involved tracking pastoral drivers (risks) and mitigation strategies on the resulting wellbeing. Similar conditions are compared to the real world scenario to examine what the model ought to represent. This ensures that the internal structures of the SD model as a whole measure the impacts of risks and allows the determination of effective and efficient strategies. Validation of the SD model was therefore performed by testing the structure before examining the behaviour producing the results. Under the structural validity test, the model's causal relationships and equations are examined in comparison with the available body of knowledge. These equations are empirically developed from the parameterisation process (Barlas, 1996, Forrester and Senge, 1980). Finally, sensitivity analysis is conducted to identify variables with a high impact on the system (Forrester and Senge, 1980). The results of the simulation model were tested against the actual data collected during the year 2011 by the ALRMP. The primary outcome of the pastoral system, livestock ownership per household, was tested against the current existing record to ensure that the SD model developed and parameterised by both primary and secondary data was producing reliable results. Other indicators such as poverty and malnutrition rates were also compared against the modelled results to test the validity of the results.

5 Results: Pastoral Risks

5.1 Introduction

This chapter presents the analysis of the primary data collected to achieve the first objective of identifying pastoral system drivers and the homogeneity across regions and income levels. Descriptive statistics on the demographics, income sources, risks, and their mitigation strategies are summarised. The variability of risks, mitigation strategies across income levels and regions are explained under the inferential analysis. The questionnaire used to collect this data is attached as appendix II.

5.2 Descriptive Statistics

5.2.1 Household Demographics

Substantial number of household members above 15 years are either unemployed (57%) or tending livestock (19%) while very few in formal employments (2%). Comparatively, 80% of household members between 5 and 15 years are either in primary (40%) or secondary (40%) schools. The remaining 20% are unemployed (5%) or tending livestock (15%). Majority of children below 5 years were categorised as unemployed (89%)[7] while 9% are enrolled in primary education and 2% tending livestock. In total, 35% of the total population surveyed were unemployed and only 1% engaging in formal employment (table 5:1).

Table 5:1: Distribution of household members by age category and main tasks

Statistics	Age Category						Household Total	
	Above 15 years		5-15 years		Below 5 years			
	Total (n)	%age	Total (n)	%age	Total (n)	%age	Total (n)	%age
Unemployed	293	57%	31	5%	269	89%	495	35%
Formal work	10	2%	-	-	-	-	10	1%
College education	2	-	-	-	-	-	2	-
Primary School	51	10%	239	40%	27	9%	317	22%
Tending Livestock	97	19%	88	15%	6	2%	191	14%
Secondary School	58	11%	241	40%	-	0%	397	28%
Category Total	511	100%	599	100%	302	100%	1,412	100%

[7] The group described as unemployed for the household members aged below 5 years represents proportion not classified as either in school or tending livestock.

Table 5:2 shows that average household had approximately 7 members, most of whom are unemployed (mean=2.37), attending primary (mean=1.52) or secondary school (mean=1.9). Very few household members were engaged in full time formal employment (0.05) or attending college education (0.01). There is however very high standard deviation of household members tending livestock as a result of variation in livestock ownership.

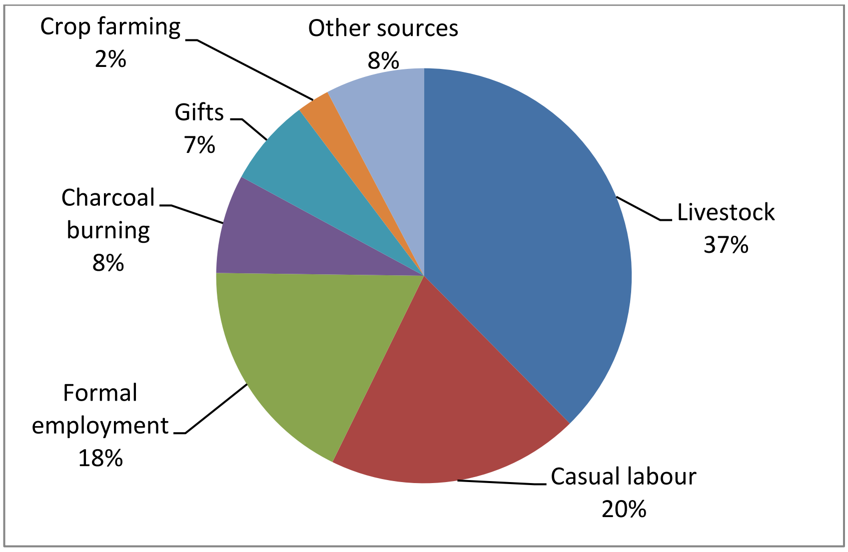
Table 5:2: Household members' main tasks

Activity	Observations (n)	Mean	Std. Dev.
Unemployed	208	2.37	1.28
Full time employment	208	0.05	0.21
Attending College	208	0.01	0.10
Attending Primary School	208	1.52	1.24
Tending livestock	208	0.92	1.19
Secondary School	208	1.90	1.40
Total Household members	208	6.77	2.67

5.2.2 Sources of Income

Substantial amount of household income is derived from livestock sources, including sale of live animals, and livestock products at 37% (figure 5:1). This is also followed by casual and formal employment with 20% and 18% respectively. Other sources such as charcoal burning (8%) are environmentally destructive while gifts (7%) and others (8%) are unsustainable as sources of household livelihood.

Figure 5:1 Sources of household income



Livestock, formal employment and casual labour supports 75% of the total household population, with the remaining quarter depending on charcoal, gifts, crop farming and other sources. Despite many households deriving their monthly income from livestock, majority of them (31.6% of the total 37.6%) earn below Ksh. 2,000 (US$ 25) translating to less than a dollar a day. Formal employment is the only major source with household monthly income exceeding Ksh 4,000 (US$ 50). A paltry 6% of the total households surveyed earned income above US$ 50 a month, majority of which come from formal employment. About 19% of households had monthly income averaging between US$ 25 and US$ 50, with substantial proportion coming from those dependent on livestock (6%), formally employed (4.3%), and casual labour (6%). Majority of the households earn less than US$ 25 a month (75%), despite the high number of household membership.

Table 5:3: Household income levels by sources

	Income class (Ksh) 1USD=80 Ksh.			
Income sources	**1-2000**	**2001-4000**	**Above 4000**	**Total**
Livestock	31.6%	6.0%	-	37.6%
Casual labour	13.7%	6.0%	-	19.7%
Formal employment	8.5%	4.3%	5.1%	17.9%
Charcoal burning	6.8%	0.9%	-	7.7%
Gifts	6.8%	-	-	6.8%
Crop	2.6%	-	-	2.6%
Other sources	5.1%	1.7%	0.9%	7.7%
Total	75.2%	18.8%	6.0%	100.0%

Ecotourism, which emerged as an important livelihood source during the focus group meeting, was also considered to investigate ways in which the households benefited. Table 5:4 shows that economic services were highly rated by households as most important benefits they are deriving from the conservation activities. Transport services (91.7%), employment (71.8%) and cash benefits (66.3%) were ranked top three benefits respectively. Services relating to mitigating droughts such as provision of water and livestock marketing services were least ranked at 5th and 6th respectively with only 24% and 21% agreeing on these services. This shows the importance of market products where households require cash from employment and means to access shopping centres to supplement livestock products.

Table 5:4: Conservation benefits

Benefits derived from conservation	Household response percentage			Rank
	Disagree	Neither agree nor disagree	Agree	
Transport services	7.73	0.55	91.71	1
Employment opportunities	24.31	3.87	71.82	2
Cash benefits	31.49	2.21	66.3	3
Bursary benefits	24.86	6.08	69.06	4
Water services	57.3	17.98	24.72	5
Medicare services	61.8	23.03	15.17	6
Livestock marketing services	70.11	8.62	21.26	6

5.2.3 Livestock Ownership and Related costs and Benefits

The average livestock ownership per household standardised into TLU is 5.31 (table 5.5) with each household owning more small stock (17.43) than cattle (3.10) on average. Household camels' ownership was minimal, with an average TLU index of 0.67. The annual costs associated with livestock include veterinary and labor. This study found that households do not spend money to build or replace fencing implying zero cost. The table indicates that households give minimal investment on livestock to prevent diseases and the expenses vary with livestock species. On veterinary services, more money is spent on treating camels than cattle against common livestock diseases with an annual expenditure of US$ 3.30 and US$ 1.50 respectively. While there was no particular cost attached to herders looking after livestock, it was necessary to assess the labour required in terms of the number of people needed to provide forage and water resources. Human labour required to look after livestock vary between rainy and dry seasons with more labour required for all species during dry period. Livestock milk productivity is also adversely affected by dry weather season with cattle and small stock milk production a day declining from 1.9 to 1.07 litres and 1.2 to 0.76 litres a day respectively. Further analysis of livestock labour requirement indicates that household TLU ownership significantly increases with an increase in TLU (table 5.6). This suggests that one herder can take care of TLU between 1 and 15 and an additional person is required for every 15 TLU to the herd size[8]. This is represented by Eq. 11 earlier discussed under section 4.3 of this study. This linear regression indicates the labour requirement and additional labour releases from other activities

[8] Additional 0.07 herders are required for every 1 TLU, therefore 1 herder required every 15 additional TLU. (1/0.07)=15

when household ownership increases. The common sources of additional labour include hiring of paid labour, dropping out school-going children, and resigning from contractual casual labour. In summary, livestock labour requirement increases with existence of drought while milk productivity reduces during drought seasons. This subjects the households with potential for labour transfer to herd livestock under condition of deteriorating productivity.

Table 5:5: Livestock ownership, production and costs

Species	Household Ownership (TLU Factor)	Vet. Cost per year (US$)	Rainy Season Labour	Dry Season Labour	Milk Rainy	Milk Dry
Cattle owned	3.10	1.50	5.19	3.81	1.9	1.07
Small stock	17.43	0.70	18.09	12.98	1.2	0.76
Camels	0.67	3.30	2.66	1.77	3.3	1.90
Total Livestock Unit (TLU)	***5.31***					

Table 5:6: Livestock ownership and labour requirement

Tending Livestock	Coef.	Std. Err.	P>t	F(1, 206)	Prob. > F	R-squared
TLU owned	0.07	0.015	0.000	22.83	0.0000	0.100
Constant	0.69	0.092	0.000			

The results of this study also indicate that most pastoral households keep livestock for social and economic reasons. Given a list of livestock uses generated from literature and focus group discussions, about 76% and above of the households agreed on the importance of livestock as insurance against losses and socio-economic reasons (table 5:7). However, when faced with ranking the top three important reasons for keeping livestock, households ranked milk, meat and emergencies respectively. Although 97.6% of the households agreed that they keep livestock for sale, very few of them ranked it as among the top three reasons. This indicates the role played by livestock in meeting the nutritional requirement for the households. Livestock are least used by these households as insurance against diseases, drought losses and raids despite being considered as important factor for holding livestock. The results show that reasons relating to short term household objectives (milk, meat, sales, and emergencies) were ranked more important than the long term objectives, such as building a self-insurance of livestock accumulation. Socio-ecological shocks affecting livestock assets are highly likely to affect food security of the sampled households.

Table 5:7: Reasons for keeping livestock

	Percentage of household agreement			
Reason for keeping livestock	Disagree	Neither agree nor disagree	Agree	Rank
To provide milk for household	0	0.96	99.04	1
Provide meat for household	1.92	5.77	92.31	2
Resource for household emergencies	9.62	0.96	89.42	3
For sale (live animals and products)	1.92	0.48	97.6	4
To keep social status	2.4	7.69	89.9	5
To provide inheritance for future generation	10.1	0.48	89.42	6
Insurance against livestock diseases	12.98	3.85	83.17	7
Insurance against drought losses	14.42	3.37	82.21	7
Insurance against ethnic raids	20.67	2.88	76.44	9

Table 5:8: Causes of livestock decline

	Household response percentage			
Causes of livestock decline	Disagree	Neither agree nor disagree	Agree	Rank
Shortage of pasture	0.96	0	99.04	1
Water shortage	9.13	2.88	87.98	2
Household consumption	28.37	5.29	66.35	3
Ethnic conflicts (raids)	26.44	4.33	69.23	4
Livestock diseases	10.1	4.81	85.1	5
Predation by wild carnivores	29.33	12.5	58.17	6
Accidents	41.35	19.23	39.42	7

There is a constant decline in livestock assets in the past 5 years arising from myriad of risks. The results showed that many households rated drought related causes as the major reasons for livestock reduction (table 5:8). Pasture (99%) and water (88%) shortages were ranked as the top two causes respectively with household consumption ranked a distant third. The least causes of livestock decline were attributed to predation and accidents. Earlier discussions during focus groups had noted frequently occurring droughts in the area causing pasture and water shortages hence livestock mortalities. Reduced livestock productivity, driven by harsh droughts, has increased sales and slaughter. Ethnic conflicts have also been identified to be more frequent in the recent years.

5.2.4 Rangeland Risks

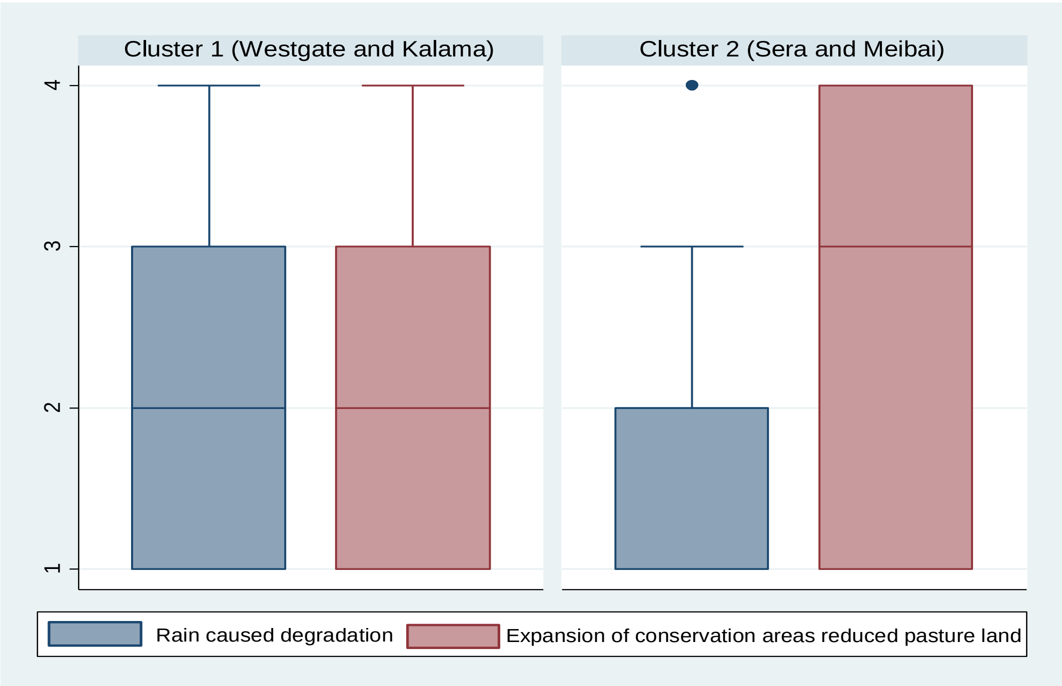
Rangeland risk, measured by the perceived reduction in pasture productivity, indicated adverse condition in this study. Generally, 100% of the sampled households acknowledged that rangeland productivity has reduced over the past 10 years. The decline was associated with both endogenous and exogenous factors relating to pastoral system. Table 5.9 shows that unreliable rainfall, causing droughts, was ranked the top factor causing rangeland squeeze, with 96% agreement. This variable was included to measure the extent of droughts in causing pasture degradation as compared with other social-political factors. Households also perceived expansion of core conservation areas (84% agreed) and human settlements (66%) as important risk elements eating into critical grazing areas ranking second and third respectively. The least contributors to reduced rangeland access are ethnic conflicts, overstocking and increased trading centres with only 25%, 17% and 7% of households agreeing.

Household ranking on the main causes of shrink in grazing rangelands differ between sample areas depending on the intensity of conservation activities being undertaken. Figure (5:2) shows that areas surrounded by intense tourism activities (cluster 1) ranked drought and conservation activities as the most limiting factors to access to sufficient pasture. Areas further away from national parks and newly created community conservancies (cluster 2) on the other hand ranked drought far much higher than creation of core conservation areas. One way ANOVA was used to test differences in means for rangeland risks ranking. While there was no significant differences in the mean ranking for drought as the top rangeland risk ($p=0.518$), we fail to accept the hypothesis of equal means for the risk associated with expansion of core conservation areas ($p=0.0057$) between the two clusters. Those areas with long standing establishment of restricted areas (cluster 1; Westgate and Kalama), rated pressure from conservation activities as a threat towards pastoral rangeland higher compared with areas with newly created conservancies (cluster 2; Sera and Meibai). Other factors affecting rangeland were not significantly different between these two broad categories based on proximity to core conservation areas.

Table 5:9: Factor contributing towards limited rangeland access

	Percentage Agreement			
Reason for reduced rangelands	Disagree	Neither agree nor disagree	Agree	Rank
Unreliable Rain	0.48	3.37	96.15	1
Enhanced conservation	14.56	1.46	83.98	2
Human settlements	30.29	3.85	65.87	3
Pest dominance	55.34	6.31	38.35	4
Predation increase	30.73	6.34	62.93	5
Increased Conflicts	63.94	10.58	25.48	6
Overstocking	80.69	1.98	17.33	7
Trading centres	90.82	1.93	7.25	8

Figure 5:2: Regional differences on drought ranking and conservation activities



Traditional and modern ways of improving rangeland productivity used in the area were tested to propose the perceived superior strategies for potential use in the SD modelling. Mitigation strategies against rangeland risks proposed during the focus group discussions were listed and preference assessed and ranked. Households asked on their agreement and ranking of the generated list of interventions, pasture utilization and preservation emerged important (table 5:10). Grass planting and rotational grazing were ranked the top two applicable strategies respectively. Previously degraded rangelands were found to have recovered since the local institutions started a program of planting grass. This sometimes is done in conjunction with rotational grazing to allow newly planted grass to develop strong roots for future germination. Rotational grazing and restriction of dry period grazing areas were closely ranked at second and third respectively. Reducing household per capita livestock was least desired with only 10% of households agreeing to it. The perception, on destocking, indicates that livestock are less destructive to rangeland productivity or they are not overstocked to the extent of causing degradation.

Table 5:10: Mitigation strategies for reduced rangeland productivity

	Percentage agreement			
Mitigating rangeland reduction	Disagree	Neither agree nor disagree	Agree	Rank
Planting grass	11.54	10.58	77.88	1
Rotational grazing	7.21	4.81	87.98	2
Restrict dry period grazing areas	12.08	4.35	83.57	3
Planned settlement	21.63	1.44	76.92	4
Destock some livestock	85.44	4.37	10.19	5

5.2.5 Market Risks

Household vulnerability hence food insecurity sometime result from lack of or unstable livestock markets to encourage pastoralists to sell their stock to acquire market products. Households keep livestock during drought crisis for varied reasons some of them social while others are economic. The results indicate that households generally hold livestock, even during stress period, as a result of low prices and lack of buyers. Table 5.11 shows that low prices and lack of buyers were ranked first and second respectively overall, although lack of buyers was highly rated by those households with monthly income between US$ 25-50 (Ksh 2,000-4,000). Regional variation was also evident in ranking the impediments towards livestock sales during drought periods. Region one ranked poor body condition as the second most important reason preventing households from sale of livestock during stress periods. The results of the analysis indicates that there is a significant difference in the medians ranking for low livestock pricing as barrier to livestock sales, χ^2 (2, N=208) =7.46, p=0.02 among the income levels. All households earning income over Ksh 4000(US$ 50) ranked low livestock prices as top three. This was closely followed by those with an income band below Ksh. 2000 (US$ 25). There is no evidence of differences in median ranking for either lack of buyers or poor livestock body conditions across income classes. The results on the regional clusters on the other hand shows a significant difference between rankings for low prices (Kruskal-Wallis, z=-2.337, p=0.019), lack of buyers (Kruskal-Wallis, z=6.367, p<0.001) and poor livestock body condition (Kruskal-Wallis, z=-2.476, p=0.013). Regional analysis result indicates that cluster two ranked lack of buyers as the limiting factor to livestock sales more than cluster one. Cluster one on the other hand ranked both low prices and poor livestock body conditions as the factors preventing livestock sales.

Table 5:11: Reasons for holding livestock during drought years

Reason for holding livestock	Overall rank	Income levels ranks			Regional Clusters	
		Below Ksh. 2000	Between Ksh. 2000-4000	Above Ksh. 4000	One	Two
Low livestock prices	1	1	2	1	1	2
Lack of buyers	2	2	1	2	3	1
Poor body conditions to trek	3	3	3	3	2	3
Expectation of sudden rains	4	4	4	4	4	4
Lack of weather forecasts	5	5	5	6	5	6
Inconsistent weather forecasts	5	6	6	5	6	5

5.2.6 Information Risks

Response strategies applied by households depends on the availability, timeliness and accuracy of early warning information. In this study, 46 % of households (n=96) responded that they never received early warning information on drought, with 54% (n=112) responded to have received some form of Early Warning (EW) information. Strategies identified during focus group discussion were listed and households asked to acknowledge all the strategies they used following the EW information. Out of those households who received early warning information (n=112), 64% of them engaged into market off take in addition to other strategies (table 5:12). Households also used a combination of other strategies such as migration to known dry period grazing areas (52%) as well as buying supplementary feeds for the animals (48%). Using a two sample Wilcoxon rank-sum (Mann-Whitney) test, the results indicate a statistically significant difference in the underlying application of response strategies given disclosure for early warning between the two regional clusters. Selling of livestock (Wilcoxon-Mann-Whitney, z=-3.238, p=0.0012), migration to known dry period pasture areas (Wilcoxon-Mann-Whitney, z=4.692, p<0.001) and purchase of supplementary livestock feeds (Wilcoxon-Mann-Whitney, z=-3.935, p<0.001) were all found to be statistically different between clusters. Sale of livestock and purchase of supplementary livestock feeds were higher for cluster two (Sera and Meibai regions) than it is for cluster one (Westgate and Kalama). Migrations in search of good pasture for livestock is however applied by more households in cluster one than for cluster two. This is because cluster two sample areas are geographically located near dry period grazing areas and a further deterioration of pasture condition indicates bleak future. Cluster two on the other hand was closer to major towns and conservation areas and migration is a common practice to mediate the effects of drought, mainly shifting to regions near cluster two.

Table 5:12: Multiple strategies undertaken given early warning information

	Strategy	No (n=112)	Yes (n=112)
1	Sell some of livestock to a manageable level	36%	64%
2	Shift livestock to traditional dry period grazing areas	48%	52%
3	Bought livestock feed supplements	52%	48%
4	Dropping school going students to provide more labour	96%	4%
5	Other strategies (e.g. slaughter or do nothing)	96%	4%

5.2.7 Mitigation Strategies

Household respondents were asked for their recollections of the recent droughts which occurred during the years 2006 and 2009. The key reason for this was to gain insights into the response strategies towards utilised to mitigate the threats on livestock as well as food security. The most common response strategy employed is mobility strategy which was ranked the top with over 90% of households agreeing on using it (table 5:13). Households receiving EW information as well as those accustomed to the traditional drought response strategies shift their livestock to areas with better pasture and water conditions. This was closely followed by a similar strategy where labour is subcontracted from relatives and friends to migrate livestock to areas where pasture and water would be available (80.68%). Households with limited labour to herd livestock (those with young children or with all their children in school) often request their neighbours to shift their livestock to areas of good pasture and water. Very few households (5%) agreed on paying for someone to take care of livestock during drought seasons. Only 4% of the households agreed on dropping out their school going children to look after the livestock. Those disagreeing on dropping out their children from school (90%) indicate that the need for extra labour to hear livestock rarely come from the school-going category. Although ranked fifth, shifting livestock and households from one place to another in search of pasture and water was acknowledged by about 9% of the households sampled indicating reduced level of nomadic lifestyle.

Table 5:13: Response strategies towards poor pasture conditions

Response Strategy towards 2006 & 2009 drought	Level of agreement (percentage)			Rank
	Disagree	Neither agree nor disagree	Agree	
Shift livestock only in search of pasture	8.65	0.48	90.87	1
Request relatives/ friends to look after livestock	18.36	0.97	80.68	2
Buy supplementary feeds/forage for livestock	50.72	0.48	48.79	3
Sell some heard to a smaller population	43.48	14.49	42.03	4
Migrate livestock and households together	86.34	4.88	8.78	5
Pay for someone to look after livestock	94.63	0.00	5.37	6
Drop out school going to heard for livestock	90.73	4.88	4.39	7

Households respond towards droughts and other shocks by utilising on their available resources. In this study, households responded towards food insecurity associated with drought period mainly using small stock. Small stock represents sheep and goats while large stock represents cattle and camels in this study. Table 5.14 shows that over 96% of households acknowledge to have sold small stock to respond to food shortages arising from the drought years 2006 and 2009. Sale and slaughter of small stock were the most common food security strategies and were ranked first and second respectively. Interestingly, households ranked the traditional livelihood source of drawing blood (79%) above either sale or slaughter of large stock, 58% (rank 5) and 52% (rank 4) respectively. Other forms of food insecurity response strategies adopted were charcoal burning (12%), migrating to trading centres (5%) and hunting of wild animals for food (1%). The results clearly show the importance of livestock as a response strategy towards food insecurity. The risks associated with livestock ultimately exacerbate the vulnerability of these sampled households. Frequent cases of food insecurity are likely to increase livestock sales, slaughter and mortalities associated with drawing of blood. The table also provide, at glance, the role played by small stocks in meeting food insecurity. Absence of food diversification strategies tie these households to the sources related to livestock.

Table 5:14: Response strategies towards food insecurity

Response Strategy towards food insecurity	Level of agreement (percentage)			Rank
	Disagree	Neither agree nor disagree	Agree	
Sell small stock	2.42	0.97	96.62	1
Slaughter small stock	9.13	9.13	81.73	2
Draw blood from livestock	19.71	0.96	79.33	3
Slaughter large stock	34.47	12.62	52.91	4
Sell large stock	31.71	9.76	58.54	5
Engage in charcoal burning	86.47	1.45	12.08	6
Migrate to trading centres	94.61	0.00	5.39	7
Wild hunting	98.55	0.48	0.97	8
Exchange livestock for cereals	99.03	0.97	0.00	9

The current practices carried out by the government and other development partners were also investigated to establish their effectiveness. The four main strategies being carried out include supply of relief food aid, livestock destocking, supply of drinking water, and veterinary services. Food aid is supplied to households and schools while destocking program is carried out for cash or for slaughter. On the effective drought response strategies, households unanimously ranked relief food distribution as the best mitigation strategy towards drought disasters (table 5:15). This was closely followed by school feeding programme which includes distribution of food items to school going children. The results indicate a close link that households attach to droughts hence response strategies aimed at supplementing their food shortages. The third strategy involves the government buying emaciated livestock and distributes back the meat for as food relief. Strategies linked to livestock asset were however least ranked as effective strategies. These are market off-take (sales) for cash and veterinary services indicating the priorities of households as satisfying food shortfall first. There were no significant differences observed in ranking drought response strategies between different income levels using the Kruskal Wallis test. Similar results were observed for the two regions Wilcoxon-Mann-Whitney test indicating homogeneity in risk response among the pastoral households. The results show that households' perception towards the effectiveness of strategies is dependent on their immediate impact. The first three strategies involved relief food in one way or another while the last four relate to reactive strategies likely to prevent future vulnerability.

Table 5:15: Proposed effective drought response strategies

Drought response Effectiveness	Income levels ranks			Overall
	Below Ksh. 2000	Between Ksh.2000-4000	Above Ksh. 4000	
Relief food	1	1	1	1
School feeding program	2	2	3	2
Destock for slaughter	4	3	4	3
Permanent water	5	4	2	4
water tankering	3	6	5	5
Veterinary services	6	5	6	6
Destock for cash	7	7	7	7

Having ascertained the role played by livestock in this pastoral system, the study examined strategies perceived by the households as the most sustainable in ensuring survival of pastoralism. Table 5.16 shows both ranking and percentage of agreement to the strategy. Over 97% of households agreed that migration strategy is still a viable strategy used to mitigate adverse impact of rainfall variability. Other strategies highly recognised were herd split (88%) to diversify risk and maximise pasture consumption, investment of small stock species such as goats and sheep (83%), believed to be less affected by droughts. Similarly, veterinary services (91%) were considered as vital to reduce vulnerability of livestock to diseases so as to allow livestock to accumulate fat reserves necessary during droughts. These strategies were ranked in the order explained in this paragraph and as shown in table 5:16.

Table 5:16: Sustainable livelihood strategies

Rank	Sustainable livelihood strategy	Response percentage		
		Disagree	Neither agree nor disagree	Agree
1	Migration for pasture and water	0.48	2.4	97.12
2	Herd split-grazing management	9.13	2.88	87.98
3	Herd diversification-small stock	9.62	7.69	82.69
4	Veterinary services	5.29	3.85	90.87

5.3 Inferential Analysis

The study used Kruskal-Wallis test for non-parametric ordinal variable for independent groups to test the differences between the drought response strategies between income sources. There were no significant statistical difference between the underlying household rankings on food security responses and the main income sources (table 5.17). However, there is some statistical difference between slaughters of small stock among households receiving casual labour income with those without casual labour income (Kruskal-Wallis, z=1.808, p=0.07). Many households with no income from casual income ranked slaughter of small stock as a least option they adopted to respond on the food insecurity faced during the year 2006 and 2009 droughts. This suggests that households with casual income supplement their nutritional requirement by slaughtering small stocks. The results in general show that the responses towards food insecurity does not vary much with casual, livestock and employment incomes, which support 75% of the sampled households.

Table 5:17: Kruskal-Wallis test for income sources on food insecurity

	Household income sources					
	Casual labour		Livestock sales		Employment	
Response strategy	Z-score	P-value	Z-score	P-value	Z-score	P-value
Sell small stock	-0.094	0.9252	-0.703	0.4818	0.454	0.6496
Slaughter of small stock	1.808	0.0706	-1.595	0.1107	1.426	0.1539
Draw blood from livestock	0.73	0.4653	0.795	0.4267	0.234	0.8148

Further, the study investigated whether livestock ownership affects the amount of household income levels. The initial normality test was done for household livestock ownership and results indicated that they are negatively skewed. Livestock ownership measured by Tropical Livestock Units (TLU) was then transformed by using logarithms. The transformed data presented in figure (5:3) indicate a normal distribution. The results were tested again using skewness (p=0.49) and kurtosis (p=0.67). Using one way analysis of variance (ANOVA), there was no significant evidence showing differences in the number of livestock owned between the household income levels (table 5:18). This implies that the number of livestock owned did not significantly dictate the amount of monthly cash income earned by the households. Households do not sell their livestock regularly unless they are faced with food or emergency crisis. Despite the insignificance of the relationship between TLU and monthly household income, table 5.19 shows marginal increase of income levels with increase in the number of livestock. The results show that households with more livestock (mean log of TLU), were among the high income class, with those earning over US$ 50 monthly having higher TLU (log 1.20) as compared to those earning less than US$ 25 (TLU log 0.81).

Figure 5:3: Logarithm of TLU normal probability plot

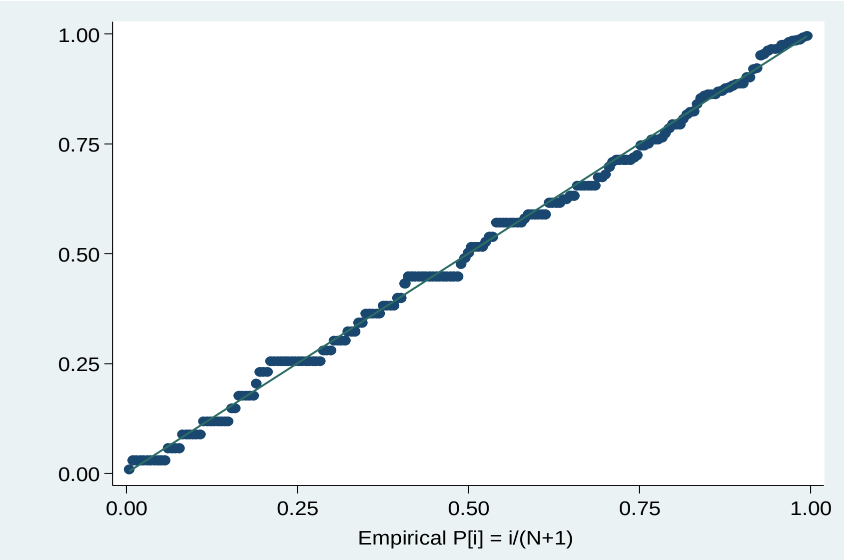


Table 5:18: ANOVA results for livestock owned against income levels

Source	Partial SS	Degrees of freedom	MS	F	Prob>F
Model	2.93	2	1.46	0.84	0.43
Income class	2.93	2	1.46	0.84	0.43
Residual	329.10	190	1.73		
Total	332.02	192	1.73		

Table 5:19: Logarithm of TLU distribution between income levels

Income class	Mean (log of TLU)	Standard Deviation	Frequency
Below Ksh. 2000	0.81	1.33	137
Ksh. 2000-4000	0.88	1.18	34
Ksh. Above 4000	1.20	1.43	22
Total	0.87	1.32	193

5.4 Chapter Summary

Cross-sectional data results showed that 49% of household members are either unemployed or tending livestock and 50% attending schools. About 37% of the sampled households substantially generated their monthly income from livestock directly or indirectly. Regardless of the income source reported by the households, 75% of them earned below US$ 25 a month translating into less than US$ 1 a day. Only 6% of the sampled households earned US$ 50 and above per month majority of them from those mainly depending on formal employment.

On average, households owned 5.31 TLU with small stock dominating domestic species owned. The amount of human labour required to look after livestock and milk produced during drought and non-drought years varied. Investment on veterinary services was found to be minimal for all the livestock species but relatively higher for camels than it is for small stock and cattle.

The results further indicated that livestock, kept for milk, meat and sales have declined over the past 5 years. The decline is attributed to the recurring droughts, household consumption, ethnic conflicts and diseases. The rangeland supporting pastoral system is also under great risk of reduced productivity with 100% of households reporting decline in rangeland productivity resulting from droughts, enhanced conservation activities and increasing human settlements. Other effects of droughts include collapse in livestock markets due to reduced buyers, increased sellers and poor body conditions for the livestock. These conditions limit the likelihood of farmers to sell off their livestock even during drought conditions.

Mitigation strategies mainly used by households to reduce livestock mortalities included migration, planned settlement, grass planting, buy supplementary livestock feeds. Households also respond to the effects of droughts by selling small stocks, slaughter of small stock and draw blood from live animals. There was no statistically significant difference between the strategies adopted and (1) the income level (2) region or (3) income source. This showed greater homogeneity among pastoral communities living in the sampled area.

6 Results: Pastoral Drivers and Wellbeing

6.1 Introduction

This chapter focuses on the analysis of the two sources of secondary data used to achieve the second objective of this study. This chapter is organised according to the framework adopted (see section 1.7) to assess the effects of droughts and other selected drivers on the key vulnerability indicators. The chapter uses a 5-year panel data sourced from ALRMP to establish vulnerability links and NDVI data for the period 1984-2010 to establish the frequency and extents of droughts in the sample area.

6.2 Sample Characteristics

6.2.1 Household Demography

The secondary household-level data available provided information on the spatial and temporal variability in the regions being investigated. The average monthly samples for all regions were 30 households with a total of 6,630 interviews (table 3:2). Data for some months was missing for some sample areas and where data was available, some values were missing. These missing months and values were random among the sample areas. Generally, the 5 sites had been surveyed between 36 to 48 times out of the possible 51 waves (January 2006-March 2010). At least 80% of annual desired waves were carried out every year for the period under review and 87% of the total period[9]. Households across the region were equally distributed in terms of members per households (table 6:1). On average, there were 5.9 members per household, with higher household populations recorded in Swaari and West gate at 6.1 members. The lowest average household membership was observed in Sereolipi (5.5) for the period 2006-2010.

Table 6:1: Household size

Sample Area	Monthly households interviewed	Household Members (mean)	Standard Deviation	Frequency
Laresoro	30	5.9	0.45	47
Lodung'okwe	30	5.7	0.35	48
Sereolipi	31	5.5	0.28	36
Swaari	30	6.1	0.31	42
West Gate	30	6.1	0.48	48
Total	30	5.9	0.44	221

[9] Computed as [(222 actual samples/(5 sites * 51 possible waves)]=0.87

6.2.2 Financial Capital Dynamics

As discussed earlier, the proxy for pastoral financial capital is measured by TLU dynamics. During the two drought years (2006 and 2009), the total livestock ownership varied with a lower mean of 8.05 TLU in drought years compared to 9.52 TLU during higher rainfall years (table 6:2). The average mortality rates for 2006 and 2009 combined have remained high especially during drought years with the Small Stock Unit (SSU) registering 9.4% and 8.26% for cattle. The high standard deviation arises from disparity in the mortality rates within the year where earlier months of the year posting low rates compared to the very dry months of August-October. Sales rate was also influenced by drought conditions with more SSUs sold during drought years. SSU sales rate during drought years was 4.77% compared to non-drought years, which reported monthly sales rate of 3.47%. There was a marginal observable increase in the sales rate for cattle from 1.07% monthly during good rainfall years to 1.54% during drought years.

Table 6:2: Herd size, births, mortalities and sales

Drought State	*Household TLU*	*Birth Rate SSU (%)*	*Birth Rate Cattle (%)*	*Mortality Rate SSU (%)*	*Mortality Rate Cattle (%)*	*Sales Rate SSU (%)*	*Sales Rate cattle (%)*
No Drought	9.52	10.90	7.06	5.59	0.89	3.47	1.07
Drought Exist	8.05	6.55	2.23	9.41	8.26	4.77	1.54
Total	8.83	8.93	4.87	7.36	4.31	4.06	1.28

There are significant relationships observed between livestock birth, mortality and sales rates (table 6:3). Small stock birth rates were positively related to the TLU ($r = 0.607$ $p < 0.01$) and were negatively related to cattle sales ($r = -.4304$ $p<0.001$). The drought factor was negatively related to birth rates for livestock species ($r=-0.459$ & $r=-0.354$ for SSU and cattle respectively both with $p<0.05$). However, drought was correlated with livestock mortality rates and sales rates. In this case, cattle mortality rate was positively correlated with drought factor ($r = .571$ $p<0.001$).

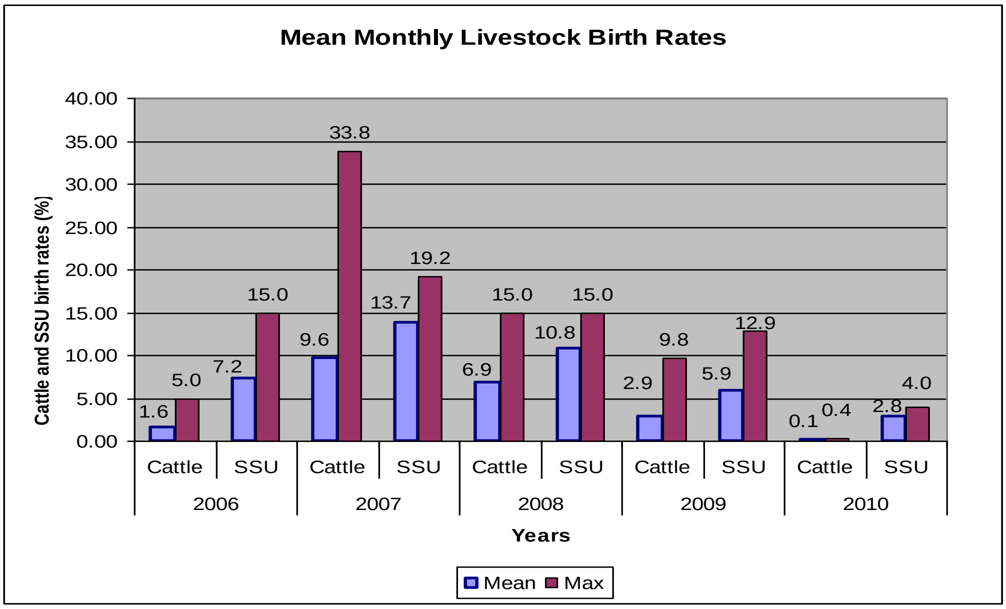
Monthly birth rates for both small stock and large stock (SSU and cattle) appeared to follow a similar trend over the years with a higher annual variability observed for cattle than SSUs. The year 2007 recorded the highest birth rates for both species; mean monthly rates of 9.6% and 13.7% were recorded for cattle and SSU respectively while 2010 recorded the lowest birth rates (fig. 6:1).

Table 6:3: Correlation between herd size, births, mortalities and sales

	TLU	*Birth Rate SSU*	*Birth Rate Cattle*	*Mortality Rate Cattle*	*Mortality Rate SSU*	*Sales Rate SSU*	*Sales Rate Cattle*	*Drought Factor*
TLU	1							
Birth Rate SSU	0.607*	1						
Birth Rate Cattle	0.445*	0.365*	1					
Mortality Rate Cattle	-0.337*	-0.512*	-0.301*	1				
Mortality Rate SSU	-0.307*	-0.473*	-0.265*	0.820*	1			
Sales Rate SSU	-0.215*	-0.252*	-0.250*	0.298*	0.1959*	1		
Sales Rate Cattle	-0.430*	-0.27*	-0.169*	0.210*	0.1949*	0.436*	1	
Drought Factor	-0.38*	-0.46*	-0.35*	0.57*	0.36*	0.39*	0.37*	1

**Significance level at 95% confidence interval*

Figure 6:1: Livestock birth rates by year and species



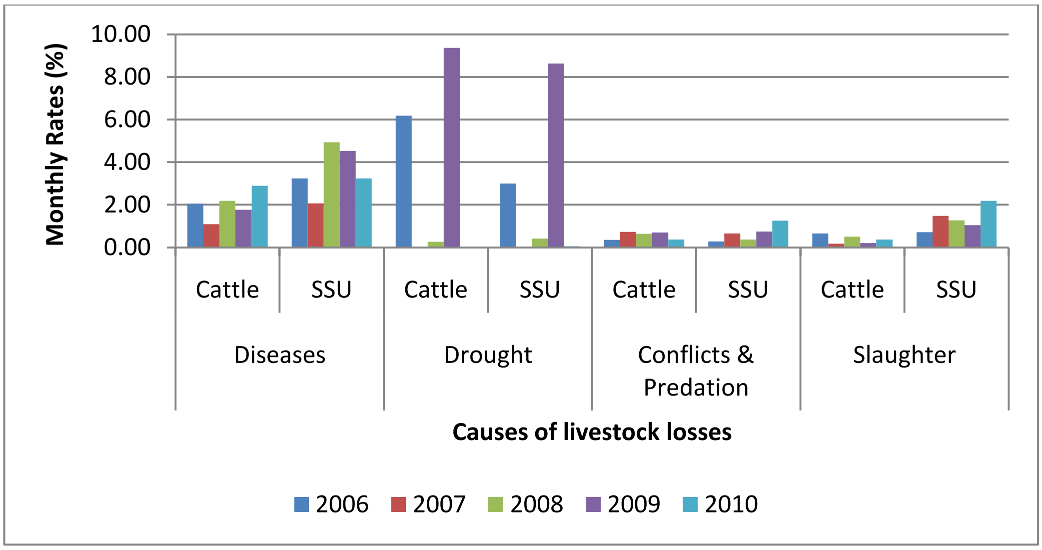
Birth rates for both small stock and cattle were correlated with NDVI used as a proxy for pasture resource condition. Table 6:4 shows that current NDVI values have lower effects on the cattle's birth rates than the small stock. Significantly higher birth rates for cattle were recorded in the 10-12 months following an increase in NDVI. The results showing a lagged birth rate is not surprising because the gestation period of cattle is 9 months and good pasture condition increases fertility. Similarly, small stock animals whose gestation period takes between 4-5 months is also observable from the statistics as a higher significant correlation is evident after a lag of 4-8 months ($r=.34-.54$, $p<0.001$).

Table 6:4: Correlation between livestock birth rates and NDVI

	Normalized Differenced Vegetation Index (NDVI)								
	Lag 0	*Lag 4*	*Lag 5*	*Lag 6*	*Lag 7*	*Lag 8*	*Lag 9*	*Lag 10*	*Lag 11*
Birth Rate Cattle	0.09	0.03	0.11	0.29*	0.46*	0.33*	0.15	0.32*	0.45*
Birth rate SSU	0.30*	0.49*	0.54*	0.50*	0.47*	0.34*	0.04	-0.07	0.01

Livestock losses from diseases are common to both cattle and small stock for the period under review (figure 6:2). However, small stocks are more affected than cattle with a monthly mortality rate of between 2% and 5% as compared to 1-3% for cattle. Slaughter, conflicts and predation accounted for less than 2% each for both species during the period. The highest mortality rate recorded for both species was from drought related causes. A monthly percentage of livestock dying from drought was recorded for the years 2006 and 2009. The percentage for cattle was 6% and 9.5% for the years 2006 and 2009 respectively while SSU recorded 3% and 8.5% for the same years.

Figure 6:2: Livestock monthly mortality rates by year, species and causes.



The variability of livestock mortality rates seems to be influenced by the existence of drought. Figure 6:4 shows the variability of livestock mortality rates during drought and non-drought years. The years which experienced droughts, 2006 and 2009, had the highest monthly mortality rates averaging at 10% and 5% for SSU and cattle respectively. This rate was high compared to 5% and about 2% for SSU and cattle respectively during good rainfall years.

Figure 6:3: Livestock mortality rate between drought and non-drought years

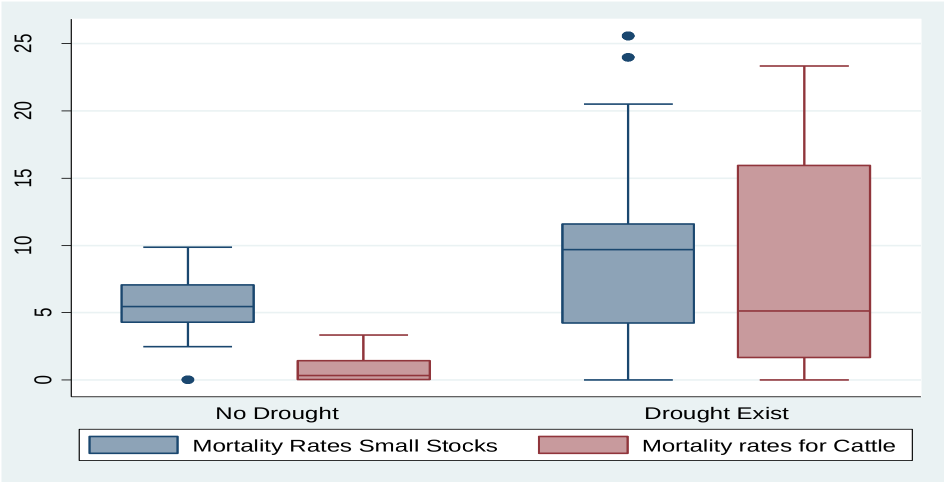
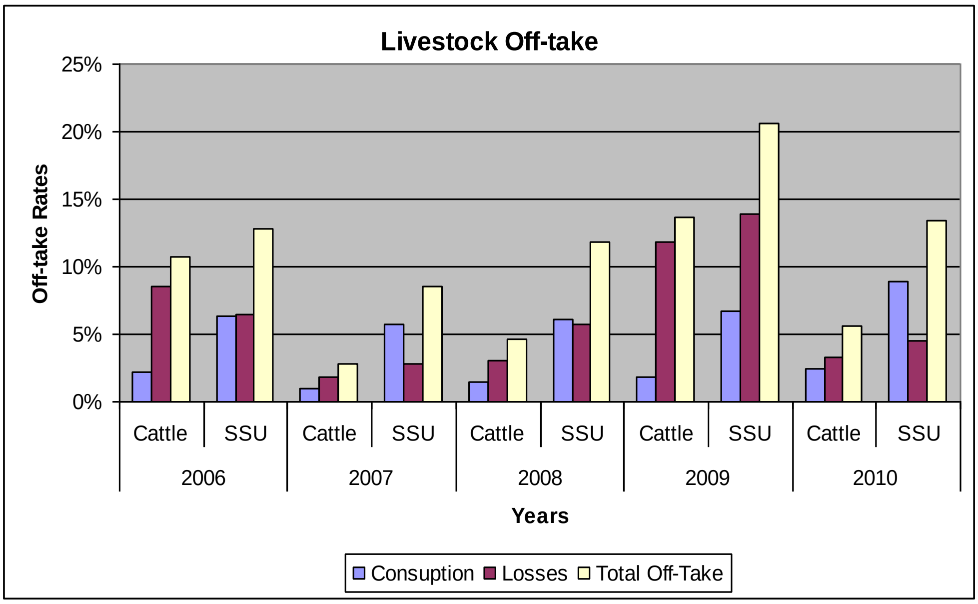


Figure 6:4: Causes of livestock off-take



Livestock dynamics depend on births and off-take resulting from sales, slaughter, deaths, and other losses such as theft. Sales and slaughter are mainly for household consumption and generally fall within household control. However, some off-takes are external to household decisions and result into losses. These monthly off-take rates arising from externally-driven losses (diseases, drought, conflicts and predation) and household consumption (sale and slaughter) range between 2-14% for cattle and 9-21% for SSU (fig 6:4). Losses were significant for both species during the years 2006 and 2009, the same years when mortalities were highly influenced by drought. It is indicative that pastoral households suffer a perpetual loss on their financial capital.

6.2.3 Human Capital Dynamics

Human capital relates to the capacity of the pastoral community to respond to environmental stressors when they arise. These include knowledge and skills endowment as well as the health status of the population (the current data only allows for a proxy measurement of health condition, MUAC). Malnutrition among children below 5 years is a chronic indicator of food insecurity and measures respond rapidly to nutritional stressors. The population is assumed to be in need of food supplement depending on the percentage of children at risk of malnutrition measured by their Middle Upper Arm Circumference (MUAC), a commonly-used anthropometric index. The percentage at risk refers to children whose MUAC readings are below 135mm, a target used by The World Health Organization (WHO) as the possible minimum before children are exposed to malnutrition.

Table 6:5: Effects of drought on Malnutrition and distance to pasture resources

	Variables Measurements	Mean	Standard Deviation	Minimum	Maximum
Good Rainfall Years	MUAC percentage	16.87	5.67	8.54	32.46
	Grazing distance (km)	10.35	3.53	2.02	19.08
	Distance to water source (km)	5.17	2.72	0.94	13.66
Drought Years	MUAC percentage	24.03	6.15	13.26	38.60
	Grazing distance (km)	36.52	28.79	2.56	88.00
	Distance to water source (km)	7.02	4.33	0.98	15.75
The Whole Period	MUAC percentage	20.20	6.89	8.54	38.60
	Grazing distance (km)	22.49	23.67	2.02	88.00
	Distance to water source (km)	6.03	3.67	0.94	15.75

Table 6:5 shows that a higher malnutrition among children age 5 years and below is observed during drought years. Malnutrition rate during drought years is 50% higher than the malnutrition level during normal rainfall years. Normal year's malnutrition rates average at 16% which increases to 24% during drought years. On average, there is a high rate of malnutrition among the children below 5 years at about 20%. There is an associated high variability on malnutrition rates during drought event as compared to the normal rainfall years. Grazing distances for the livestock increases from 10 km to 36 km as pasture condition deteriorates around densely populated areas. Similarly, rainy season water access points for households dry up forcing them to travel an average distance of 7 km to fetch water during drought period compared to the normal 5 km.

Pastoral households with higher livestock ownership are less likely to have malnourished children. Children depend on livestock output, directly and/or indirectly for dietary requirements. Table 6:6 shows that 61% of households owning less than 5

TLU are likely to experience a risk of greater than 29% malnutrition rate with only 8% of those households having a rate of malnutrition below 10%. Wealthier households with TLU exceeding 15 are less likely to suffer high rates of malnutrition. These households are likely to have about 52% of their children experiencing a risk of malnutrition rate below 10%. Only 16% of households in the wealthy class of above 15 TLU are likely to have over 30% of their children at risk of malnutrition. In total, 25% of households had over 30% of their children at risk of malnutrition. On the other hand, 31% of households experience a child risk of malnutrition rate below 10%.

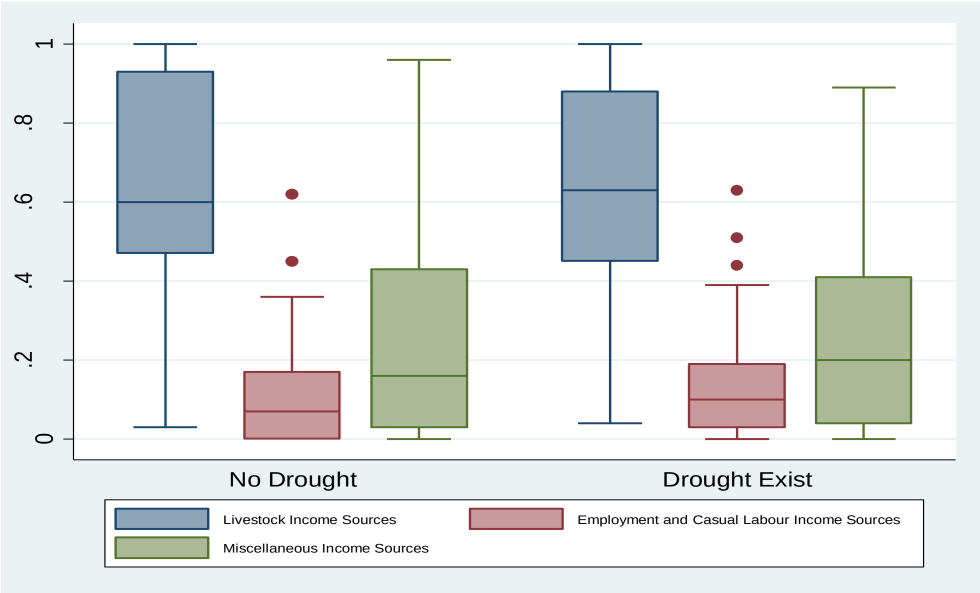
Table 6:6. Distribution of malnutrition by livestock ownership

		Categorical variable for TLU				
		0-4	5-9	10-14	15 and above	***Total***
Categorical variable for malnutrition	Below 10%	4	19	33	13	***69***
		8%	21%	56%	52%	***31%***
	10-19%	3	34	13	5	***55***
		6%	37%	22%	20%	***25%***
	20-29%	12	21	8	3	***44***
		24%	23%	14%	12%	***20%***
	30% and above	30	17	5	4	***56***
		61%	19%	8%	16%	***25%***
Total		***49***	***91***	***59***	***25***	***224***
		100%	***100%***	***100%***	***100%***	***100%***

6.2.4 Social Capital Dynamics

It is difficult to define an adequate measure of social capital in communities at local to regional scales without access to a detailed analysis of social networks and material flows at the household level. Many social support mechanisms in times of hardship are informal (through family, friendships, etc.). In a formal sense, however, the development of a proxy for social capital can be identified through government interventions during crisis events, such as the provision of food relief or through international food aid and other charitable support. Indeed, as countries become wealthier, benevolent governments generating financial resources through taxes or the sale of natural resources capital create national social security systems such as unemployment benefits. For this study, our proxy of social capital was represented descriptively by the proportion of households receiving government food relief and the variability in the proportion of their total income sources between sustainable and unsustainable.

Figure 6:5: Impact of drought year on household sources of income



Pastoral households derive income from three main sources. The most common source is the sale of livestock and livestock products such as milk, hides and skins. This is supplemented by other income derived from employment and miscellaneous sources. Formal and casual sources comprise the employment income. Miscellaneous sources on the other hand include gifts from family and friends, sale of firewood and charcoal and financial remittances from outside the region. The diversity of livelihood sources remained relatively stable between drought and non-drought years with around 60-65% households depending on livestock income (figure 6:5). Miscellaneous sources were the next most important income supporting between 18% and 20% of the households while employment sources supported about 10-15% of the pastoral households.

Government and non-governmental organisations offer responses towards food insecurity by providing food relief. Food supplies are distributed to various communities for further sharing among the households. The proportion of households receiving food relief was recorded. The years 2009 and 2006 indicated a higher proportion of households were supplied with relief food with 78% and 74% respectively (table 6:7). On average, relief supply has served 25-100% of households for the period under review with the minimum number of households increasing from 25% to 40% during drought years.

Table 6:7: Proportion of households receiving food relief

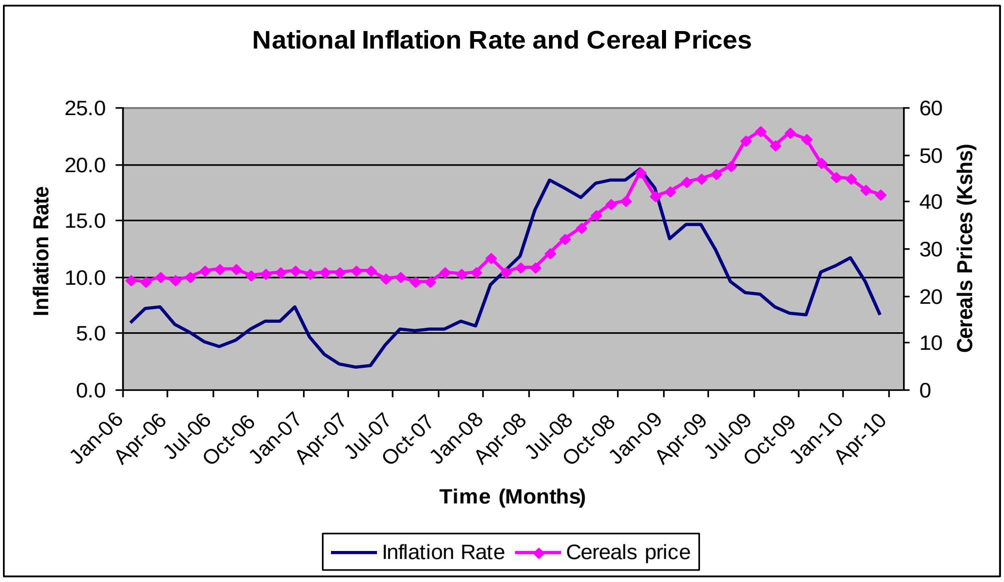
Year	Mean percentage of households receiving relief food (%)	Standard Deviation (%)	Minimum (%)	Maximum (%)
2006	74	28	40	100
2007	70	27	32	100
2008	68	23	25	100
2009	78	22	40	100
2010	67	17	42	80
Overall	***72***	***25***	***25***	***100***

6.2.5 Physical Capital Dynamics

Market condition is dictated by both micro and macro-economic factors. Prevailing food prices are influenced by national macro-economic effects such as inflation. Plotting inflation rates and cereals price trends indicate a strong relationship between the two. However, inflation rate has a delayed lag effect on cereals prices (figure 6:6). Stable inflation rates were observed in the period prior to January 2008. Despite the delayed effects, food prices and inflation rates are significantly correlated (r=.43 p<0.001). The spike in both food prices and the national inflation rates in the early period in 2008 could be attributed to the instability arising from the post-election violence which lasted for over two months between January and March 2008.

Figure 6:6: Inflation rate and cereal price trend

Table 6:8 shows annual trend of inflation rate, food and livestock prices. Cereal food



prices reached their highest levels at US$ 0.60 per kilogram in the year 2009 where inflation recorded second highest rates compared to the period average. Inflation and food prices rose over the period. There was no observable increase in cattle prices. The average annual cattle prices ranged between US$ 60.50 and US$ 102.00 with the lowest prices reported during the 2006 and 2009 against the 5-year trend of US$ 86.40. A similar trend is also observed with small stock prices where 2006 recorded the lowest price of US$ 8.30.

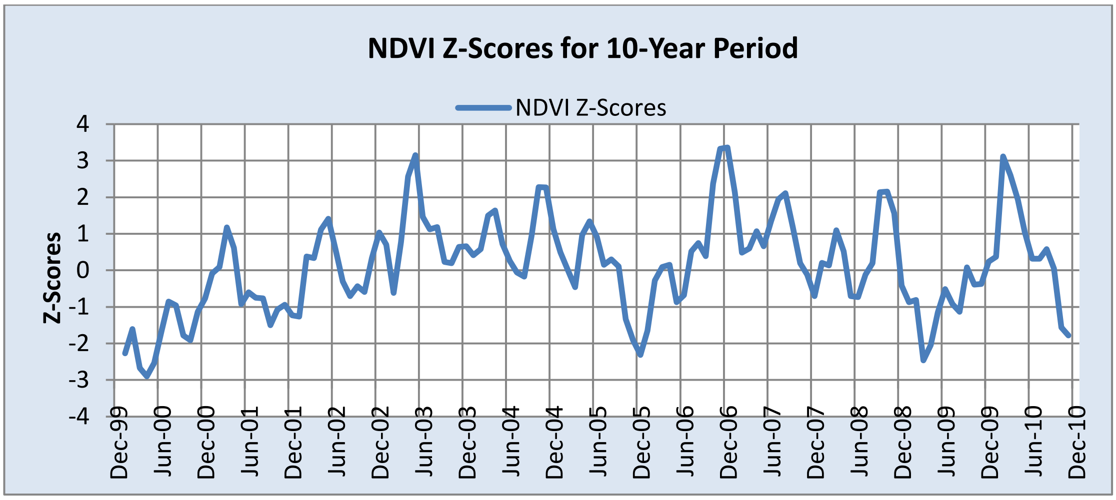
Table 6:8: Summary of inflation rates, food and livestock prices

Year	Statistics	Inflation Rate (%)	Food Prices (US$)	Cattle Prices (US$)	SSU Prices (US$)
2006	Mean	5.69	0.30	60.50	8.30
2007	Mean	4.25	0.30	102.00	11.20
2008	Mean	16.15	0.40	102.00	12.30
2009	Mean	10.28	0.60	77.00	10.30
2010	Mean	9.30	0.50	99.10	12.50
Total	***Mean***	***9.11***	***0.40***	***86.40***	***10.70***
	SD	***5.13***	***0.10***	***21.70***	***1.80***

6.2.6 Natural Capital Dynamics

The condition and health of Arid and Semi-Arid Land (ASAL) is measured by the land vegetation cover based on NDVI readings. In the past 10 years, there have been three major negative NDVI deviations from the long term mean suggesting poor pasture conditions during these events. The main droughts occurred in the years 1999-2001, 2005/6 and 2008/9 with year 2010 indicating a drought in 2011 (fig. 6:7). The poorest pasture condition (NDVI) was recorded in the years 1999, 2005 and 2009 with 2 standard deviations below the mean. Good conditions were observed during the short rains (October-December) of 2003, 2006 and 2009.

Figure 6:7: NDVI Z-scores for the period January 1999 to December 2010



Pasture condition (monthly NDVI) was highly positively correlated with the rainfall amount. The effects of rain was more significant in the month following the rainfall month indicating that there was a lag of one month for a substantial impact to be realised. Table 6:9 shows a higher correlation (r=.62 p<0.001) between the one month lagged rainfall amount and NDVI compared to concurrent monthly rainfall (r=.58 p<0.001).

Table 6:9: Correlation between rainfall and NDVI

		Rainfall		
		Lag 0	Lag 1	Lag 2
NDVI	Correlation Coefficient	0.5849	0.6207	0.1606
	Significance	0.0000	0.0000	0.0303

Based on the VDI model generating the results of figure 6:8, the year 2006 was concluded to be a moderate drought with an average index of about 0.9 (fig 6.9). The years following (2007 & 2008) enjoyed a relatively higher index of 1.8 and 1.3 respectively indicating a "no drought" state. However, the year 2009 recorded the worse pasture condition with an index of 0.3. This, according to the VDI model, suggests a "severe" drought condition compared to the rest of the 27 years period (1983-2009) which was used to calculate the long term means.

Figure 6:8: Drought identification using Vegetation Drought Index (VDI)

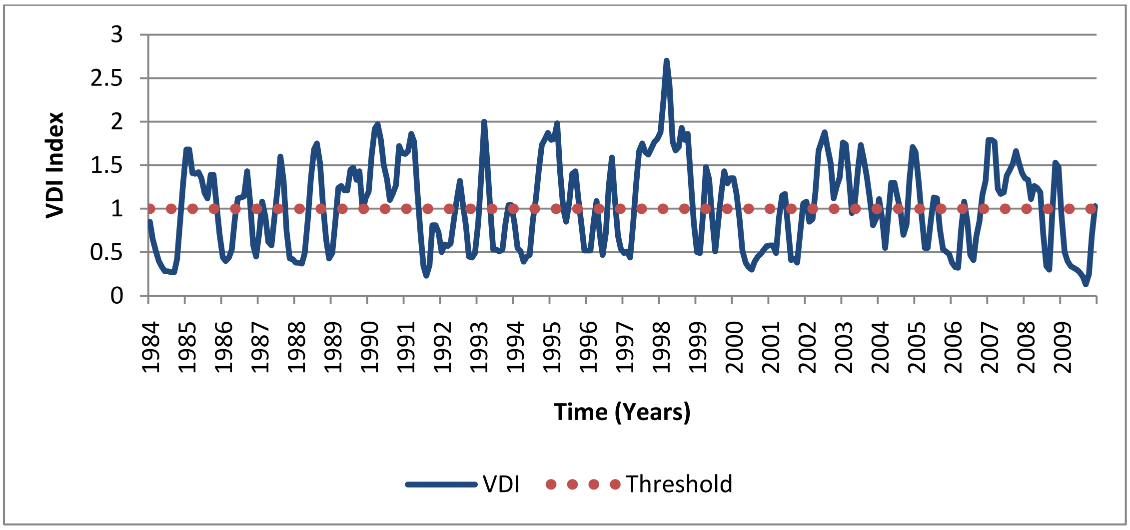
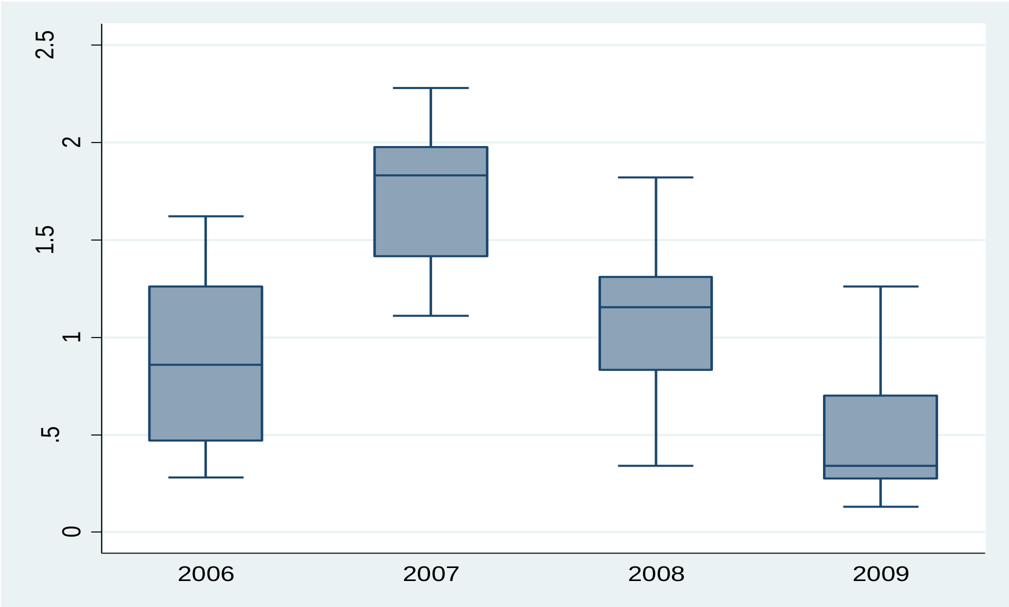


Figure 6:9: Vegetation Drought Index (VDI) by year



During the period January 2006 to March 2010, 53% of the time experienced non-drought conditions with the rest of the time being designated a mild, moderate or severe drought condition (table 6:10). Out of the 81 observed MUAC with percentage below 10%, 64% of the observations were recorded during the non-drought months. On the other hand, 50% of the 64 observations made for malnutrition risk above 30% occurred during moderate to severe drought months. The distribution percentage declined as malnutrition increased during the non-drought months but increased with moderate and severe droughts.

Table 6:10: Distribution of malnutrition on pasture condition

		Pasture condition			
		No drought (good condition)	Mild drought	Moderate to Severe drought	Total
Percentage of children (under 5 years) with MUAC below 135mm	Below 10%	52	5	24	**81**
		64%	6%	30%	**100%**
	10-19%	34	6	21	**61**
		56%	10%	34%	**100%**
	20-29%	22	4	23	**49**
		45%	8%	47%	**100%**
	30% and above	27	5	32	**64**
		42%	8%	50%	**100%**
	Total	**135**	**20**	**100**	**255**
		53%	**8%**	**39%**	**100%**

6.2.7 Vulnerability Dynamics

Stability of the previous forms of capitals determines the vulnerability state of the pastoral households. Healthy community with stable financial capital and physical capital supported by productive rangeland is less likely to be vulnerable. Pastoral households assess their vulnerability (poverty) based on the food, rangeland, market, livestock, and social network conditions. From table 6:11, West gate and Lodung'okwe sites recorded high poverty rates with only 11% and 23% respectively classified as better off households. Laresoro and Sereolipi however recorded the lowest proportion of poor households at 57% and 59% respectively. There is also an associated high variability with these wealthier regions indicating high sensitivity to drought occurrence. This can be attributed to the fact that poverty status is measured by the number of livestock owned at a point in time.

Table 6:11: Wealth categorization by sample area

	Wealth categorization		
Sample area	Mean Percentage Poor (%)	Mean Percentage Wealthy (%)	Standard Deviation (%)
Laresoro	57	43	12
Lodung'okwe	77	23	7
Sereolipi	59	41	21
Swaari	67	33	10
West Gate	89	11	9
Regional total	**71**	**29**	**17**

Figure 6:10: Wealth classification Trend by study area

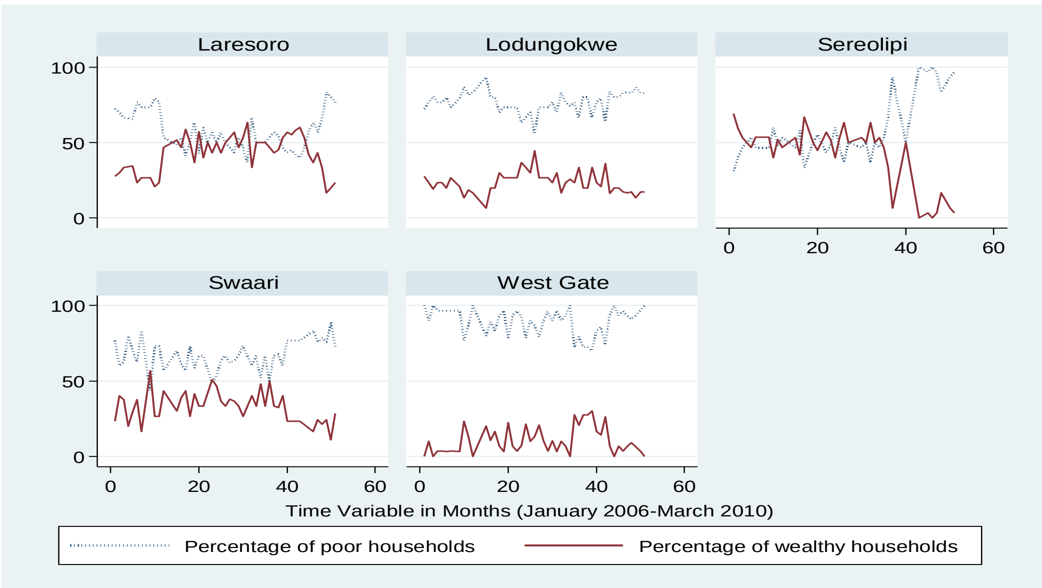


Figure 6.10 shows the trend in wealth classification among the target pastoral households. The period between month 1 and 12 is characterised with a rise in poor households and declining between month 13 and 36. A similar pattern was observed from the onset of the year 2009 (month 37) with increasing poor households.

6.3 Testing Normality

The main dependent variables for this study were fairly normally distributed and passed the assumption for statistical inferences and interpretation of results (D'Agostino et al., 1990). Livestock ownership (HHTLU), poor household percentage (POORPOP) and Meat-Cereals Price Ratio (MCPRATIO) have a low skewness suggesting a normal distribution. The percentage of children at risk of malnutrition was relatively highly positively skewed. Household TLU also has a Kurtosis close to normally distributed and not significantly different from 3, the desired target. Generally, the skewness for all dependent variables were not very much higher than 0 while the Kurtosis values were not much different from 3. Based on the results of Shapiro-Wilk normality test (Shapiro and Wilk, 1965), these dependent variables appear to be from a normally distributed sample for all the regions other than the MUAC percentage which was highly positively skewed. This test is appropriate for a sample size between 7 and 2000 (N-Range $7 \leq N \leq 2{,}000$). These results confirmed the test conducted above based on skewness-kurtosis (table 6:12). MUAC was then normalised by computing the logarithm of the regional percentages.

Table 6:12: Test of normality

	Dependent Variables			
	MUAC	HHTLU	POORPOP	MCPRATIO
Mean	20.195	8.835	70.502	109.849
Standard Deviation	16.147	4.381	17.256	31.942
Skewness	1.127	0.423	-0.122	0.061
Pr.(Skewness)	0.000	0.011	0.448	0.702
Kurtosis	4.670	2.913	2.066	2.261
Pr(Kurtosis)	0.001	0.953	0.000	0.001

6.4 Sustainable Livelihood Estimation

Table 6:13 summarises the drivers of pastoral wellbeing as classified into financial, human, physical, social and natural capital. Dependent variables, used as proxies for measuring these forms of capital, hence vulnerability are listed in the columns. The summary statistics reported include the coefficients of the independent variables (beta), significance level indicated in stars, the direction of change in the dependent variable, the constant (alpha) and the R-squared value.

Herd size accumulation which is derived from the natural biological process of births seems to be driven by SSU birth rates more than the cattle. On mortalities and herd reduction, cattle death rates associated with drought, diseases, and predation drives down TLU significantly more than the small stock. Sales rates for both SSUs and cattle reduce TLU although with varying significance levels. SSUs sales rate was highly significant (β=0.477, p<0.01) while that of cattle (β=0.477) was not significant at 90% confidence interval. The herd size (TLU) is highly influenced by good pasture conditions over the long term more than over short periods measured in 6 months. These variables and the model explain 67.1% of TLU variation in the area under review.

Physical capital comprises of the infrastructure available that allows the households to respond to vulnerability appropriately. In this study, market infrastructure is considered as the stability in market prices for both food and livestock prices. Market infrastructure is considered as the stability in market prices for both food and livestock prices. SSU prices were standardised to reflect the cost of a single kilogram of meat for comparison with same weight of cereals (Eq. 18 and 19). Table 6:13 shows MCP as positively driven by the cattle birth rates (β=0.869, p<0.01), TLU (β=2.972, p<0.05), child malnutrition rate (β=2.141 p<0.01) and both short and long run NDVI (β=133.56, β=164.25, β=115.326 for lag 0, 3 and 6 months respectively) However, cattle mortality rates (β=2.057 p<0.01) and sales rates (β=12.035 p<0.01) have a negative impact on the MCP. Relief supply, which is aimed at reducing demand for market cereals is observed to be negatively affecting MCP (β=0.295 p<0.01). The explanatory variables account for 82.1% of MCP variability.

$$P_{meat} = \left({}^{P_{stock}}/_{W_{stock}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 18$$

$$MCP = \left({}^{P_{meat}}/_{P_{cereals}}\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 19$$

Where in equation (18), P_{meat} represents the price per Kg of meat, W_{stock} is the standard weight of small stock (24 kg) and P_{stock} is the current market price for small stock. In equation (19), MCP represents cereals meat price ratio while $P_{cereals}$ is the price per kg of cereals (staple market foodstuff). The rationale is that one kilogram of meat is exchanged with a similar weight of cereals and an increase in this ratio suggests a superior purchasing power for the pastoral households.

The study also investigated the effects of the main sources of nutrients on MUAC. The

	Forms of Pastoral Capitals (significance p<0.01=***, p<0.05=**, p<0.1=*)

primary source is milk from breeding livestock. In this case, the lactating proportion of livestock is used as a proxy for measuring milk availability. Due to differences in milk production, lactating stock was subdivided into SSU and cattle. High birth rates among cattle (table 6:13) were highly significant in reducing the percentage of children at risk ($\beta=0.267$ $p<0.01$). Households also sell stock to purchase market foodstuff and other household utilities. The analysis showed a significant negative effect of small stock sales on malnutrition ($\beta=1.327$ $p<0.01$) while sale of cattle indicated a positive effect ($\beta=2.375$ $p<0.01$). Total assets ownership measured by TLU, which provide unmeasured nutritional benefit was also used and showed a significant negative relationship indicating a low risk of malnutrition with higher livestock levels ($\beta=1.454$ $p<0.01$).

On pasture condition (NDVI), malnutrition rate was higher during poor pasture conditions. The effect was more evident and highly significant when using a 3-months lag analysis ($\beta=43.446$ $p<0.01$) than observed for concurrent ($\beta=36.678$ $p<0.01$) or longer runs up to 6-months ($\beta=18.47$ $p<0.05$) lag NDVI. The results also show a positive impact of Meat-Cereal Price (MCP) ratio on malnutrition ($\beta=0.108$ $p<0.01$). Despite the government effort to supply food relief, the effect was still not sufficient to reverse the rate of malnutrition as the result indicate a statistically significant positive influence by proportion of relief on malnutrition ($\beta=0.053$ $p<0.01$). These independent variables explained 78.5% of variability in child malnutrition in the study area.

Vulnerability is measured by the proportion of poor households among the pastoral communities under investigation. Pasture condition, asset ownership, purchase power and malnutrition are used as covariates to social status. Table 6:13 shows that both short and long term NDVI seem to reduce the proportion of poor households ($\beta=9.349$, $\beta=7.802$, $\beta=35.677$ for lag 0, 3 and 6 months respectively) but only statistically significant in the long run, after 6 months ($p<0.01$). Similarly, an increase of TLU reduces the proportion of poor households significantly ($\beta=2.233$, $p<0.01$). Purchasing power measured by the MCP positively increases the proportion of poor households ($\beta=0.014$) but not statistically significant at 90% level of confidence. The analysis indicates a significantly higher influence of MUAC percentage on poverty levels ($\beta=0.194$ $p<0.1$). Covariates selected were strongly correlated to the dependent variable ($r^2=0.712$).

Table 6:13: Summary of the fixed effects model statistics

		Financial	Human	Physical	Social	Natural
Dependent Variables		Total Livestock Units (TLU)	Malnutrition (MUAC %age)	Market Volatility (MCP Ratio)	Poor Households (POOR)	Pasture Condition (NDVI)
Independent Variables	Birth rate Cattle	0.004 (+)	0.267*** (-)	0.869*** (+)		
	Birth rate Small stock	0.142***(+)	0.136 (-)	0.551 (+)		
	Mortality rates Cattle	0.062* (-)	0.297*** (+)	2.057*** (-)		
	Mortality rate Small stock	0.010 (-)				
	Mortality rate Camels			0.433 (-)		
	Sales rate Cattle	0.323 (-)	2.375*** (+)	12.035***(-)		
	Sales rate Small Stock	0.477*** (-)	1.327*** (-)	2.919 (-)		
	NDVI Lag 0	5.265* (-)	36.678*** (-)	133.561***(+)	9.349 (+)	
	NDVI-Lag 3	4.598 (+)	43.446*** (-)	164.25*** (+)	7.802 (-)	
	NDVI-Lag 6	9.262***(+)	18.470** (-)	115.33*** (+)	35.677***(-)	
	Livestock Asset Ownership-TLU		1.454*** (-)	2.972** (+)	2.233*** (-)	
	MCP Ratio		0.108*** (+)		0.014 (+)	
	MUAC<135mm percentage			2.141*** (+)	0.194* (+)	
	Proportion of food relief		0.053***(+)	0.295*** (-)		
	Rain Lag 0					0.0005***(+)
	Rain Lag 1					0.0007***(+)
	Rain Lag 2					0.0002** (+)
	Rain Lag 3					0.0001 (-)
Constant		7.898 (+)	56.452 (+)	52.639 (-)	96.644 (+)	0.301 (+)
R-Squared		0.671	0.785	0.821	0.712	0.645

6.5 Chapter Summary

The descriptive results of the panel data showed the existence of high human population growth with estimated average membership of 7 per household. Droughts, established to be a common phenomenon in this chapter affect households in various ways. Droughts influence livestock ownership, food insecurity, pasture availability, and poverty levels. Livestock herd accumulation is adversely affected by droughts by reducing birth rates and increasing mortality and sales rates. These conditions put households into intense food insecurity causing malnutrition among children. Government and other development partners have responded towards food shortages by providing food reliefs indicated by the results as increasing community proportion served. While the main sources of income do not vary with drought condition, the purchasing power is adversely affected by raising food prices compared with low livestock prices. There is also evidence of influence drought has on poverty rates despite high district poverty level average.

Statistical analysis showed significant effects of droughts on the TLU, malnutrition, purchasing power, rangeland and poverty rates. These were the main parameters estimated based on the research framework discussed earlier in section 1.7. On financial capital, TLU is significantly driven by birth and sales rates for small stocks, mortality rates for cattle, and pasture conditions. Human capital measured by malnutrition is also significantly affected by food availability from lactating livestock, sales of stock to acquire market products in addition to the pasture condition measuring drought level. The ultimate measure of pastoral poverty was also found to be highly and significantly affected by pasture condition, livestock ownership and the level of malnutrition. The selected variables for the models were significantly sufficient in predicting the proxies for the pastoral wellbeing, measured here using the 5 C's.

7 Results: System Dynamics Simulation

7.1 Introduction

Policy options tested on the pastoral SD model show varying outcomes when applied singly or in combination. The target outcome variables observed in this model were clustered around the forms of capital discussed in section 1.7 of this study (research framework). The policy options were generated from the survey interviews and focus group meetings with household and community representatives respectively, in addition to the literature review. These options aimed at improving the pastoral economy include reclamation, planned settlement, veterinary services, restocking, peace initiatives, destocking, supplementary feeding programs, and enhanced conservation of wildlife explained in detail in section 4.4. The variables, equations, and parameters are annexed as appendix III (a) and (b), parameterised into the visual SD models shown by appendices IV (a) to IV (f).

7.2 Human Capital Scenario Runs

Human population estimated using SD building blocks and growth model showed consistent results. The population grew from 59,000 to a total of 113,000 people over the 25 years, increasing the number of households from 9,800 to 19,100. The details of population growth and expansion in the number of households are important in evaluating policies affecting both human, financial, social and natural capitals. Growth in the human population dictates the amount of natural capital required for settlements, the number of livestock held and the general pressure that the subsystems exerts on the pastoral system as a whole. The SD model, building blocks and the causal loops are further illustrated in Appendix IV (b).

Table 7:1: Simulated result for skills base

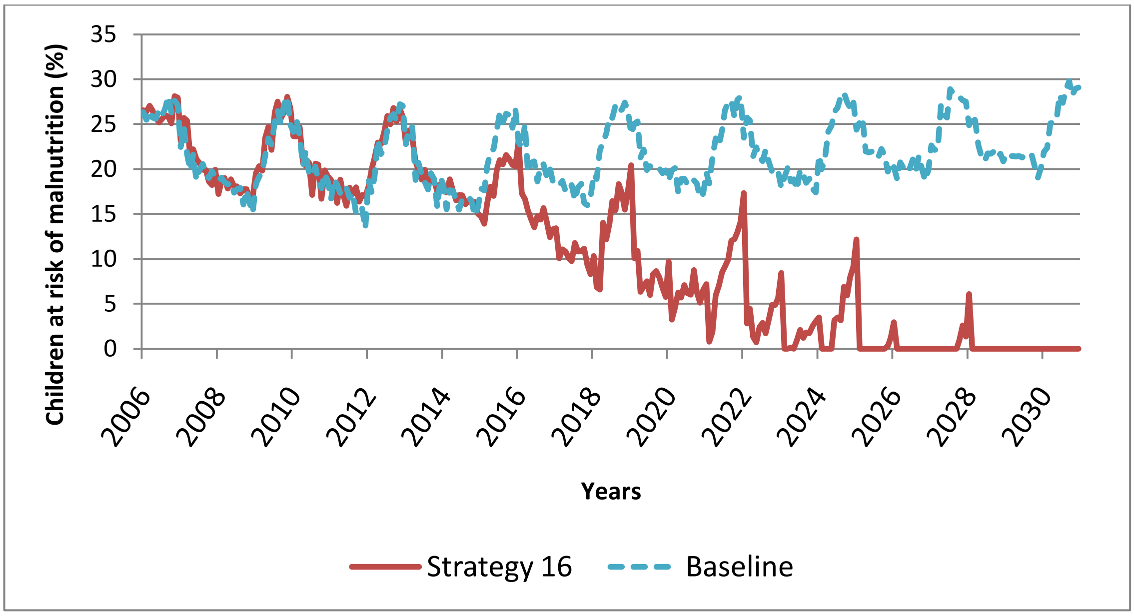
Year	Percentage of Skilled labour				Percentage of skilled and semi-skilled labour			
	Baseline	Enrolment	Dropout	Combined	Baseline	Enrolment	Dropout	Combined
2006-2010	0.12	0.12	0.12	0.12	1.82	1.82	1.82	1.82
2010-2015	0.56	0.56	0.56	0.56	3.38	3.40	3.24	3.24
2016-2020	1.72	1.76	1.76	1.80	6.00	6.44	4.96	5.16
2021-2025	3.34	3.66	3.60	3.96	8.96	10.44	7.24	8.14
2026-2030	4.96	5.96	5.60	6.72	11.76	14.62	9.68	11.74

Human capital measured by skill base is expensive and the impact is not felt until after a very long time. However, governments keen on development target the education system as an important avenue to create the skills base. The model results indicate a slow growth in the skills base for this pastoral community under the current circumstances dictated by low school enrollment rates and high dropout rates. In general, the proportion of both skilled and semi-skilled people in the total population remains below 13% in the year 2030 with less than 50% being skilled (appendix VII). Higher proportions of skilled and semi-skilled populations are observed over time, when the strategy of a national enrolment target is employed, leaving the dropout rate unchanged. This shift is caused by higher dropouts joining the semi-skilled population. Examination of the proportion of the skilled labour force to the total population offers the best measure for the human skill base.

The baseline result indicate a growth from the current figure of under 1% of skilled labour to total population to about 5.6% in the year 2030. This percentage is lower compared with 6.9%, 6.4% and 7.9% for the enrolment, dropout and combined strategies respectively. The results of the combined strategy indicate a better outcome in the long run in contributing towards building skills based human capital. The percentage of skilled and non-skilled labour combined was higher when enrolment rate is increased without reducing the dropout rate, with 16.3% in the year 2030 as compared to 13.2% based on a combined strategy.

Table 7:1, which shows five-year derived averages, confirmed the superiority of the combined strategy on improving the proportion of skilled labour. The proportion of skilled labour rose from below 1% in the period between 2006 and 2010 to 6.72% in the period 2025 and 2030. This was high compared with 5.6% and 5.96% for reducing dropout rates and enhancing enrollment rates respectively during the same period. all the three strategies produced much higher proportions of skilled labour than the baseline scenario which stood at 4.96% in the forecasted period of 2026-2030.

Figure 7:1: Comparison of strategy 16 against the baseline level of malnutrition

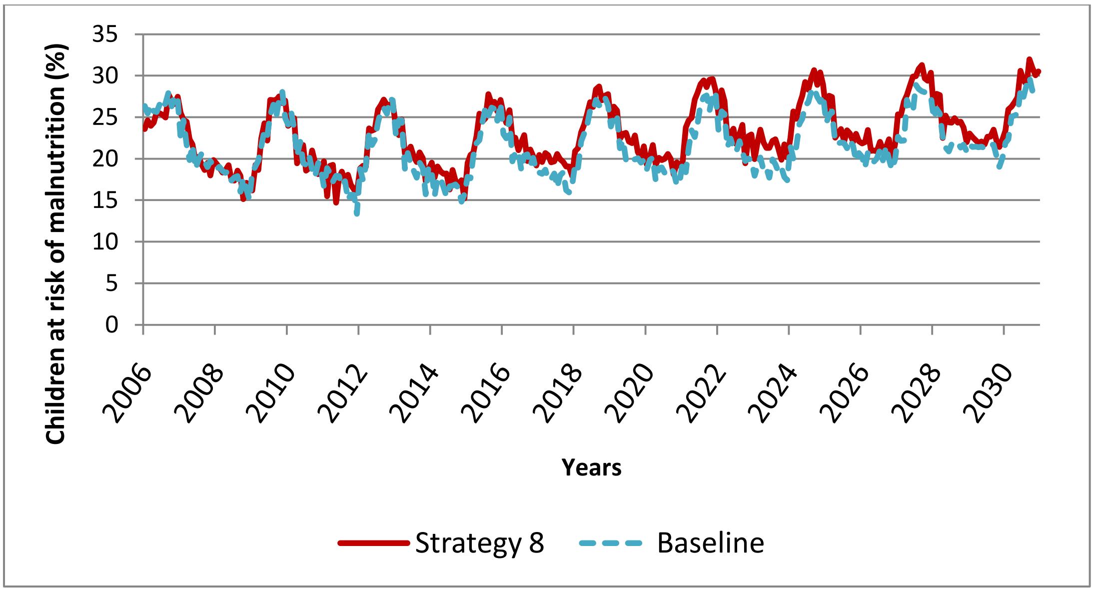


The results of the simulation runs (table 7.2), interacting livelihoods and malnutrition, indicate the effectiveness of strategies number 16, 13 and 12 in reducing the percentage of children at risk of malnutrition. This is further displayed graphically in figure 7:1 indicating how strategy 16 affected children at risk of malnutrition as compared with the baseline scenario. Strategies 16, 13 and 12 reduce the rate of malnutrition from an average of around 22% during the period 2006-2010 to less than 1% during the period 2026-2030. The most unique element of these combinations of strategies is the use of restocking, security, destocking and reclamation programs in combination.

Table 7:2: Effects of the top three strategies on the level of malnutrition

	Percentage of children at risk of malnutrition (%)			
Year	Baseline	Strategy 16	Strategy 13	Strategy 12
2006-2010	21.79	22.06	21.84	21.64
2011-2005	19.95	19.37	19.80	19.88
2016-2020	20.53	10.96	10.87	11.36
2021-2025	22.53	3.87	4.13	4.92
2026-2030	23.32	0.23	0.27	0.51
Average	**21.62**	**11.30**	**11.38**	**11.66**

Figure 7:2: The effect of conservation strategy on malnutrition



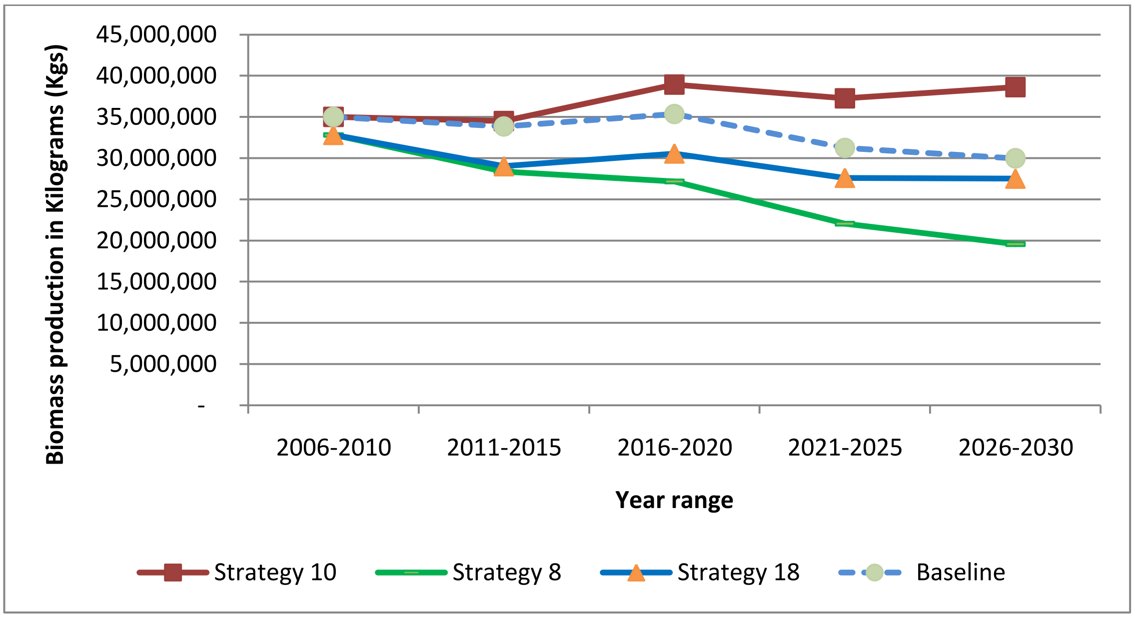
Competition for common resource however has a negative impact on malnutrition. Strategy 8, which involves targeting reclamation of 50% of the degraded rangeland by secluding 30% of productive rangeland to wildlife conservation, indicates a negative impact on malnutrition (figure 7:2). Increased malnutrition arises from higher livestock mortality rates and a subsequent decline in livestock ownership.

7.3 Natural Capital Scenario Runs

Natural capital in this study is represented by the common resource base which supports the pastoral system. This common resource is in the form of the area (measured in hectares) and the productivity of rangeland, measured by the quantity of biomass produced (in Kilograms). The SD model generating the results for this sub-system is shown in Appendix IV (a). The simulation results indicate minimal impacts in the long run by many policy options in forage productivity (figure 7:3). The main policies targeted directly on increasing or maintaining rangeland productivity have minimal impact. For instance, reclamation rate at 5% annually during good rainfall years indicate a 9.91% increase in productive rangeland driving up biomass production by 10.07%. Productive rangeland and hence biomass productivity increased to 11.05% when a combined strategy of planned settlement and reclamation of 5% annually is applied in the model (strategy 10).

However, the policy option of targeting 30% of productive rangeland for wildlife conservation reduced both the size and the amount of biomass produced by 21% despite a compensatory 50% reclamation rate on the degraded rangeland (strategy 8). When the conservation policy is supplemented by 5% reclamation rate and a planned settlement program (strategy 18) the percentage reduction in size and productivity drops by 11%, compared with the baseline scenario. (Appendix VI).

Figure 7:3: The impact of reclamation and conservation on rangeland

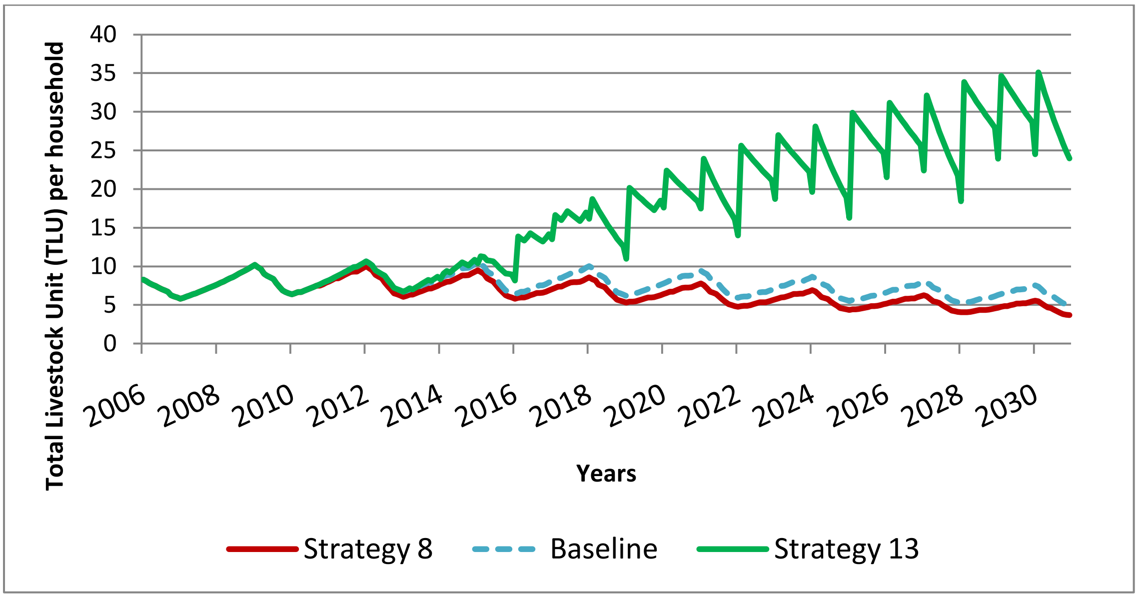


Monthly biomass productivity over the period of interest gives similar indications with strategies likely to create competition with productive rangeland causing a shrink in production (fig. 7.3). The baseline scenario shows a slight decline in average monthly biomass production from about 35,000 tonnes[10] in 2006-2010 to about 30,000 tonnes during the period 2026-2030 based on the Sinclair model of biomass productivity in east African rangelands. The productivity however is further reduced by secluding some productive areas for wildlife conservation to as low as 20,000 tonnes per month under strategy 8 but is slightly improved to about 28,000 tonnes by implementing planned settlements and reclaiming 5% of degraded rangeland annually (strategy 18).

7.4 Financial Capital Scenario Runs

The SD STELLA© model producing the results for the financial capital evaluation is shown in appendix IV (c) & (d). The simulation results show that some combinations of strategies help in boosting TLU and milk production per household. Strategies 13, 12 and 16 were ranked the top three possible policy combinations respectively, with high impact in increasinging TLU and milk production (appendix VI). All these strategies more than double the baseline long term average in the number of TLU, which then directly influenced both financial value and milk produced. Figure 7.4 shows the simulation runs for projected TLU dynamics with the best and the worst strategies. Strategy 13 gives the best result, raising the number of TLU per household from just above 5 in the years around 2012 to between 25 and 35 in the years around 2028 and 2030.

Figure 7:4: Simulation result for TLU under best and worst case strategies



[10] Conversion rate 1 tonne=1,000 kilograms

TLU dynamics are influenced by the variability of cattle, Small Stock Units (SSU) and camel populations associated with mortalities, births, sales and other losses. Figure 7.5 summarises the dynamics of livestock species under the best policy option (strategy 13). The simulation results show a steady increase in small stock driving up the livestock index measured by TLU. Cattle dynamics on the other hand increase over time from about 4 cattle per household in January 2012 to as high as about 12 cattle prior to the year 2025, when this figure started declining due to overstocking and high sales of cattle to settle annual insurance premiums. The population of camels on the other hand steadily increased from an average of 0.6 per household to 1.3 per household in the 14th year (between 168-180 months) before it stabilised at 1.2 until the end of the simulation period. Strategy 8 on the other hand which produced less than baseline TLU dynamics shows a downward trend in both cattle and SSU while camels increased (fig. 7.6). Creation of wildlife reserves by targeting 30% of productive rangeland by the end of the simulation runs, in exchange for reclamation of 50% of the initial degraded rangeland in the same period, drive SSU and cattle per household down from 37 and 6 to 5 and 2 respectively. Under this strategy however, the camels per household consistently grew over time but ranged between 0.7 and 2.4 per household during the simulation period.

Figure 7:5: Livestock species dynamics under strategy 13.

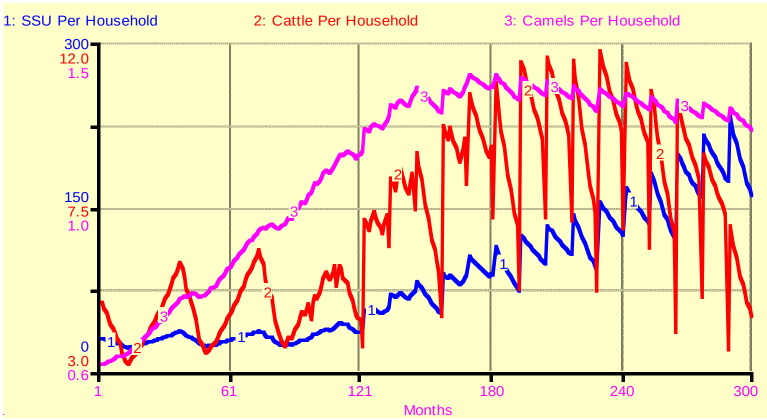
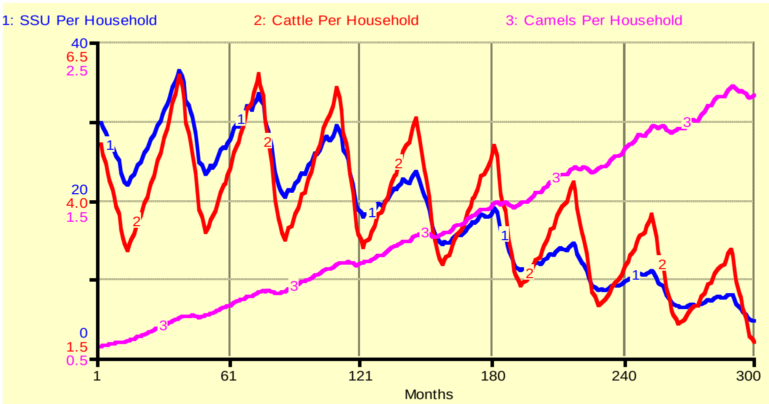
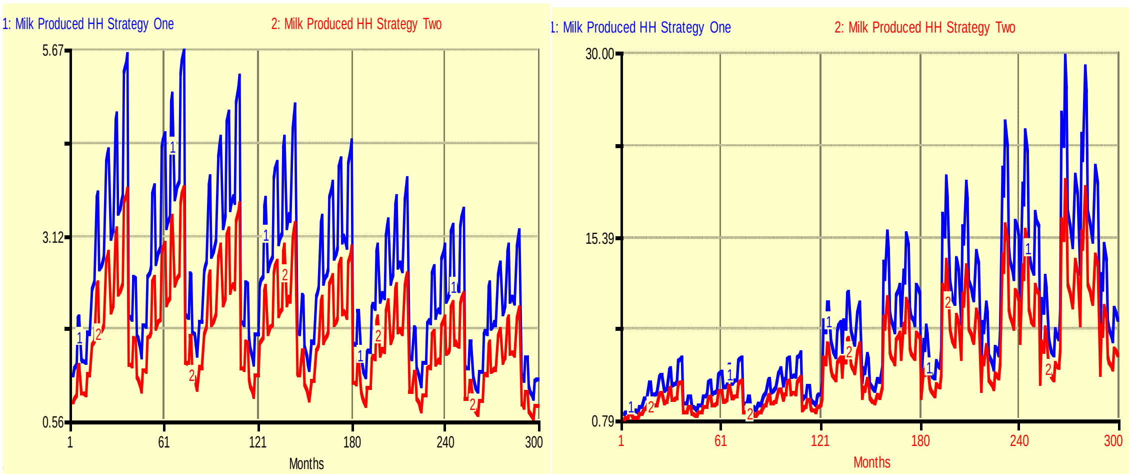


Figure 7:6: Livestock species dynamics under strategy 8.



TLU daily milk production per household varied with stock ownership, pasture availability and the strategy adopted. Figure 7.7 (a) shows the impact of severe droughts coupled with normal periods of rainy and dry months. Two strategies were compared in the model as these may be adopted by the different social classes. Poorer households which adopt a strategy of milking 75% of lactating herds experienced a decline in output from about 6 litres per day during good rainfall at the start of the simulation to a low of below 1 litre per day. The milking strategy adopted by wealthy households of milking 50% of their lactating herds yielded around 6 litres daily but declined to below 1 litre during the year 2030. On the other hand, adopting strategy 13 increases milk production from the current production level of below 1 litre a day to as high as about 30 litres daily in the years between 2028 and 2029 (figure 7.7 (b)). This clearly shows the impact of applying strategy 13 as intervention towards building natural base resource as well as reducing threats to livestock losses.

Figure 7:7: Milk production

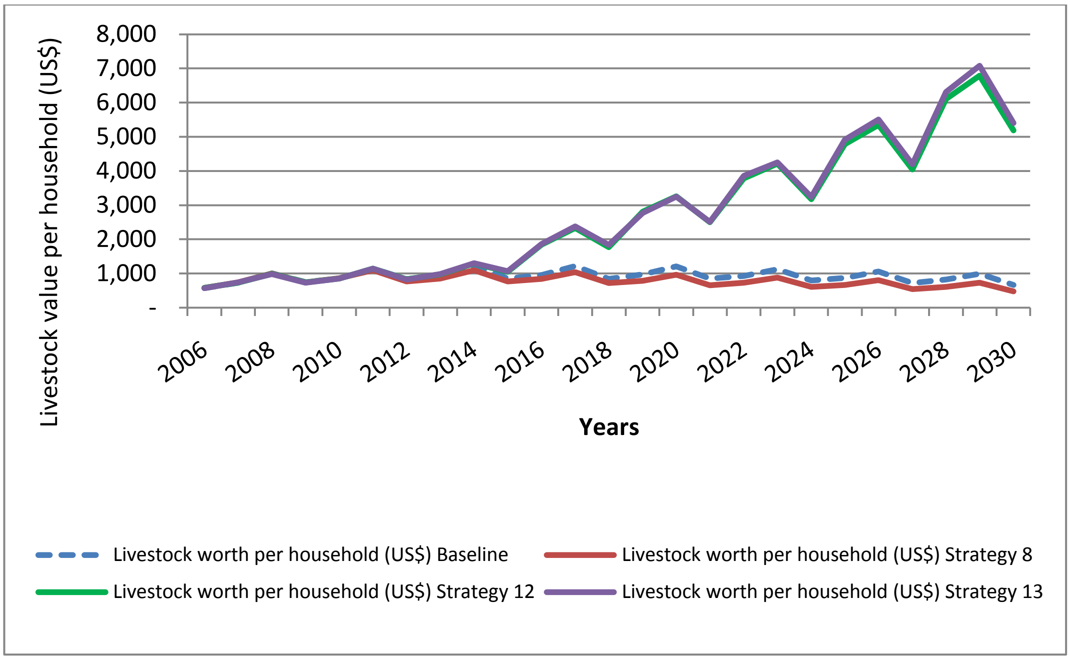


(a) Milk production baseline scenario (b) Milk production under strategy 13

In the long run, baseline scenario for milk production showsa continous trend of reduction as was shows earlier by TLU long run trend. The trend is marked by systematic climate patterns indicating both long and short rains. Similar cyclical patterns are observed when strategy 13 is applied. However, more milk is available despite the impact of droughts when compared with the baseline scenario.

Finally, livestock value, which is a function of livestock numbers and the market price, is used in this study as a measure of finacial capital likely to provide a basis for policy evaluation. The results of the simulation shown in figure 7.8 indicate a significant role for restocking, rangeland reclamation, panned settlements, veterinary and destocking programmes under strategy 12. The most important element is the constant replenishment of herd size following drought periods through a livestock insurance policy (strategies 12 &13). Supplementing these strategies by minimising losses arising from inter-ethnic conflicts helps build herd size and by extension financial value under strategy 13. Under the baseline scenario, the financial value of livestock remained at around US$ 1,000 prior to drought years. Strategy 8, which involve increasing protected areas by targeting 30% of productive rangeland in return for reclaiming 50% of degraded rangeland, produced results by the end of the simulation period which were lower than the baseline scenario. Livestock financial capital is however increased under strategy 12 and 13 from US$ 1,000 to as high as about US$ 7,000 in 2029.

Figure 7:8: Livestock financial capital strategies comparisons



7.5 Social Capital Scenario Runs

Social capital in this study is represented by the percentage of poor households among the pastoral community, SD model and variable relationship shown in Appendix IV (f). This is a function of rangeland condition, livestock ownership and malnutrition levels. The baseline scenario shows fluctuating poverty rates between 60% and 80% with the general trend indicating a slight increase (figure 7.9). Strategy 8, which had adverse effects on both household livestock ownership and the percentage of children at risk of malnutrition, increased poverty rates above the baseline scenario. Strategies 12 and 13 on the other hand drove down poverty rates in the long run to less than 20% in some occasions where rangeland condition is good and malnutrition levels are low. Drought years show spikes of increased poverty arising from degrading rangeland condition, declining household livestock and raising prevailing malnutrition levels.

Figure 7:9: Modelled poverty rates under the best and worst strategies

7.6 Costs of Mitigation Strategies

The two most important costs selected for the analysis in the current study are those huge sums arising from insurance premiums and supplementary feeding. Insurance premiums paid at 5.5% of livestock capital are summarised under table 7:3, where a combination of policies involved restocking by way of subscribing to livestock insurance. High insurance premiums are dictated by both the prevailing livestock prices as well as the number and species of livestock held. Internal sources financed more on the insurance premiums with strategies 13, 12 and 16 recording higher expenses than strategy 5 and 18.

A combination of policy strategies 12 and 13 raised livestock premiums from US$ 745,000 and US$ 764,000 in year 2013 to a high of US$ 6,490,000 and US$ 6,746,000 in the year 2029 respectively (appendix VIII). Despite the huge insurance expenses, the sources of these funds are internally generated by sale of livestock (cattle, small stock and camels). Ultimate growth in livestock ownership per household is therefore value addition on the strategy adopted. Strategies 13, 12 and 16 showed higher total premiums paid for livestock insurance scheme, an indication of increased TLU per household and greater economic wealth (fig. 7.10).

Table 7:3: Livestock insurance premium and feeding expenses

Strategy	Strategy Details	Mean operational costs in US$	
		Insurance premiums (US$ "000")	Supplementary feeding (US$ "000")
3	Purchase of supplementary feeds	-	1,395.00
5	Restocking through livestock insurance policy	1,404.00	-
10	Reclamation, planned settlement and supplementary feeding	-	1,515.00
11	Reclamation, planned settlement, supplementary feeding and veterinary services	-	3,913.00
12	Reclamation, planned settlement, veterinary services and restocking program	2,842.00	-
13	Reclamation, planned settlement, veterinary services , restocking program and bolster security	2,897.00	-
14	Reclamation, planned settlement, veterinary services , supplementary feeding and bolster security	-	4,096.00
15	Reclamation, planned settlement, veterinary services , supplementary feeding, bolster security and destocking	-	4,667.00
16	Reclamation, planned settlement, veterinary services , restocking, bolster security and destocking	2,602.00	-
17	Reclamation, planned settlement, veterinary services , supplementary feeding, bolster security, destocking and enhanced conservation	-	3,757.00
18	Reclamation, planned settlement, veterinary services , restocking, bolster security, destocking and enhanced conservation	2,061.00	-

Strategies 11, 14 and 15 which included the purchase of supplementary feeds increased household TLU on average by 17%, 19%, and 24% respectively, compared with the baseline scenario (appendix VI). These simulation runs are illustrated in figure 7:11 showing the costs related to the purchase of supplementary feeds during pasture shortage months. The result shows increases in the annual total cost spent on livestock feeding but varied among policies. Strategy 15 which involved rangeland reclamation, planned settlement, veterinary services, destocking and increased security programs, raises per household TLU and the associated livelihoods much higher than strategies 11 and 14. Strategy 11 however does not involve extra costs associated with implementing security and destocking programmes while strategy 14 excludes only the destocking program. Figure 7.11 indicates fluctuation arising from livestock, rangeland and rainfall dynamics over the interest period.

Figure 7:10: Livestock insurance premium expenses

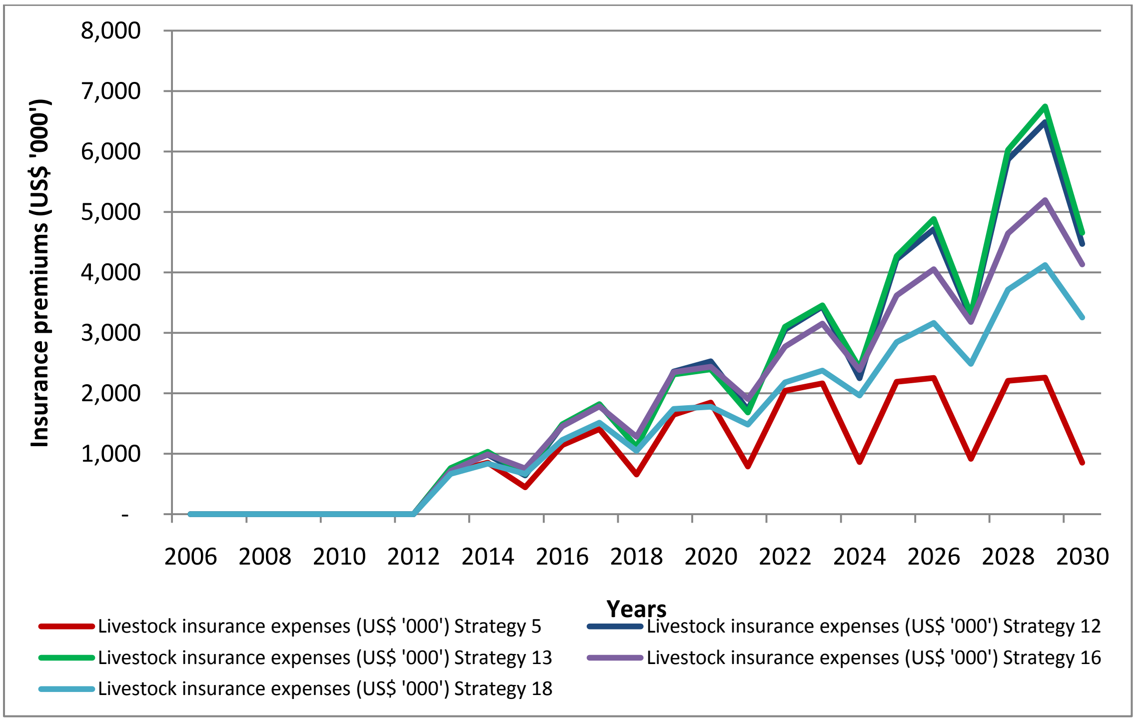
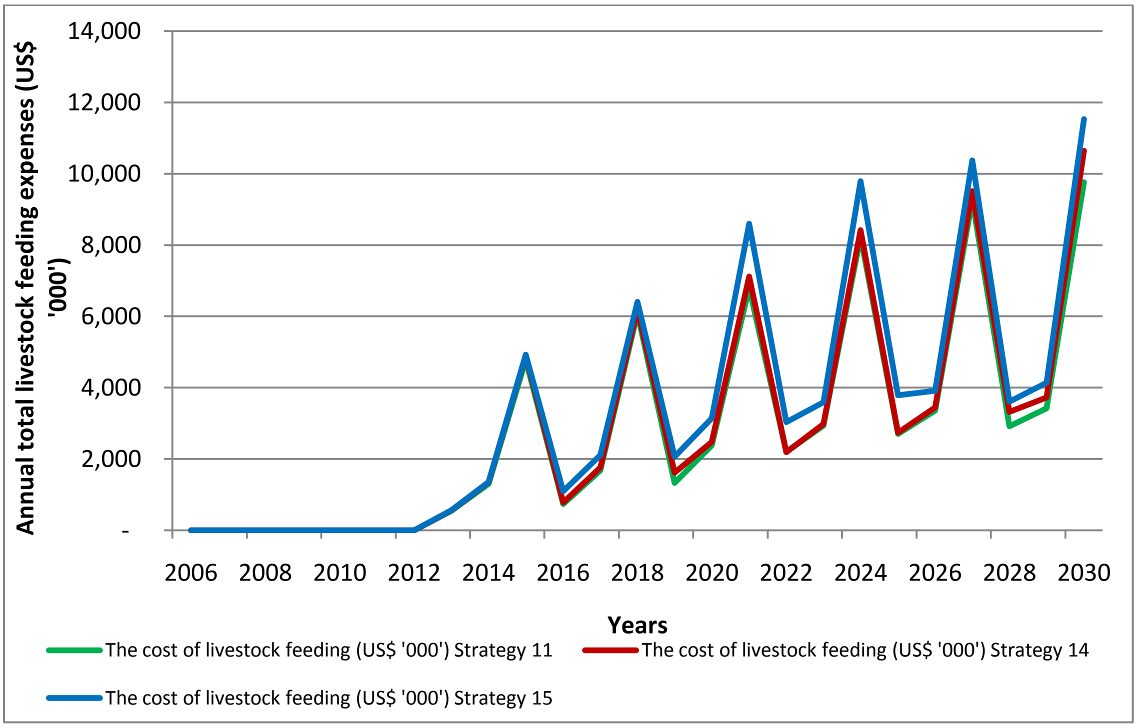


Figure 7:11: Annual cost of livestock supplementary feeds



7.7 Testing the Accuracy of the SD Model

Two main outputs from the model were tested against the actual field data collected during and after the model period. These outputs are the percentage of children at risk of malnutrition (figure 7:12) and the percentage of households classified as poor (figure 7.13) referred to in the current study as poverty rates. The SD model output indicated a strong relationship with the actual data signifying the validity of both the structure and the rules guiding the interaction of its building blocks.

The correlation coefficients between SD model result and the actual data collected during the period of simulation were 0.34 (r^2=12%), 0.71 (r^2=51%) and 0.37 (r^2=14%) for TLU, malnutrition and poverty rates respectively. Although the coefficient of determination for malnutrition was found to be high, the actual values from the SD model output underestimated the actual variability (fig. 7:12). The smooth line behaviour for both modelled poverty and malnutrition rates is explained by the use of fixed-effects regression coefficients which assume the existence of autocorrelation over time. Testing the same results with a 3-months moving averages of the actual data, both the Pearson's R correlation coefficient and the coefficient of determination were marginally improved for all the outcome variables. The results of the interaction between actual modelled results and the 3-months moving averages were 0.41 (r^2=17%), 0.78 (r^2=62%) and 0.39 (r^2=16%) for TLU, malnutrition and poverty rates respectively.

Figure 7:12: Comparison between SD model and actual malnutrition rates

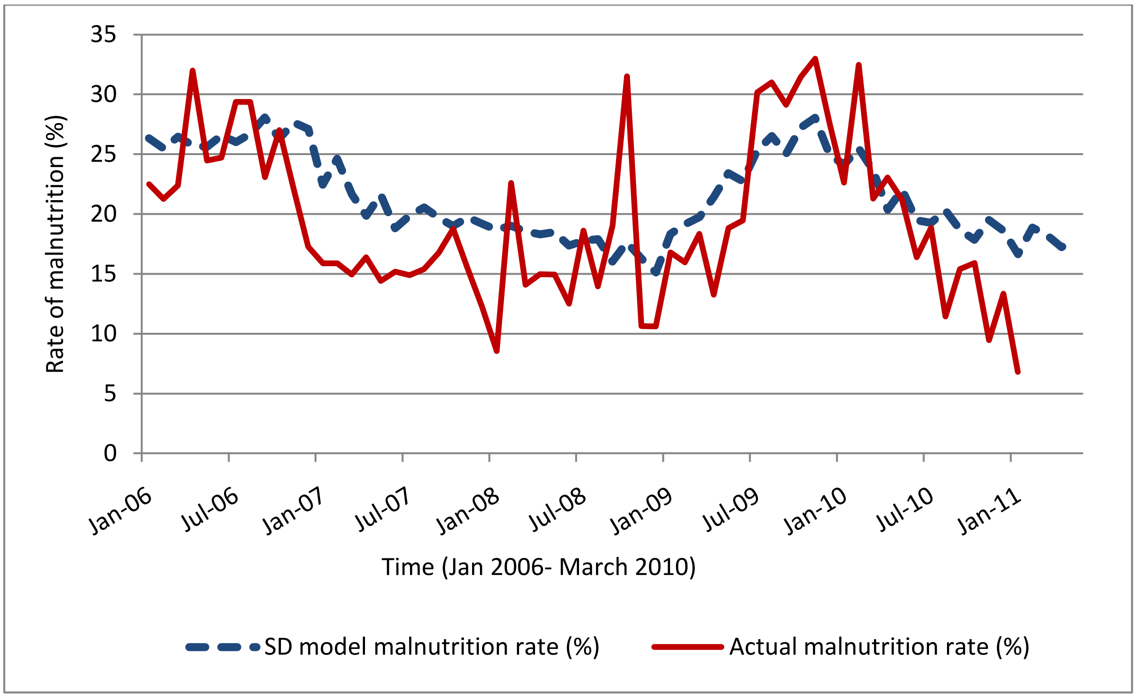
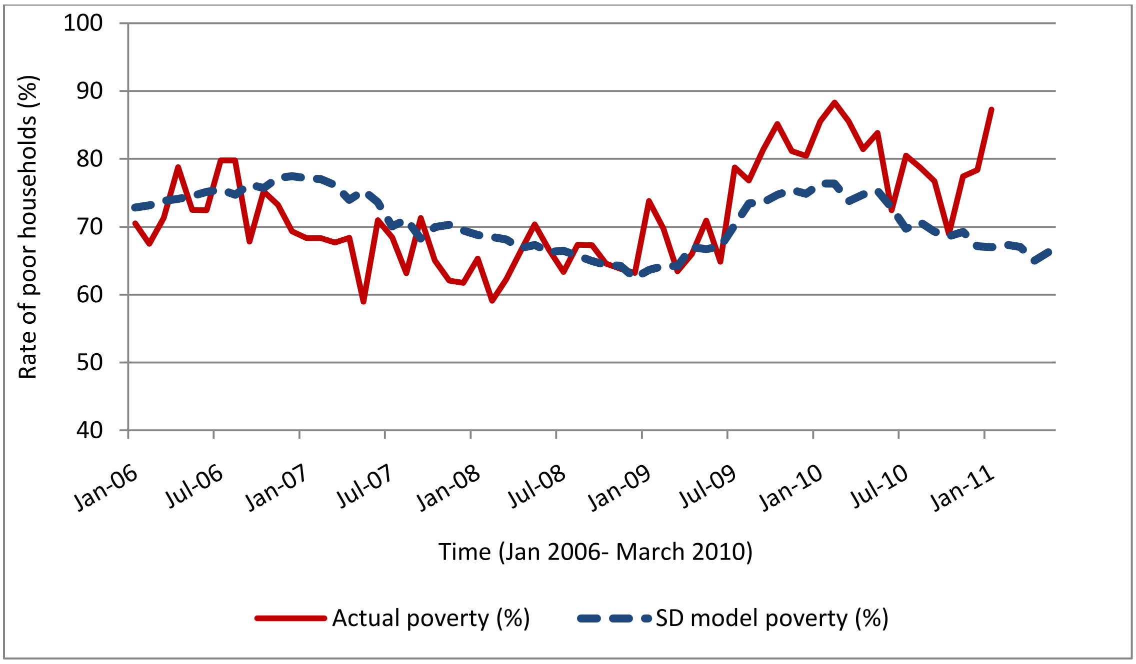


Figure 7:13: Comparison between SD model and actual poverty rates



7.8 Chapter Summary

The results of the SD model shows a more than double growth in human population in the sample area and a rise in the proportion of college level education to about 5% under the baseline scenario as compared to policy options of enhancing enrolment and retention rates yielding 7% by year 2030. Also under baseline scenario for the simulation period of 2006 to 2030:-

a) The percentage of children at risk of malnutrition is expected to range between 15% and 30% with lower rates recorded during good rainfall years. The trend is however increasing over time.
b) Pasture productivity and availability range between 30,000 to 35,000 tonnes monthly.
c) TLU owned per household ranged between 10 and 5 indicating declining trend affecting both milk production and total livestock wealth in US$.
d) Poverty rates between 70% and 85% also indicating increasing trend.

However, strategies directed to pasture management, planned settlement, conflict resolution, diseases control, restocking and destocking under strategy 16, 12, 13, and 18 in different combination produced better simulation results evaluated based on TLU, malnutrition, and poverty rates.

8 Discussion

8.1 Sources of Pastoral Risks

The analysis (detailed in chapter 5) provided basis from which the sources of pastoral risks and their associated risks were identified. Literature on socio-ecological vulnerability (Adger, 2006) and pastoral policy development (Swift et al., 2002) stresses on understanding of the drivers of the system and their dynamic nature. In the current study, the nature of the socio-ecological system was examined by understanding the community's responses towards the risks affecting them. The results indicated that risks affecting pastoralists in Samburu often arise from the variability of rainfall affecting rangeland and livestock assets. Their ability to respond to future shocks is hampered due to reducing asset endowment (McCabe, 1987) and increasing sensitivity of rangeland to perturbation (Barn, 2002, Boone et al., 2006, Galvin et al., 2004).

8.1.1 Socio-Economic Sources

Household population is high among the pastoral communities in Kenya with the current study showing an average of 7 members. Most of the household members are unemployed, attending lower level education or tending livestock, a common practice among many pastoral farmers (Lesorogol, 2008b, Roth, 1991). A substantial number of these households therefore derive their entire income from livestock (37%) and casual labour (20%) which is variable in nature and dependent on many socio-economic and natural factors (Thornton et al., 2007). Households are also dependent on some other unsustainable income sources such as charcoal burning (8%) and gifts (7%). The size and quality of livestock ownership determines the socio-economic status of an average pastoral household (McPeak, 2004, Mogues, 2004). Adverse conditions affecting either existence of livestock and casual labour thereby limits a household's ability to meet their daily needs (Steinfeld et al., 2006). This trend of income sources is unlikely to change as households are yet to diversify their livelihood to other sources such as trade or formal employment. Very few household members are likely to join the formal employment bracket as indicated by the low percentage of members in either college (<1%) or high school education (28%).

The majority of pastoral households are poor earning below US$ 1 a day. In this study, only 6% of households earned over US$ 50 a month ($ 1.7 a day). The majority (75%) earned below US$ 0.8 a day. Despite high household dependency on livestock income, the results show that the majority of them derive less than US$ 0.8 a day from this source. Casual labour and employment on the other hand, where available, contribute substantially to the household income basket. Most of the casual labour was reported as sourced from either conservation activities or government's decentralised project activities at the constituency level. Conservation activities, which have lately been considered as emerging form of livelihood, is contributing considerably towards wellbeing. Ecotourism has also emerged as an important livelihood source among many of the pastoral communities surveyed. Government created community group ranches to promote development through conservation of flora and fauna and strengthened sense of ownership of land. Samburu district's Namunyak Wildlife Conservation Trust (NWCT) is among the earlier models established by development organisations to promote conservation through the group ranch umbrella (NRT, 2009). The results showed a high percentage of households ranked transport services and employment opportunities as the benefits derived, suggesting the importance of infrastructure and job opportunities in supporting pastoral systems (Lesorogol, 2008b). There is an increase in the dependency of the market products by many pastoralists. In order to access the markets and purchase products, necessitating the need to travel to the market centres. The community conservation projects help the community to access markets either to sell livestock products or buy market products to supplement reducing livestock production (Little, 1992). This could explain why the results showed ranking of transport services even higher than creation of job opportunities for permanent and casual labour.

Livestock ownership has significantly reduced over the past five years with current per household ownership averaging at 5.31 Tropical Livestock Unit (TLU)[11] with 100% of the households interviewed reporting decline. The decline confirms the results of studies conducted in other pastoral areas in Eastern Africa suggesting shrinking pastoral productivity (Garedew et al., 2009). The decline is risking household outputs such as milk, meat and cash generated from livestock which directly depend on rangeland productivity. The outcome of the survey conducted by the current study found that households keep livestock mainly for milk, meat and household emergencies confirming the earlier research on rangeland and pastoral resources by Abule et al. (2005). The role of livestock as insurance against losses brought about by diseases, droughts and conflict on the other hand, emerged as the least reasons as to why households keep livestock. While milk and cash sales are vital products for pastoral households, they are highly variable. Milk production for instance is highly variable with a drastic reduction in litres produced per day during droughts resulting from reduced pasture and water availability. The average daily milk production ranged closely with previous studies in other areas of Northern Kenya where the lactating cow

[11] TLU is computed as equivalence of livestock considering metabolised energy requirement and productivity. 1 TLU=1 cattle=10 sheep/goats=1.4 camel (TLU=cattle+0.1*small stock+0.7*camels)

average production of 0.94 litres daily, with 0.65 and 1.2 litres for drought and good rainfall months respectively (De Leeuw et al., 1991, Galvin, 1992). To maximise on the livestock productivity, more human labour is added to provide the much needed scarce water and pasture during dry periods from the current demand of at least one household member. The results indicate that households bridge the gap between the existing labour and the need to provide more during droughts. The common practices by many pastoral communities is to use all the available idle labour and supplement it by discontinuing school-going children (ALRMP, 2007).

Households in the area reported a continuous decline of livestock in the past five years. The decline was highly associated with drought related causes with pasture and water condition ranked as the top two causes despite the fact that only two droughts were reported in the past five years occurring in the years 2006 and 2009 (Nkedianye et al., 2011, ILRI, 2010). Household consumption through slaughter and sales, diseases and conflicts also contributed largely on the livestock ownership decline. The inclusion of conflicts among the main causes of livestock decline, which in other studies found minimal, could be explained by the many cases of ethnic conflicts reported in the area during the recent years (GoK, 2010a). Despite huge losses arising from disease-related causes, little is spent on treatment of livestock against diseases with camels accounting for larger amount at US$ 3.30 and cattle US$ 1.5 annually. Households finance the cost of veterinary services by selling livestock contributing further towards reducing per capita ownership. While the current study did not investigate the proportion of livestock sold to purchase livestock drugs, Oba (2001) noted that households sell livestock during drought years to purchase market food, livestock drugs and pay debts. This small investment in animal health could explain the relatively high losses arising from diseases. This study confirmed the results of other studies carried out in other dry areas of Eastern Africa which concluded that the decline of livestock is highly driven by causes related to droughts (Abule et al., 2005, Oba, 2001). The occurrence of droughts therefore is likely to intensify the rate of livestock decline, especially in Northern Kenya, estimated to experience frequent droughts and lacking insurance and other appropriate response mechanisms (Chantarat et al., 2009b).

8.1.2 Land Use Changes

Changes in the land use system, especially rangeland size is considered by many households a major risk affecting pastoral system. The perception of rangeland degradation and therefore sustainability of the pastoral system in this study corroborates with earlier studies on rangeland degradation in the Eastern Africa region (Solomon et al., 2007). Rangelands which form the core resource for the pastoral system are under threat of reduced dependency affecting size and/or productivity.

Unreliable rainfall has contributed significantly to reduced pasture availability causing degradation. The prior focus group meetings with community members expressed how unreliable the rain patterns have become forcing them to continuously utilise areas initially reserved for the dry months. Indeed, areas with continuous use by livestock are likely to experience declining productivity over time (Bagchi et al., 2006). Changes in plant variety are also observed among the communities as a major environmental risk with past grazing areas now perceived to be producing less palatable pasture.

Policy measures to reduce the rising human-wildlife conflict and protect endangered wildlife species are paramount. The government and the development partners are continually engaged with the communities to design appropriate measures to protect wildlife and ensure tourism is not affected (Low et al., 2009). In doing so, areas dominated by wildlife have been secluded for wildlife conservation and tourism activities to ensure free movement of wildlife (Lamprey and Reid, 2004). Also competing for rangeland and perceived to be a high risk is the growing human population expanding settlements to previously grazing areas. Risks associated with droughts and increased human population are not significantly different across regions signifying the homogeneity on the perception of the causes of rangeland reduction. However, secluding some portions of the rangeland for conservation is highly ranked, by areas with newly established community conservation, as a major risk to the pastoral system. Sera and Meibai group members felt that the introduction of core conservation areas takes away the reserve areas for pasture resource during drought periods. Westgate and Laresoro on the other hand, recognising the potential for reduced rangeland, their possible long standing relationship and benefits from established lodges, reduced the ranking of the conservation areas as a factor contributing towards rangeland decline.

Inter-ethnic conflict causes both financial and human loss and has negatively impacted the social and economic environment in northern Kenya (Haro et al., 2005). The recent conflicts in the study area are blamed for the increased poverty in the region with many households left without livestock following the raids. Comparing the perceived impact of some risks on livestock and environment, the results indicated that conflicts are regarded more highly as risks to livestock than they are for the rangeland as pastoralists can still access pasture areas regardless of conflicts. However, during the 2008/2009 drought years in northern Kenya, ethnic conflicts exacerbated livestock mortalities (ILRI, 2010). Higher mortality rates arose from the fear of accessing areas which still had pasture during the drought season confining many pastoralists to small patches of “safe havens”. The confusion created by the ethnic tension forced people to move to remote areas further affecting their already emaciated livestock thereby causing more losses. Droughts events are associated with shortage of pasture and water resources and conflicts arise as a result of competition for pasture resources.

Rangeland access and utilisation is affected by the existence of predators causing livestock losses and human injuries. Predation in this study emerged as affecting access to rangeland more than it reduces livestock ownership. Although studies on the impacts of predation on livestock showed minimal losses (Solomon et al., 2007, Bekure and Chabari, 1991), the dynamic nature of rangeland and the interaction with wildlife provides an avenue for potential risks. The reducing wild herbivores and increased encroachment of human settlements in areas previously used by wild animals (Ogutu, 2000), means that carnivores are likely to feed on livestock to substitute their reduced food reserves. In the current study, households perceive predation as a challenge that prevents them from exploiting rangelands as they access before. The findings support the current policy negotiations of creating pasture buffer zones by restricting livestock access so as to increase growth and the concentration of wild herbivores hence reducing predation. In doing so, the available size of rangeland for pastoral use is reduced.

8.1.3 Market and Information Sources

The market plays an important role in a pastoral economy by converting economic assets into liquid cash. Livestock markets in sub-Sahara Africa are seldom integrated and are affected by a high level of intra-market and inter-market variability (Barrett and Luseno, 2004, Fafchamps and Gavian, 1996). Livestock price volatility arises from low demand, high supply or poor quality of livestock being sold in terms of body condition. People hold livestock during drought periods mainly because of low livestock prices, lack of buyers or poor livestock body conditions which only enables them to access the nearest market place. The results of this study confirm the descriptive results that low prices and poor body condition contribute significantly towards reduced sales during drought seasons. This condition was however more dominant in areas located far from the major towns such as Sera and Meibai. Households in these areas drive their livestock for very long distances to access markets and in cases where the animals are too weak, they opt to retain them with the expectation of surviving the drought. The study further showed that high income households considered pricing significantly in making decisions on whether to sell or hold livestock. These households ranked livestock market prices as one main consideration in the choice of selling livestock. Their alternative sources of livelihood arising from employment and casual labour could explain this behaviour. They have the alternative resources which enables them to risk livestock survival given that they depend on the livestock the least. Regardless of the regions, livestock prices drive the households' economic value in the direction of the volatility thus affecting their wellbeing. This implies that when prices rise, the economic value attached to the livestock goes up and vice versa. The economic value is important especially when household decide to sell some of their stock to acquire other market products.

The nature of response strategies employed by households to threats on livelihood depends on the availability, timeliness and accuracy of information forewarning them against potential threats. Frequently occurring events, which can be predicted with some level of certainty, are managed by organisations through creation of institutional knowledge relating to response strategies (Toft and Reynolds, 1994). Information is vital and the risk of either erroneous or complete absence can deprive many households of their livelihoods. Although the majority of households in this study had received weather forecasts, formally or informally, before 2006 and 2009 droughts (54%), only 64% of them engaged in market-related off-take. This was conducted by selling some livestock to create reserves for market foodstuff to supply households with their nutritional requirement. Other strategies engaged in by the majority include migrating livestock in search of pasture and/or buying livestock supplementary feeds. Important to note is that 4% of those in receipt of this information discontinued their school-going children to look after livestock while 4% did nothing about the information.

Lack of a formal drought early warning system coupled with a strong cultural traditions and poor infrastructure, further damages market prices. The current study ,while confirming the absence of an early warning system as observed earlier by Stuth et al. (2003), also indicated a strong traditional culture of livestock accumulation discussed by some as “livestock complex” (Konaka, 1997). Lack of early warning information indicates that drought takes many pastoralists by surprise and causes huge livestock losses as is found by many studies in arid areas of East Africa (McCabe, 1987, Nkedianye et al., 2011). The existence of the occasional markets, characterised by fewer buyers, many sellers and poor livestock body conditions, destabilises the market prices. Accurate and timely rainfall forecasts helps herders to update their traditional beliefs and reduce their expectation to take advantage of good seasons and sell at the right time when livestock are sufficiently marketable (Lybbert et al., 2007).

8.1.4 Mitigation Strategies

Mitigation strategies for pastoral systems are directed either at improving the core resource rangeland, preserving asset capital or responding to the effects of the adverse conditions. These were approached as the levels of risk mitigation strategies adopted based on their contribution to the system at large. The first level involves rangeland which forms the core resource for pastoral systems. Rangeland health, measured by pasture productivity, determines the dynamics of a pure pastoral system affecting not only the species kept but also largely contributing to poverty rates

(Kassahun et al., 2008). The traditional risk coping strategies often used to respond to risks also entirely depend on rangeland productivity. The continuous decline in rangeland productivity could ultimately drive many pastoralists into a poverty trap. With already large tracts of land affected by erosion and other agents of degradation (Tefera et al., 2007a), restoring it back into productivity is necessary. In the current study, restoration of rangeland was considered as an important strategy likely to improve range productivity. The strategies which were highly rated included planting of grass in degraded areas, rotational grazing and planned settlements. This followed previous work undertaken in some areas by the conservation organisations and seen by many to have rehabilitated by employing similar activities (NRT, 2011). In so doing, pasture production will be enhanced and utilisation controlled and planned for drought years. The government of Kenya has also contributed to rangeland rehabilitation in various ways such as by distributing indigenous grass seeds to various community organisation to improve on pasture productivity (GoK, 2010a). Targeting these degraded rangelands was found in this research to be a priority by many households indicating the importance of not only maintaining the productivity of the current rangelands but also creating extra supply of productive rangeland to satisfy the increasing human population.

The second level of mitigation strategies revolve around the preservation of livestock which is considered as the main economic asset for pastoral communities. In preserving this economic asset, households apply both traditional and commercial means to reduce drought related losses. The traditional methods adopted by pastoralists to reduce livestock losses arising from drought include migration and the storage of acacia pods (Aklilu and Wekesa, 2002). Another emerging means of responding to pasture shortages among the pastoral communities includes commercial feeds commonly used in established commercial ranches (Bebe et al., 2003, de Leeuw et al., 1995). The results of this study showed that households responded to the recent droughts in 2006 and 2009 by either migrating to areas perceived to have pasture reserves or by purchasing supplementary livestock feeds. The strategy allowed them to utilise spatial and temporal pasture resources from the sporadic rainfall patterns observed in the recent years (ALRMP, 2007). Furthermore, the study observed a shift in the pastoral practices with a majority of the households sending their livestock to satellite camps as opposed to the traditional nomadic pastoral system where households move with their livestock during droughts seasons. There is a strong indication of high level sedentarization among many households as noted in earlier studies investigating pastoral production systems and impacts on their socio-economic and health status (Little, 1992, Roth et al., 2005). The strategy requires planning for grazing patterns and restricting access to areas used during drought seasons to such periods when resources in other areas are exhausted.

The third level response strategies were linked with the consequences of drought and its associated risks. Food insecurity, considered as a major consequence of drought events globally, was assessed in the current research. Holtzman (2007) assessed the coping strategies to address reduced food security in the same community and found that many households reduced consumption during periods of shortage. Households in this study responded to food insecurity caused by the droughts of 2006 and 2009 by mainly selling and slaughter of small stock. Households facing food insecurity sell or slaughter livestock to supplement declining livestock productivity which comprise over 60% of the dietary requirements for an average pastoral household in Kenya (Bollig, 2006:175-176). The sales proceed is spent on market cereals such as maize, beans, sugar and other food items mainly used as substitutes to livestock products and sources of food are diversified (Little, 1992). They also mitigated food shortages by adopting a traditional strategy involving drawing of blood from livestock while still keeping the livestock alive.

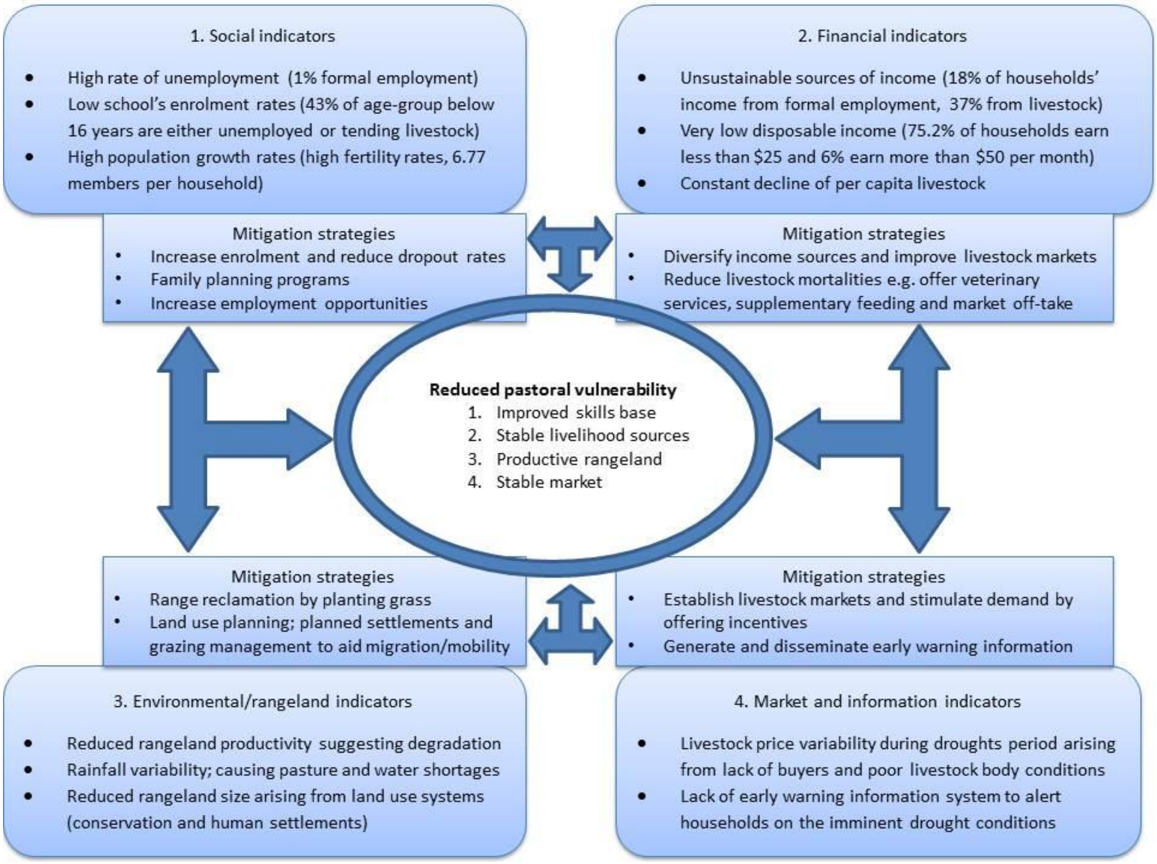
There were no significant differences among income levels and regions on the top three strategies employed in responding to food shortages. This study fails to show the various household or regional specific characteristics regarding the extent of risk and possible mitigation strategies reported in Chantarat et al. (2009a) and made a basis for premium valuation. Chantarat et al. (2009b) had argued for a variations in the livestock insurance premiums between regions because of the regional-level risks and idiosyncratic characteristics of the households. Sieff (1999) similarly found considerable differences existed between income and asset classes among the pastoral communities in Tanzania. The only marginal difference found in the current study was that for those households in receipt of casual labour, they slaughtered slightly more livestock than those not engaging in any casual labour. This could be explained by the fact that they slaughter small stock to supplement market products acquired from cash receipt from work. Measuring the extent of the homogeneity in the group under review was important because the objective of the study was aimed at building an SD model and applies mitigation strategies at the regional level.

The most sustainable strategies to maintain pastoral economy proposed, and ranked by households as important, were derived from past experiences. Birch and Shuria (2002) noted in a pastoral project review that the development of pastoral land and in effect, changing their mitigation strategies, depends on the extent of inclusion of the local knowledge. Households rated migration in search of pasture and water, and splitting of herds as the top two most applied strategies and proved to mitigate adverse effects of droughts. The current study supported the recent studies on the importance of mobility as an effective risk management tool used by pastoral communities (Nkedianye et al., 2011, Angassa and Oba, 2007). This indicates the significance of rangeland management policies aimed at improving productivity and planned settlement to allow them space to practice mobility. Other long-term strategies proposed in this study included herd diversification, involving investment in small stock (sheep and goats) that have been found to be more resistant to droughts. McCabe (1987) concluded that households recorded more mortalities on cattle than they did for both camels and small stock indicating lower financial losses. Similar findings were later reported in other studies (Lesorogol, 2008b). Ownership of small stock also helps in rebuilding the herd size following drought periods because of their ability to maximise on scarce rainfall and reproduce frequently than cattle or camels (Fratkin and Roth, 2005). Diversification as a risk management strategy is commonly used in the field of finance when mixing stock assets (shares and debt instruments), in minimising risks and maximising opportunities. Thornton et al. (2007) noted that pastoralists diversify their livelihood options as risk mitigation strategies.

Although the study did report a minimal role played by diseases in reducing livestock ownership in the past five years, the result of the mitigation strategies indicated a strong consideration of veterinary services. These services are aimed at reducing diseases during both good and bad pasture years. Studies in other pastoral areas in East Africa noted the success of veterinary services and restocking programs (Barn, 2002). The government has responded to diseases in various ways, some of which have negatively affected the pastoral system. The common response by the government to impose quarantine in order to reduce regional disease spread, was found to have a negative effect on livestock prices and hence livestock market imbalance (Barrett et al., 2003). However, the occasional government exercise to offer veterinary services emerged as an important strategy to reduce livestock losses. The reports prepared at the district level currently, indicate reported incidences of livestock diseases and the action taken including quarantine, vaccination, deworming or slaughter for disposal (GoK, 2010a). The government of Kenya’s effort supplements the household level activities aimed at reducing disease-related livestock losses.

Figure 8.1 summarises the pastoral risks identified and mitigation strategies proposed. It shows that pastoral risks clustered around social, financial, environmental and market aspects which affect the pastoral system and hence wellbeing. The outcome variable of measured vulnerability is then influenced directly or indirectly through mitigation strategies applied to a single aspect. Poverty trap is evident among these pastoral communities without intervention to improve opportunistic drivers and reduce effects of adverse system drivers. For instance, enhancing human skills allows households to diversify income sources thereby increasing the percentage of households generating income from employment. Similarly, issuing timely early warning information, facilitated by appropriate market related policies, helps households to sell some livestock and reduce grazing capacity while at the same time providing them with income to substitute reduced livestock productivity. Generally, the outcome of this study shows that mitigating the adverse conditions of the pastoral system is non-linear and requires a multifaceted approach to monitor the desired outcome against individual and composite strategies.

Figure 8:1: Pastoral risks indicators and the associated mitigation strategies



8.2 Impacts of Drought on Pastoral Wellbeing

Chapter 6 covers the analysis of the ALRMP and NDVI dataset to establish the link between the various biotic and abiotic drivers established and discussed in the previous section (section 8.1). Comprehensive analysis of vulnerability requires an extended understanding from a mere identification of socio-ecological drivers to establishment of the links affecting the interacting variables (Turner et al., 2003, Adger, 2006). The current study, having identified drought as a major driver of pastoral system in Samburu (see chapter 5), identifies the frequencies and impacts of droughts individually and in combination with other confounding factors. The following discussion therefore centres on the discussion of the drought situation in Samburu and its effects on the selected vulnerability indicators, identified based on the research framework adopted.

8.2.1 Drought Assessment

Rainfall in Arid and Semi-Arid Land (ASAL) regions in Kenya vary in time and space. Indeed Samburu district is classified into two livelihood zones depending on the rainfall amount among other factors. The monthly bulletins issued by the ALRMP refer to these two zones as agro-pastoral and pure pastoral regions, with agro-pastoral areas receiving marginally higher rainfall (see figure 3.1). Using NDVI, the descriptive and statistical analysis show that drought is a common phenomenon in the district, with at least a drought event occurring once every 2-3 years. NDVI analysis, and drought event estimation, produced results confirming the severity of the reported drought in the recent past (ILRI, 2010, Aklilu and Wekesa, 2002). Other research studies either looking at the droughts strategies or impacts have also made reference to the main droughts identified in this study (Nkedianye et al., 2011, Chantarat et al., 2009b, Oba, 2001). During the period of review, the district had experienced below normal pasture condition for over 50% of the time. Important to note is the existence of a bimodal pattern of rainfall in the area which divides the livelihood conditions into short rain, short drought, long rain and long drought periods. These are commonly occurring conditions and households are aware of them (Lybbert et al., 2007). However, failure of either short or long rains or both pushes households into periods of livelihood uncertainty (Kere et al., 2008). The occurrence of frequent droughts ultimately affect household herd accumulation by reducing recovery period (Oba, 2001, McCabe, 1987). The pattern of droughts in the study area allows policy makers to develop strategies to respond towards consequences of its adverse effects and maximise on the condition of above normal rainfall. In order to develop these strategies, the associated impacts of pasture condition on the livelihoods have to be understood. This include; the effects it has on the herd size, human wellbeing, food security, and ultimately on pastoral poverty.

Droughts affect livestock dynamics by influencing births, sales, mortalities, and household consumption through slaughter. In this study, it was very clear the extent to which the presence of drought drives TLU dynamics. The average TLU owned by households drastically decline during drought years, while the trend shows upward rise during the years with above normal rainfall. These dynamics are associated with variations observed with mortality, birth and sales rates. Livestock experienced higher mortality rates during the two drought years (2006 and 2009) arising from lack of water and pasture. The result confirmed the findings of other studies on the effects of droughts on livestock dynamics, indicating that pastoral communities suffer huge economic losses during droughts (McCabe, 1987, Lesorogol, 2009). However, in this study, mortality rate for small stocks (sheep and goats) surpassed that of cattle. SSUs registered a monthly mortality rate of 9.4% during drought years as compared with

8.26% for cattle. This scenario occurred because the data on mortalities included those livestock slaughtered for household consumption. Similarly, the rates could have risen due to the influence of other factors such as disease epidemics affecting SSU more than cattle during drought events (Oba, 2001). This finding could then put pastoral communities at risk of a slow herd rebuilding process, as many have in the past turned to stocking small stocks as a way of facilitating faster herd accumulation (McPeak and Little, 2005).

Loss of SSUs also affects households' income sources. Households sold more of SSUs than cattle during the entire period of study, with monthly average sales rates recorded at 1% and 4% for cattle and SSU respectively. There was marginal increase in sales rates for the livestock species drought years to an average of 2% and 5% for cattle and SSU respectively. This rise suggests the extent of distress caused by drought due to food insecurity, with most of the food sourced from the market. Oba (2001) in his study on the effect of multiple droughts on the pastoral communities of the Northern Kenya found that households increase livestock sales, recorded at 42% in the 1984 and 46% in 1991/2 drought years of the total livestock decline. Livestock birth rates on the other hand are negatively affected by existence of drought condition. The year 2007 for instance, which enjoyed a relatively stable above normal rainfall condition recorded the highest birth rates with 13.7% and 9.6% for SSU and cattle respectively. The high rate observed for SSU actually confirms the strategy adopted by pastoral communities by stocking more of small stock to encourage faster herd accumulation process. The results also showed that birth rates for both SSU and cattle highly correlate to 4-9 months. This shows that good rainfall seasons can have both short and long term effects on herd dynamics.

8.2.2 Wellbeing Variability

Empirical analyses of TLU dynamics indicate that environmental health, measured by NDVI, highly influences birth rates for both small stock and cattle confirming the results by Desta and Coppock (2002b) that livestock growth occurs mainly through births. The results further indicated that 6-months lagged NDVI is an important predictor of the size of TLU. This shows the importance of environmental condition in reducing sales and mortalities, while increasing birth rates. However, it is the birth rates for small stock that is currently driving up TLU in the study area, indicating the preference for small stock by many impoverished pastoralists (McPeak and Little, 2005). This could be as a result of the higher proportion of small stock in the composite index in the current sample. King et al. (1984) noted that the Maasai pastoral community have adopted herding more proportion of small stock as they have a better survival rate in harsh droughts than cattle and offer quick market in case of an emergency requiring money. While sales are important in regulating herd dynamics, the rate is still very low and does not significantly influence the absolute livestock population confirming the findings by Bollig (2006) who noted that only 13% of livestock off take in Baringo (Kenya) arises from sales and the rest are from drought related causes. However, households are forced to make more sales during drought periods. The study partially confirms the findings by Roth (1990) indicating that TLU dynamics is mainly driven by drought related mortalities and market sales. There are minimal changes in sales rate for cattle in the events of droughts in the current study. However, SSU sales is found to be an important driving force reducing TLU ownership in these pastoral areas more than the mortality rates for both species.

There has been a higher mortality rates for cattle either resulting from diseases, conflicts or drought with the latter being more pronounced. The common livestock diseases in most arid lands of the northern Kenya affect both cattle and SSUs. The main livestock diseases causing Small stock (goats) mortalities is the Contagious Caprine Pleuropneumonia (CCPP) while East Coast Fever (ECF) affects cattle in various regions in northern Kenya (Bollig, 2006). The outbreak of the Rift Valley Fever (RVF) in the 2006 and 2008 brought about concern for animal diseases as an important pastoral risk. The outbreak claimed several livestock from pastoral areas, especially those not well accessible to quick veterinary attention (Munyua et al., 2010). The high mortality rate associated with diseases reported in this study could be linked to low investment by households on veterinary services highlighted earlier in this study (section 8.1). Previous studies have also indicated low investment in disease control by the Maasai community, with mean annual expenditure per TLU estimated at US$ 0.15 (Bekure and Chabari, 1991).

The ability of the household to respond to current and future risks is determined by their general health condition. Rampant food insecurity and consequently malnutrition among children has been proposed in previous reports and scientific studies as an appropriate measure of pastoral vulnerability (Mude et al., 2009a, Khan et al., 1992). Households which are self-sufficient in supplying nutritional needs, from meat and milk, have lower malnutrition rates and are generally healthy (Galvin, 1992). Nutritional needs supply in this study was linked to the availability of milk, cash generated from livestock sales, livestock assets and pasture condition. Malnutrition is highly reduced by increased cattle birth rates than it is for SSU birth rates. This difference could have arisen due to the difference in the amount of milk produced by the lactating cattle compared with that from SSU. While it is evident that small percentage of milk is marketed by pastoral households of arid areas in Kenya (McPeak and Little, 2005), much of the household milk consumed is generated from cattle and camels (Fratkin, 2004). This finding highlights the importance of the availability of milk in reducing malnutrition among children under the age of 5 years.

Pastoral households respond to food shortages by selling livestock to acquire market products, mainly cereals, which is the main staple food for most pastoral communities in Kenya (McPeak, 2004). In this study however, sales rate for SSU and cattle have opposite effects on malnutrition. Sales rate for small stock showed significant reduction in malnutrition rate, while the sale of cattle actually showed an increase effect. It appears that households respond to food shortages and income shocks by selling small stock, to acquire foodstuffs (McPeak, 2004), which then reduces malnutrition by supplementing livestock products. The opposite effects that the cattle sales have on malnutrition could be explained in light with previous studies which indicate that cattle are mainly sold for major reasons such as paying hospital bills, school fees and other significant expenses (Roth, 1990). There is a significant reduction of malnutrition with the increase in livestock ownership (TLU). This could be linked to other uncontrolled variables associated with owning livestock such as blood which provide a significant alternative nutritional source (Bollig, 2006, Dahl and Hjort, 1976, Holtzman, 2007).

The results further indicate that improved pasture condition, higher NDVI, reduces the risk of child malnutrition. This explains the fact that livestock productivity, in terms of milk and sale proceeds, is higher during the period with stable pasture (ALRMP, 2007). However, current and short-term (3 months lag) have more impact than the long term period (6 months lag). During rainy seasons, livestock are returned back from satellite villages, where they are kept during dry spells (McPeak and Little, 2005). This study indicated similar behaviour where the distance to the nearest pasture area increased from 10 km during above normal rainfall years to about 37 km during drought years. This phenomenon could further explain the reason why mortality rate of cattle increases malnutrition. The carcasses of dead livestock are not available for household consumption. Households are therefore able to utilise milk, meat and blood during periods with high NDVI before the rangeland deteriorate once again. Increase in household purchasing power, measured by MCP, and the availability of food aid, provided by the government as a response strategy on food insecurity, did not seem to have desired result of decreasing malnutrition. Although both variables were highly significant, they showed positive effects suggesting that market condition and supply of relief food is currently not sufficient to reverse malnutrition rate. Possible explanation could be that relief food was offered throughout the study period and the proportion was marginally increased during the drought period. The three variables, MCP, MUAC and proportion of food relief moved in the same direction showing that drought condition affected market condition, malnutrition and government response in a similar manner. Despite some of these inconsistencies from the expectation, the variables predicted variations in the model reasonably (r-sq. = 0.785).

Market dynamics play an important role in influencing pastoral policy and subsequently managing risks. Strong pastoral recommendations have always called for strengthening of livestock markets to allow stability of food and livestock prices (Barrett and Luseno, 2004, McPeak, 2004). However, droughts and the associated forces of supply and demand have driven prices in pastoral areas (Barrett et al., 2003). The current study tested the influence of demand and supply for market products on purchasing power (MCP). Increase in milk production (proxy by livestock birth rate), TLU ownership, and improved pasture condition increases the purchasing power. Availability of milk, meat and blood provides pastoral households with the main nutritional requirements, thus reducing the demand for market products (Holtzman, 2007). The results of this study to a larger extent confirm the role played by the forces of supply and demand on pastoral market prices. First, the purchasing power was positively influenced by improved rangeland condition, denoted by increasing NDVI. During these periods, as demonstrated by descriptive statistics, pastoral systems are characterised by higher livestock birth rates and lower mortality rates. There is therefore sufficient milk available for household consumption to meet the nutritional requirement.

Cattle birth rate and herd size improved purchasing power, while mortality and sales rate for cattle reduces household purchase power. While the data does not allow further analysis of the reasons for the decline, our remote argument could be justified from previous studies. Barrett et al. (2003) noted that the prices of livestock are influenced by a myriad of forces ranging from the characteristics of the animal itself to the circumstances surrounding the sale. Mortality rate indicate that the animal’s body condition is not good enough to fetch higher prices and it signifies that the seller would be ready to dispose-off the livestock at any price available, instead of losing it to droughts. Similarly, increasing cattle sales further drives down the price as the supply increases and the demand reduces. Barrett et al. (2003) found that events such as droughts and some intervention strategies, such as livestock quarantine, reduce livestock buyers driving prices downwards. The demand for market product was also investigated by including the measures of food insecurity, indicated by food aid and the level of malnutrition, on the purchasing power. The results showed that malnutrition increases purchase power while food relief reduces it, despite both variables being highly significant. These observations were inconsistent with the expectation. It was earlier mentioned that households distressed with food insecurity sell livestock to acquire market products. This would then have increased supply of livestock to the market and on the other hand increasing demand for market products driving local prices upwards. This however was not established by our analysis, instead showed the opposite effects. The variables selected however explained much of the variability of purchase power (r-sq. =0.821) despite of those inconsistencies noted.

Finally, pastoral wellbeing, hence poverty, was highly driven by the rangeland condition, livestock asset ownership, the state of human health among pastoral households and their purchasing power. Poverty is at the heart of the sustainable livelihood framework adopted for this study. There is a general increasing trend in poverty levels among the households in the study area with every sample site registering at least 50% poverty rates. The percentage of poor households, used as a dependent variable, was found to be significantly reduced with improved rangeland conditions. Rainfall availability, and by extension increased NDVI, brings along favourable conditions through which livestock production provide the necessary household requirement (Campbell, 1999). In this study, 6-month lagged NDVI highly influenced the percentage of poor households; an indication that pastoral system take some time to reap the benefits of higher precipitation. This could be explained by other events such as higher birth rates and low sales rates following a period with above normal rainfall. The study also supported the argument claiming that accumulation of livestock helps in reducing pastoral vulnerability as earlier suggested by other studies (Lesorogol, 2009, McPeak, 2004). On the contrary, the results showed that increased malnutrition and purchasing power increase poverty rates. Studies on pastoral health showed that, poor households are susceptible to poor health, characterised by high level morbidity and malnutrition (Roth et al., 2005). This study confirmed this argument by indicating that higher percentage of children at risk of malnutrition predicts an increase in poverty levels. Although not significant, the purchasing power showed a similar impact of poverty. The predictor variables used in this model explained substantially on the variation of poverty percentage (r-sq. =0.645).

Generally, fixed-effect regression models clearly showed the active role played by the rangeland condition (natural capital) across all other forms of capital; namely human, social, physical and financial. The panel data exposed the direct linkages existing between these forms of capital which are vital in pastoral policy development. The direct policy impact of a single intervention can have far reaching implications generated by the interdependence of these capital forms. Most importantly, monitoring of these wellbeing indicators fell under the mandate of different government departments. The variables selected as predictors for the financial, human, physical, social, and natural capital had high predictability power with r-squared between 65% and 82% for all the models (table 6:15).

8.3 Pastoral Policy Evaluation

The diverse understanding of vulnerability, the causes, and human intervention to create a resilient socio-ecological system has partly been contributed by the variables identified as key indicators, the frameworks and methods used for analysis (Adger, 2006). The subsequent analysis draw discussions from the results described in chapter 7 generated form SD modelling methods. The basis of analysis for this analysis is grounded on the sustainable livelihood framework, which considers vulnerability as events or processes causing adverse effects on pastoral assets. The discussion also considers the policy options proposed as mediating the impacts of pastoral shocks in addition to creating a resilient socio-ecological system (Sen, 1981). This study first discusses the level of accuracy derived from the selected SD building blocks and further compares the outcome of 21 proposed strategies (see chapter 4) against the baseline scenario. Selecting SD scenarios with positive outcome is in some way appraising the combination of those policies in play affecting the internal structures of the pastoral system (Turner et al., 2003).

8.3.1 Model Accuracy

The links derived from the literature review and confirmed from both the cross-sectional and the panel data analysis were used to develop SD model. The SD modelling results showed a relatively good replication of a pastoral system and, by extension, wellbeing dynamics. The results highlighted the complex nature of the pastoral system. The model was developed to allow policy makers to examine the effects of policies on the pastoral wellbeing given the limitation of resources. Measuring the accuracy of the SD model outcome therefore is paramount due to the implications of the outcome in terms of resource utilisation. The primary outcome of a pastoral system, which is livestock ownership per household, was tested against the current records to ensure that the SD model developed and parameterised by both primary and secondary data was producing reliable results. Other indicators of capital measurements such as poverty and malnutrition rates were also compared against the modelled results to test validity of the result. The test results indicated a relatively high predictability power of the model results as discussed in section 7.6 with r-squared of 51% and 14% for malnutrition and poverty rates respectively. Although the r-squared values reported were low, the long term trend observed showed a uniform direction (figures 7:12 and 7:13). The values were therefore affected by the short term variability existing in the actual data as compared with the modelled results showing a smoother trend. There was marginal improvement in the predictability power of the SD model when the current results are compared with the 3-month moving averages arising from the current month and the previous two. The estimation assumed for 3 months made sense in testing our model with current data for two reasons. First, as had been mentioned earlier in section 3.6, the data collection process faced a myriad of challenges regarding data collection and storage. Lack of complete data for some sample areas in one particular month would affect the average for that period and 3 months were considered a sufficient duration to compute the average. Secondly, the SD model was run on a step time equal to a month based on the statistics of the same data. The results outcome of the SD model therefore produced smooth results utilising the coefficients of the selected variables simulated from averages over time.

8.3.2 Income Diversification

Human population, hence the number of households, is expected to double by the year 2030 ceteris paribus. The results on the growth of the human population in the area indicated similar findings among the pastoral Maasai in southern Kenya noted to have had a 4.4% growth over the period 1983-1999 (Lamprey and Reid, 2004). Growth in human population and households is expected to have effects on the pastoral systems in various ways affecting conservation (Barn, 2002, Lamprey and Reid, 2004), rangeland size through degradation (Garedew et al., 2009) and livelihoods (Kassahun et al., 2008). First, the system should be productive enough to sustain the social and economic needs. As the population grows, there is an equivalent rise in the need for more rangeland to raise livestock capable of meeting their social and economic needs. Households in a purely pastoral system require a minimum of 4.7 TLU per person for basic subsistence (Rutten, 1992, Dahl and Hjort, 1976). This threshold translates into 10-15 TLU for an average household size of 6-6.5 members (Upton, 1986, Coppock, 1994, Lybbert et al., 2004b). This increased demand for more livestock, being the main livelihood source, exerts pressure on the existing rangeland to the extent of causing degradation (Kassahun et al., 2008). Increased households also call for more land for settlements. These are areas purposely dedicated for construction of houses, fences and other compounds which are regarded as not suitable for pasture growth and therefore excluded from the productive rangeland. A substantial proportion of arid rangelands are used as home for wildlife, estimated at over 70% of the national population found in these areas (De Leeuw et al., 2001).

The fact that tourism plays a role in local and national economies of these areas means that the government and other interest organisations have stepped up efforts to secure their protection, creating competition between wildlife and human populations. An increase in human population and competition between livestock and wildlife for forage resource, adversely affect the general wellbeing of the pastoral households. The situation is worsened by the recurring droughts thus reducing pasture regeneration. Such unchecked population growth not matched with growth in resources ultimately generates vulnerability among these pastoral households. Greater involvement in non-livestock income (Desta and Coppock, 2002b) in addition to provision of public goods

(Soini, 2005, Freeman et al., 2004) have been offered as a solution to the income variability hence pastoral vulnerability.

Livelihood diversification is discussed widely by pastoral system scholars (Little, 1992, Thornton et al., 2006, Thornton et al., 2007). One major diversification programme is enhancement of human skills among the pastoral communities so that graduates from these communities can participate in employment and have a sustainable income source for the households. Lesorogol (2008b) noted that households exhibit different strategies based on their wealth status. The study further called for greater investment in the regional infrastructure and education to boost income diversification into employment. The target area for this education policy is in many cases directed at increasing enrolment and retention rates. A review of literature in this study has earlier noted in this study (section 2.5) low enrolment and high dropout rates among the pastoral communities. Effective programs are then evaluated based on the impact they have on facilitating higher schools intake and minimising dropout rates. Haro et al. (2005) found that conflicts and the environmental variability impact largely on education attainment and future prospect for the pastoral population.

Programs advocated in this area include the use of local administration to force parents to enrol their children in schools to enhance skills and make them competitive in formal employment. This program is aimed at improving the low levels of enrolment in most arid and semi-arid regions. Despite the delay of the impact of this policy, as the student have to complete the whole education process (8-4-4 system) before the outcome is felt, researchers have highly recommended it as a way out of poverty and vulnerability among pastoral communities. The simulation results indicated a rise on the percentage of the skilled manpower to the total population in the research area from baseline percentage of 5% to 7% by the year 2030 if the enrolment policy is adopted. The results showed the significant contribution played by the three strategies; increased enrolment, reduced dropout rates and the composite of the two, tested on a skills base. However, the positive contributions of the strategies differ with the combined strategy of increasing enrolment and reducing dropout rates, having the highest impact. The strategy contributed to an increase estimated at 41% at the end of the simulation period[12].The enrolment policy was aimed at targeting the enrolment rate by recruiting at least 74% of the children reaching the school going age from the existing 50%. From the focus group discussions and the cross-sectional data, it had emerged that many children who have attained school-going age still remained at home.

[12] Computed from combined strategy (7.9%) and baseline scenario (5.6%) =((7.9-5.6)/5.6)*100= 41%

Similarly, maintaining the current enrolment rate and dealing with dropout rate alone also indicated an improvement on the skills base. The results showed an improvement of the baseline rate to 6% when a policy targeted to reduce dropout rate by half was employed in the system from the current 5%. Measures to retain students in school in order to minimise dropout include school feeding programs, free education and accommodation at boarding school to cater for pastoral students whose parents migrate in search of pasture and water (Somerset, 2007). The major causes of dropouts experienced by pastoral communities in Kenya include lack of financial ability and early marriages (Nyamongo, 2000), traditions (Roth, 1991), in addition to climatic variability (Haro et al., 2005). The model however measured the outcome of the system assuming that the necessary policies are put in place to the level applied in the simulation. There are many success stories on the role of development organisations in providing a framework that supports both enrolment as well as retention. NRT (2009) for instance has widely created an avenue for parents to enrol their children by helping in providing accommodation through building dormitories and supplying water to schools. Focus group discussions confirmed the role played by the alternative accommodation in reducing the impact of droughts on school attendance as households are forced by drought to migrate.

8.3.3 Simulation Scenarios and Policy Outcomes

The previous discussions in section 4.4 outlined the details of the mitigation strategies employed in the study providing a wide range of the proposed policy options. The strategies are summarised in table 4:6 showing a total of 21 strategies directed at improving the environment, reducing livestock losses or increasing human skills. The outcome variables, also used to test the model accuracy, were used to appraise the policy options against the baseline scenario. Table 8:1 shows a summary rank of the top three strategies for every form of capital investigated. Policies directed at increasing both enrolment and retention rates in schools (strategy 21) produced positive results by increasing the proportion of skilled labour during the projected period. Application of individual policies such as increasing enrolment (strategy 20) and increasing retention by reducing the dropout rate by 50% (strategy 19) were ranked second and third respectively in boosting the skills base in pastoral households. Despite the delay associated with the length of the education system (16 years), the impact of either increasing students' retention or enrolment produced a higher proportion of a skilled population than the baseline model. These policies introduced in the model during the years following 2012 significantly influenced the skills base.

Human capital, measured by prevalence to food insecurity, was monitored by the percentage of children below 5 years old with Middle-Upper Arm Circumference

(MUAC) readings less than 135mm. This measure is a common method used to monitor wasting among children exposed to diseases or food insecurity (Mude et al., 2009a). Comparing various strategies, the simulation results indicate that malnutrition was significantly reduced by implementing policies directed towards conserving or creating more pastoral capital. Strategies 16, 12 and 13 played a big role in minimizing the risk of malnutrition hence pastoral vulnerability. Strategy 16, which included a combination of rangeland reclamation, planned settlement, veterinary services, restocking, security and destocking programmes, had the highest impact on reducing malnutrition among children below five years. Reclamation and planned settlement was aimed at improving the extent of productive rangeland to raise livestock carrying capacity of the existing area. Veterinary services and security programs on the other hand helped to minimise losses arising from diseases and conflicts respectively, thereby ensuring constant growth of the herd size (TLU). Other policies also tested for adoption are the various forms of restocking programs where households losing stock are compensated. Destocking programs on the other hand aim at reducing the value exposed to risk by selling, slaughter or lending livestock prior to a risk event (drought). Some organisations such as the NRT have in the past implemented widespread livestock marketing programs aimed at increasing market off take (NRT, 2011). Such a program is aimed at reducing pressure on the declining pasture resource, generate cash for the household to spend on market foodstuff, and reduce the labour requirement during drought periods.

Livestock insurance, currently under pilot study, has been widely argued to be an important way of both destocking and restocking (Chantarat et al., 2009b). However, both market driven off take, as well as an insurance program, are tested under strategy 16. The outcome of this strategy enhanced human capital by reducing the level of malnutrition better than strategies 13 and 12 which ranked second and third respectively. Strategies 13 and 12 contained the same policy programs applied in strategy 16, except destocking for strategy 13 and security programs in addition to destocking for strategy 12. Increased sales rates associated with a destocking program allow households to have reserve cash to supplement declining livestock productivity during drought years. The exclusion of destocking and security programs exposes households to higher livestock mortalities and loss of capital, important in providing nutritional value.

Financial capital, measured by the number of TLU per household, milk production and the financial value of livestock owned, indicate wealth and socio-economic status in pastoral communities. The simulation results showed a declining trend of TLU in the long run under the baseline scenario contradicting the findings that the mean relative growth rate for herds in East Africa, net of births, sales and mortalities is estimated to be about 3-4% (Dahl and Hjort, 1976, Oba, 2001). Livestock species which include cattle, shoats (sheep and goats) and camels however indicate varying directions of growth, with camels showing an increasing trend over the baseline scenario while cattle and SSU decline in the long run. This could be explained by low mortality rates for camels compared to SSU and cattle resulting from a high pasture requirement (Coppock et al., 1986). Different proportions of livestock types are required at different times of the pastoral cycle. Small stocks for instance provide milk and meat during drought seasons while at the same time they remain sufficiently marketable (Barrett and Luseno, 2004). The composition of these livestock types and their structures are altered during droughts ultimately affecting milk production and financial wealth. Strategies 13, 12 and 16 were ranked as the top three in that order, based on the simulation results for financial capital. The results showed the role played by destocking and security programs in increasing herd size. While the security program has a continuous effects on livestock dynamics, destocking takes place at some selected harsh periods causing a decline on stock ownership steadily during drought years. Improving security in addition to land reclamation, planned settlement, veterinary services and restocking programs (strategy 13) increases financial capital more than including a destocking program (strategy 16). Fluctuation in herd size directly affects the pastoral production system, particularly milk production, which provides many households with their nutritional requirements (Galvin, 1992).

Policies affecting rangeland included in the simulation model were aimed at improving productive size and pasture yield. Combined programs of reclamation, planned settlement and livestock feeding (strategy 10) produced the best results as measured by the amount of pasture stocks. This is explained by the fact that as households supplement pasture with commercial feeds, the herd size increases requiring more livestock sales. Strategy 9, which was ranked second, excluded supplementary livestock feeding indicating the role of overstocking on degradation. Supplementary feed is capital intensive and households sell much of their livestock in order to purchase it. Livestock sales through this program reduce stocking rates ultimately reducing the absolute degradation arising from overstocking. Further increases in the livestock off-take help reduce rangeland vulnerability. Strategy 11, which included an extra program of increasing investments in veterinary services, ranked third suggesting a similar observation as provision of supplementary feeds. The three strategies improved the baseline condition by 11%.

The ultimate vulnerability measure was derived from the performance of human, natural and financial capitals. Vulnerability measurement in this model did not take into account strategies directed towards enhancing skills as there was no established relationship between skills-base and employment on vulnerability. Strategies affecting financial capital however affected vulnerability in the same way, showing the direct link between pastoral policies and wellbeing. Poverty was reduced significantly when rangeland measures of reclamation and planned settlement were combined with insurance and security programs (strategy 13). Adopting this policy reduced the baseline long term poverty rate by 38%. Strategies 12 and 16 on the other hand reduced the baseline poverty rate by 37% and 36% respectively (Appendix VI). These simulation runs indicate how improvement in security to minimise conflict-related losses helps in reducing the proportion of poor households. Destocking of livestock during drought conditions on the other hand allows households to dispose of livestock and gain cash to be spent on buying market product. Such a strategy allows them to acquire market products to supplement declining livestock production. The impact of sufficient cash held by households was not however tested on vulnerability due to the lack of established relationships in our model. Due to the price differential between good rainfall and drought years, the number of livestock repurchased is lower than the number sold.

Table 8:1: Top three strategies of minimizing vulnerability

Forms of Capital	Measurements	Strategy rank for best output		
		1	2	3
Human Capital	Percentage of skilled labour to total population	Strategy 21	Strategy 20	Strategy 19
	Percentage of Children at risk of malnutrition	Strategy 16	Strategy 13	Strategy 12
Natural Capital	Productive rangeland size (ha)	Strategy 10	Strategy 9	Strategy 11
Financial Capital	Total Livestock Unit (TLU) per Household	Strategy 13	Strategy 12	Strategy 16
	Livestock Worth (US$)	Strategy 13	Strategy 12	Strategy 16
Vulnerability measure	Percentage of poor households (%)	Strategy 13	Strategy 12	Strategy 16

The dynamics of livestock, hence the pastoral system, is influenced indirectly by the cost of implementing the policy programs. The model used the rules of self-sustainability where every mitigation strategy is internally financed by selling livestock, although some strategies such as disease control can be financed by the government, as provided for by the Vision 2030 framework set out by the government of Kenya (IMF, 2010). The top three strategies 13, 12 and 16 in that order from the SD simulation results comprised of a combination of programs which included reclamation of degraded rangeland, planning for settlements, veterinary services, enhancing security, destocking and restocking programs. The cost of reclamation, planned settlement and security were omitted in this study because of the lack of a method to estimate them. Similarly, the responsibility for fighting degradation and offering security lies with the government as these are classified as public goods. We were left with the two most commonly discussed methods in the pastoral risk management literature, control of livestock diseases and stocking capacity. All these top strategies included quantifiable expenses relating to veterinary and insurance premiums. Despite the high costs of disease control and insurance premiums, these strategies sustained themselves under the current rules of efficient range utilisation dictated by the availability of pasture. While livestock supplementary feeding was considered a viable and effective mitigation strategy to minimise drought losses, the high investment required makes it unsustainable. Increased human population pressure, coupled with the high frequency of droughts reducing productive rangeland, means that more investments are made to purchase supplementary feeds from the market. The rules set in the model included the ability of the pastoral system to self-reinforce by allowing livestock sales to cover the need for these feeds. Although the general outcome for the period under review is quite positive for some strategies (such as strategies 15, 14 and 11), they however lagged far behind the results of restocking by way of insurance in combination with other programs.

8.4 Chapter summary

Pastoral communities are without doubt still highly dependent on livestock and their products as a major livelihood source. Although there are opportunities for livelihood diversifications, there are little prospects of immediate outcomes as a result of poor climatic conditions limiting agriculture to livestock only and low skills base from poor school enrolment and high dropout rates. These factors limit the wellbeing of pastoral communities on the condition of rangeland; size and productivity. However, changes in land use systems arising from the effects of droughts, human population and wildlife conservation activities have emerged as competing interests in the development of arid areas. Relevant risk mitigation strategies therefore need to address issues of rangeland productivity and planning, information dissemination, enhance market information and increase livestock price stability, and finally designing mechanisms to respond towards drought related losses.

Droughts, which were found to be common in the region, have far reaching effects than just rangeland and livestock. Droughts directly or indirectly affect wellbeing by influencing on the 5C's discussed under section 1.7 and results elaborated in chapter 6. There are close relationships existing between droughts and the other forms of capital such as pasture condition, number of livestock owned, purchasing power, malnutrition and ultimately poverty rates. Frequent droughts without effective policies could therefore drive pastoral communities into a poverty trap. The SD model developed in this study to look into the future of the baseline scenario shows a bleak future for the households dependent on livestock. The simulation results indicated an expected reduction in livestock ownership, reduced productive rangeland size, and livestock productivity. Reduction in TLU ownership arises mainly from droughts, human consumption, disease losses, and conflicts while reduced rangeland productivity results from changes in land use systems shifting rangeland into human settlement and core conservation areas. Strategies directed at responding towards droughts, improve market prices, and reduce livestock disease and conflicts losses help households to build their herd size. Increased herd size mitigates the adverse effects of food insecurity causing malnutrition and ultimately poverty levels.

The discussions in this study, centred around identification of pastoral risks, their impacts on wellbeing and policy development, is to a larger extent suggesting the importance of the standard risk management process. The discussion on sources of pastoral risks (section 8.1) extensively elaborated the identification and description stages of the process. Risks affecting the households directly or indirectly were identified and described. The second section of the chapter (section 8.2) went further to provide the estimation and evaluation criteria for those significant pastoral drivers. The causal effects of the variables driving wellbeing, classified as 5 C's, were established showing how important some variables such as livestock assets and pasture condition on reducing poverty and malnutrition among the Samburu pastoral communities. The final discussion section (section 8.3) involving policy evaluation discussed the last three activities of the standard risk management process. These include risk treatment, reporting and monitoring. The discussions were based on the results of the SD model.

9 Conclusions, Recommendations and Future Work

9.1 Key Findings and Conclusions

The conclusions were drawn from the key findings arising from the main objectives set out earlier under section 1.5.

9.1.1 The Drivers of Pastoral System

The task of identifying pastoral system drivers utilised multiple approaches. First, a series of focus group meetings were conducted in four selected areas representing the diversity in their proximity to main towns and protected areas, population densities, access to main infrastructure, and climate conditions. The aims were to generate debate surrounding pastoral systems, identify impediments to successful practices and propose strategies that have worked. The outcome of the focus group sessions were then used to develop survey questionnaire structured around the themes of the debate to evaluate household level perceptions towards risks and possible response strategies. Further, the discussion were used to inform the process of model development and later used in strategy options selection.

Descriptive and inferential statistics on household level questionnaires identified the main risks driving pastoral system. The results of the analysis conducted in chapter 5 identified an increasing perception of pastoral risks caused by various reasons. First, there is an increase in human population with the results of the study showing an average household of 7 members. Second, households depend highly on income from livestock products. About 37% of the households reported substantial dependence on livestock income while 18% lived on employment income. Only 6% of the households earned income above US$ 50 monthly most of which come from formal employment. Approximately 75% of the households earned income of less than US$ 25 a month. Third, households showed very little prospect of diversifying income sources with many of their members reported to be unemployed (35%) or tending livestock (14%). The results showed only 1% of the sampled population engaged in a formal employment and the remaining percentage is attending school (50%). Fourth, households reported a sharp decrease in livestock ownership in the past 5 years arising from droughts (pasture and water shortages), household consumption, conflicts and diseases ranked in that order.

Fifth, rangeland was perceived to be degraded or shrinking in productivity by all households with 100% confirming that the productivity has reduced over the past 10 years. This reduced productivity was linked to unreliable rains (rank 1), enhanced conservation (rank 2) and increased human settlements (rank 3). Sixth, a substantial proportion of households are not served with early warning information with 46% of them responding the lack of any kind of warning information regarding droughts. For those receiving early warning information, only 64% of them engaged in market off-take. The remaining 34% engaged in other traditional response mechanisms such as mobility and slaughter. They blamed low market prices (rank 1), lack of buyers (rank 2) and poor livestock body conditions (rank 3) as the reasons for holding their livestock during droughts. Seventh, households respond to drought conditions by preserving rangeland, livestock and ensure food security. To preserve rangeland, households proposed mitigation strategies for planting grass, rotational grazing and planned settlement ranked in their order of superiority in the outcomes. To preserve livestock, households respond by engaging in mobility (rank 1), requesting relatives/friends to look after livestock (rank 2) or buying supplementary feeds (rank 3). Finally, households meet food shortages arising from droughts by selling small stock, slaughter small stock or draw blood from livestock ranked in ascending order based on their frequency of use.

Reduced livestock ownership exposes households to financial and nutritional shock. The current study indicates that households keep livestock mainly for food. With the shock arising from rainfall variability, the most immediate impact is on food security and the priority of households all shift towards satisfying daily nutritional shortfall. Reduction in livestock arises from four forms of pastoral risks: - these are environmental, livestock asset, market, and information risks. First, rangeland risks affect the core resource under which the whole pastoral system relies on. Second, overexploitation of rangeland poses threats to the existence of the principle financial asset of many pastoral households. Third, market infrastructure, which allows transformation of livestock capital into cash reserves, is prone to variability caused by pasture conditions. Finally, management of these risks is dependent on information flow on the current state of pasture condition and forecasted short and long term market conditions. Absence or delayed information poses pastoral households an additional risk, in this case referred as information risk. In conclusion, pastoral communities are highly homogeneous with very little differences observed in their sources of livelihoods, perceived risks and their response strategies. Their socio-economic and regional differences does not show any significant variation in how they perceive rangeland, assets and market risks and the manner in which they respond to the adverse effects of these underlying risks.

Understanding pastoral risks is fundamental in designing policies aimed at reducing vulnerability. The results of this study have a number of policy implications. Firstly, the results illuminate the extent of the poverty trap among pastoral households. Most of them reported declining asset capital in the form of livestock despite it providing income to a majority of households. Strategies should therefore be focused on reversing the trend to allow recovery of livestock. Secondly, the core resource in pastoralism is perceived by many as being under threat by droughts, conservation activities and human population. Strategies likely to rehabilitate degraded rangelands and ensure planned settlements are essential to rebuild grazing fields. Thirdly, this research has also indicated the importance of perceived sustainable strategies in mitigating pastoral risks. Measures should then focus on ensuring open access but planned grazing areas to allow migration to continue. Fourthly, improved marketing infrastructure could help in stabilising livestock prices allowing pastoral households to continuously generate near stable amounts of income regardless of the environmental conditions. Similarly, timely and accurate early warning information should be relayed to allow households to make informed decision. This needs to be reinforced with the establishment of elaborate financial services with incentives to influence households to sell and save the money to mitigate shocks affecting livestock assets.

Based on these results, we can therefore conclude that pastoral households rely heavily on livestock income. The expansion in human populations will continue having a negative impact on rangeland productivity as settlements grow to occupy more space. With the reported high dependency in livestock income and high rate of unemployment, population expansion will further require more livestock in the area to keep up with their needs. However, the rangeland is already under intense pressure from land use changes and frequent droughts causing doubts on its ability to sustain the increased demand from the growing population. The results also indicate the role of droughts on rangeland productivity and market prices. These interdependent pastoral variables make it complex to manage a single aspect of it without examining the interrelationships with the rest of the system.

9.1.2 The Impact of Droughts on Wellbeing measurements

The research objective was achieved using two sources of secondary data and analysed using fixed effects regression model explained in section 3.7. The objective was subdivided into two, with the first aspect seeking to identify drought years within our interest period (2006-2010). In order to achieve this, 27-year monthly NDVI data (described in section 3.6) was analysed to identify years with negative anomalies suggesting drought years and highlighting those events within our period of interest. The second part was to examine the 5-year household level panel data collected by ALRMP and examine it through a statistical analysis and interpretation. The outcome variables were structured in line with our research framework (section 1.7).

This study highlighted the frequency and impact of droughts in the arid areas, in Samburu district, Kenya. Severe droughts in the past 27 years in Samburu are common, occurring once every 2-3 years. Using the period January 2006 to March 2010, as a reference time period to observe pastoral livelihoods, the study found that droughts hugely affect pastoral livelihood in many ways. Droughts influence livelihoods by reducing rangeland productivity, which in turn reduce livestock productivity, and further affect herd accumulation negatively by influencing livestock birth, sales, and mortalities. The results of NDVI analysis which estimated vegetation condition as compared to long term means indicated that the region experienced drought conditions in the years 2006 and 2009, with Z-scores and VDI both showing the same results. The year 2009 however recorded the lowest NDVI values hence negative anomalies.

The statistical modelling of the panel data indicated negative effects on wellbeing indicators during drought years. Table 9.1 shows a summary of simple averages comparing the 5 C's between good and poor rainfall years classified based on the NDVI anomalies. Holistic analysis of pastoral variables, using SL framework, showed a great deal of interlink between the various forms of pastoral capitals. Poor pasture condition affect herd dynamics by increasing mortalities while hampering the normal livestock birth rates. The ultimate outcome is increased food insecurity, increased risk of malnutrition and the possibility of structural poverty. Many pastoral households facing structural poverty are likely to be confined in a poverty trap. The findings suggests that policies aimed at reducing poverty need to take into consideration the entire system and measure the variability of the 5 forms of capital (5 C's) namely; financial, human, social, physical, social, and natural capitals. Generally, rainfall variability and the associated shocks provide an important indicator on which area the governments and other organisations should focus in a bid to curb vulnerability of livelihood assets. It is therefore possible to link policies and processes to environmental variability and response strategies. The desired outcome for such a pastoral community is increased livestock ownership which increases milk production, provides more income and reduces food insecurity. Ultimately, the community will be less malnourished and fewer households will be poor.

Table 9:1: Wellbeing conditions between drought and non-drought years

Wellbeing Measure	**Non-Drought Year**	**Drought Year**
Financial Capital (Total Livestock Unit)	TLU=9.52	TLU=8.04
Human Capital (Malnutrition rate)	MUAC=16.9%	MUAC=24%
Physical Capital (Meat-Cereal Price Ratio)	MCPR=128%	MCPR=88.9%
Natural Capital (Rainfall mm per month)	Rain=38.8mm	Rain=19.3mm
Social Capital (Poverty Percentage)	Poor=67.9%	Poor=73%

Fixed effects regression models showed a high level interaction between natural, financial, physical, human and social capitals. Long term pasture condition and the birth rate for small stock were highly significant in building herd size. The off-take was significantly driven by the mortality rates for cattle and sales rates for small stocks. Households often show distress arising from food insecurity by recording high levels of malnutrition. The regression model also showed livestock birth rates, small stock sales and good pasture condition significantly reduces the percentage of children at risk of malnutrition. Mortality and sales rates for cattle on the other hand were found to increase the risk of malnutrition. Other key findings on malnutrition are the significant positive effects of purchasing power and proportion of relief supply. The results showed the role played by supply and demand in shaping the purchasing power for the pastoral communities. Significant positive effects were observed between purchasing power and livestock birth rates, pasture condition and livestock ownership. More important to mention, high malnutrition is associated with increased purchasing power. Increased livestock sales and livestock mortality rates negatively affected purchasing power. Finally, the model results indicated highly significant effects of long term NDVI values (6-months lag) on poverty. Increased TLU ownership and better pasture condition, measured by NDVI values suggested a reduction in the proportion of poor households. Improved purchasing power and increased percentage of children at risk of malnutrition strongly increased the proportion of poor households.

These results therefore showed how livelihoods are tied to variability in climate and existence of other pastoral risks. The study highlighted the frequency and impact of drought in Northern arid areas in Kenya. Droughts are found to be frequent and their impacts negatively affect the households' livelihood assets. The initial impact of drought in pastoral economy is pasture condition which forms the bedrock for herd dynamics. Poor pasture condition affect herd dynamics by increasing mortalities while hampering the normal birth rates. The ultimate outcome is increased food insecurity, increased risk of malnutrition and possibility of structural poverty. Many pastoral households facing structural poverty are likely to be confined in a poverty trap. Efforts to mitigate pastoral risks should take into consideration existing interrelationships and which could potentially affect pastoral wellbeing.

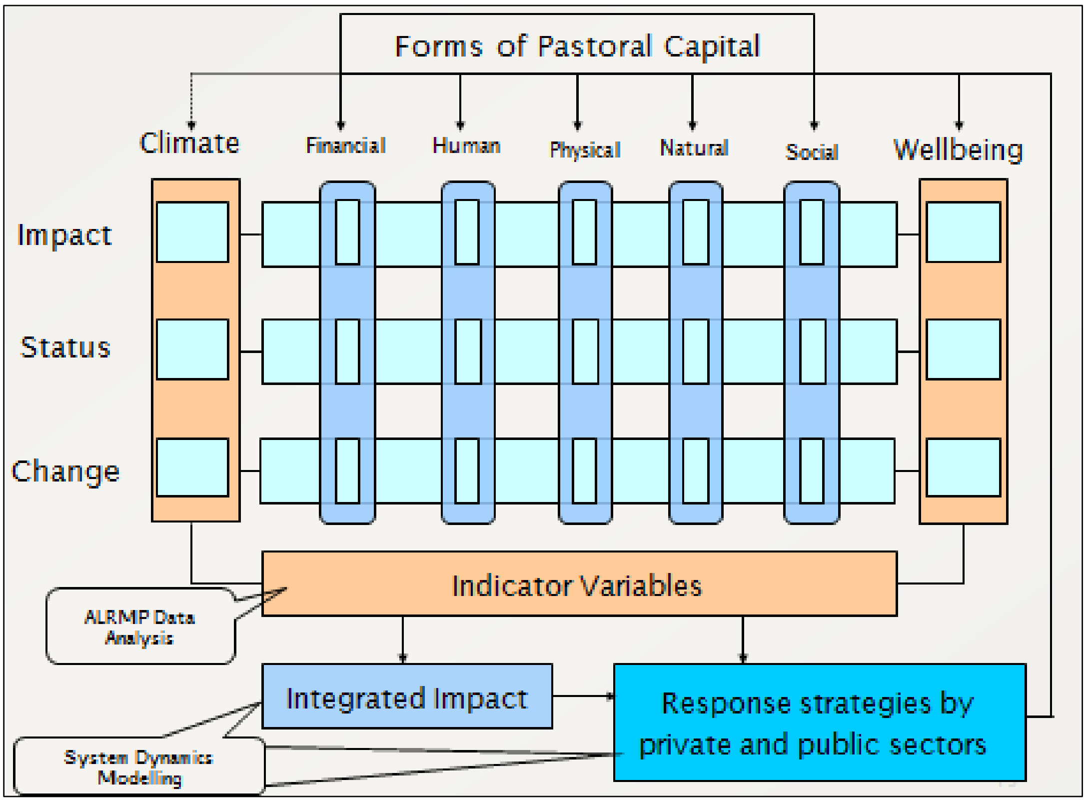
9.1.3 System Dynamics Development and Model Testing

The task was achieved through multiple approaches which included literature synthesis, focus group discussions, and parameterisation from both primary and secondary data sources. The results of the SD model were then tested against actual data collected by ALRMP from January 2006 to December 2010 to ensure that the model is valid and accurate. The SD model classified into rangeland, human population and livestock sub-models tracked monthly changes in wellbeing measurements linked with the wellbeing measures. These measures were derived from the coefficients of the statistical model generated from our objective 2 (measuring the effects of droughts on wellbeing). Testing the results of the SD model discussed in section 7.6 shows reasonable correlation between modelled results and actual data for TLU (0.41), malnutrition (0.78) and poverty (0.39). While these correlation values may appear low because of high variability in the actual data, the two data sources exhibit similar trends in the long run (figure 7:13 & 7:14).

9.1.4 Pastoral Policy Evaluation

Mitigation strategies generated during focus group discussions were further investigated from a review of the literature to ascertain applicability and achievable targets. These were supplemented with proposals made by research groups and development partners regarding the identified strategies. The strategies identified and evaluated in this study included rangeland rehabilitation, livestock disease control, insurance against droughts, livestock supplementary feeding, destocking, and inter-ethnic conflict resolution. The modelled baseline results show alarming trends of the socio-economic welfare of the pastoral community under review, confirming the worries many researchers have pointed out in the past. This supports the conventional wisdom that reduced livestock ownership without increasing alternative livelihood sources drives pastoral communities into a poverty trap. Modelled results showed a decline in TLU ownership to a level below 5 per households in the year 2030 with an associated increase in both poverty and malnutrition percentages to around 80% and 30% respectively. Strategies directed in improving rangeland by reclamation and planned settlements while at the same time secluding wildlife by increasing core conservation areas by 30% for instance improved pasture productivity by 11%. Increasing conservation rangeland alone without rehabilitating the existing degraded rangeland decreases productive rangeland size and biomass produced by 21%. The winning policy combination (strategy 16) consisted of rangeland reclamation and planning, disease control, restocking, conflict resolution, and destocking programs. The strategy reduced the average percentage of children at risk of malnutrition by 48% and poverty proportion by 36% from the baseline scenario. The strategy further increased household TLU ownership by a factor of 1.28 (128%) and livestock value by 174% from baseline results (appendix VI).

Figure 9:1: Modelling and Management Mindset



In summary, incorporating SD modelling in the management of arid lands has proved important from the results of this research. From the onset of this research, the role played by droughts was linked to various studies. Further effects and the means of mitigating were collected from focus group and a cross-sectional survey. The challenges posed by the underlying environmental complexity needed a methodology that considers both non-linearity and the counteractive feedback effects. SD therefore helped in building a model to measure the effects of variables existing within pastoral system and the impact of the feedback loops arising from mitigation strategies. Figure 9:1 shows the interaction of droughts on the 5C's, hence wellbeing, the selection of measured indicators, and the application of SD to model integrated impacts of responses.

9.2 Policy Recommendations

The policy recommendation for this study was derived from the results of the three level analysis involving a cross-sectional survey, panel data and SD simulation modelling. Pastoral risks and mitigation strategies identified and the subsequent quantification of the drought impact on strategies informed the areas for policy recommendation. The study tested the SD model performance based on the proposed risk management framework identified from the first objective in this study and suggested some recommendations.

First, the results of the analysis of the system drivers and their associated mitigation strategies (chapter 5) followed by an in-depth discussion in section 8.1 show potential for policy formulation. Rangeland, ranked as an important system driver, requires a proper plan for utilisation and recovery. Rangeland utilisation involves planned settlement, seclusion for wildlife conservation and planned grazing while recovery is achieved through reclamation of the unproductive parcels of land to allow production of more pasture resource. Second, there is a need to preserve and develop livestock which is the prime capital asset for pastoral communities. This study, in section 5.2 (sources of income), identified livestock as the key asset and income source for communities living in dry areas in northern Kenya. However, the current system provides little or no prospect for its sustainability. Improved livestock dietary and disease control from the modelled results have a significant contribution towards pastoral sustainability. Third, there is a need to improve food and livestock markets by investing in market programs aimed at facilitating destocking and restocking. The results in section 6.4 (sustainable livelihood estimation) showed that livestock prices fall during droughts driven by poor livestock body conditions, increased supply of livestock, and reduced demand (fewer buyers). It is based on this reason that many herders hold their livestock during drought-stress period, ultimately suffering losses when pasture condition deteriorate. A vibrant pastoral system is measured by the total livestock productivity. Households sell livestock to raise cash to purchase market food, pay costs such as medical and school fees, and to match livestock ownership with resource availability. However, the prevailing market price can either encourage or discourage this kind of managed livestock off-take through the market. Stakeholders need to establish livestock supply chain information to ensure less disparity exists between livestock prices in the cities and in the rural areas where the primary markets are located. The analysis detailed in chapter 6 and discussed in section 8.2 similarly indicate the need for a stronger early warning system based on the key vulnerability indicators to improve livestock and market related policies.

Fourth, the results of the SD modelling (chapter 7) discussed in section 8.3 indicate the need for a holistic management of arid rangeland to minimise vulnerability. There is a need for diversification of livelihoods to other sources such as education to provide the community with alternative income source which is less vulnerable to pastoral shocks. Although our SD analysis on the education sub-system was not linked to the wellbeing measurements, its independent analysis shows the contributions made by programs linked to increasing and retaining enrolment in schools. Other likely alternative ventures include livestock trading and small businesses. Fifth, government and other development partners should also participate in providing public goods such as good healthcare programs to reduce morbidity likely to cause unmeasured wasting used in the analysis as percentage of children at risk of malnutrition. This will give a more accurate predictability of the effects of controlled variables in the model linked to other forms of capital on malnutrition.

Generally, rainfall variability and the associated shocks provide an important indicator on which governments and other organisations should focus upon in a bid to curb vulnerability of livelihood assets (see section 6.4). It is therefore possible to link policies and processes to environmental variability and response strategies. The desired outcome for such a pastoral community is increased livestock ownership which increases milk production, provides more income and reduces food insecurity. Ultimately, the community will be less malnourished and fewer households will be poor. The results of the SD model have indicated the relevance of stakeholder participation in pastoral policy development. Strong participation by the pastoral community, in partnership with conservation organisations, government departments and the international community is required to finance and give leadership on sustainable programs. In order to achieve this at a general community level, civic education is required to influence change in socio-cultural practices likely to have adverse effects on the pastoral system.

9.3 Contribution

This research contributed in three main areas, namely; quantification of the impact of droughts on pastoral wellbeing, development of SD simulation model, planning and policy evaluation. The contribution seeks to satisfy the needs of the institutions mentioned in section 1.4. First, there is no other available study utilising panel data on pastoral system to examine the impact of socio-economic and environmental variables on wellbeing. Classifying these variables based on the vulnerability framework is by itself a contribution from this study. ALRMP, from which the household data was used, has so far been collecting data without examining variable relationships. The study provides insights into which areas effort should be made for mitigating adverse effects of droughts under the Drought Management Initiative (DMI) of the Department of the Government. This gives the ready processed data for those interest groups working towards poverty alleviation programs in pastoral areas. Armed with interlinked relationships between environmental, social and economic environment among the arid pastoral households, the government's response strategies can then be assessed in a more structured manner, focusing attention to the critical building blocks affecting the process of attaining sustainable pastoral livelihood.

The second contribution of this study is the development of a SD simulation model by identifying pastoral risks, generate interrelationships and test pastoral policies. As mentioned earlier under section 1.6 (research gap), pastoral system is a complex one and policy development requires a well elaborated investigation of cause and effect relationships between the sub-systems. Scholars and policy practitioners have in the past developed system dynamics simulations in pastoral systems to propose effective policies of stocking rates, land use systems and wildlife management. This research has gone further to integrate the current measures of vulnerability (5 C's) to examine effective policies on improving socio-economic state of the pastoral communities in Kenya. This contribution is vital in bringing together the many development partners looking at various aspects of the pastoral system to debate and forge forward strategies with greater socio-economic impact.

The third contribution of this study is in planning and management of droughts. The identification of droughts involved a thorough analysis of rainfall anomalies and the development of appropriate tools for setting drought thresholds. Section 3.7 discussed the computation based on the VDI model identifying drought years between 1984 and 2010. The results of the VDI model were since taken over by ALRMP and currently on pilot study for some districts in northern Kenya as an early warning system reporting tool. DMI has also shown interest in utilisation of the fixed effect modelling on evaluating of the impacts of short and long term policies on malnutrition and poverty.

Finally, the study has contributed to literature on policy development and evaluation in the arid and semi-arid land in sub-sahara Africa. The identification of critical pastoral drivers and linking them with pastoral wellbeing is an area with minimal research, mainly focusing on specific areas such as demography, economy, ecology or conservation. The development of the SD model in this research brought in wider inputs from various areas to determine the outcome variables hence wellbeing of the pastoral households.

9.4 Limitations

This research and indeed the findings are not without some limitations, and the interpretation of the results should take caution on them. The limitations arise from the sources of data and the assumptions made during the analysis. The study utilised both primary and secondary data sources. Appropriate measures were undertaken to minimise potential biases related to data collection and analysis for the primary data. However there was no control for the secondary data collected classified into literature, ALRMP, and FEWS-NET NDVI data sources. The secondary data sourced from ALRMP, used to establish the cause and effects of pastoral wellbeing drivers, was limited in some ways. First, there were some incomplete months within the period of interest. The presence of these months could potentially affect the results and the final conclusion despite the application of a fixed-effect regression model which reduces the potential bias arising from missing data. Second, the data collected was not linked to particular households for the period under review. The results and the interpretation could be influenced by a possibility of high variability in monthly data at the household level. The study however mitigated this limitation by assessing cause and effects at the regional level. Pseudo-panel dataset was developed by averaging sampled households for every region to represent the state of wellbeing of the community living in those sample areas. This does not however clear all potential biases arising from random sampling of households on monthly basis, for the period of investigation, and expect to represent the data as regional situation analysis. The data nonetheless provided a rich avenue to examine the causal relationships for selected wellbeing drivers.

The spot NDVI satellite data, sourced from FEWS-NET, also suffers from inaccuracies identified from other studies utilising it for policy and planning purposes. An important limitation in this case is the false signals of greenness, especially arising from non-pasture plants such as *acacia tortilis* shrubs. The measurement of rangeland condition using NDVI therefore does not conclusively, by its own, tell the amount of pasture stock available. Similarly, dried grass show less greenness suggesting drought condition although livestock could still heavily depend on them. This limitation was however reduced in this study by using established models of pasture productivity to compute pasture resource instead of depending exclusively on NDVI alone. Descriptive analysis was also carried out to ensure that much of the NDVI variability is driven by rainfall amounts. The limitation arising from the non-green pasture was reduced by adopting time lags in both short and long term.

Finally, the policy evaluation process in this study heavily relied on the results of the SD model. The development and parameterisation of the SD model presented the research with some challenges. There are many assumptions made to simplify the pastoral systems, which in reality is complex. Some of the SD model variables which were not established utilised macro-level estimates to measure wellbeing. Some of these estimates have potential biases depending on the source data while some variables applied for a different time period. Several measures were taken to mitigate the adverse effects arising from the assumptions on development and parameterisation of the SD model. First, the model and the results were shared with a wide range of experts for evaluation of the reasonableness of the assumptions made. Second, basic outcome variables were tested against actual available datasets for the period of the simulation. Caution is however needed when using the SD model and should not be used as a predictive tool rather as a policy appraisal mechanism.

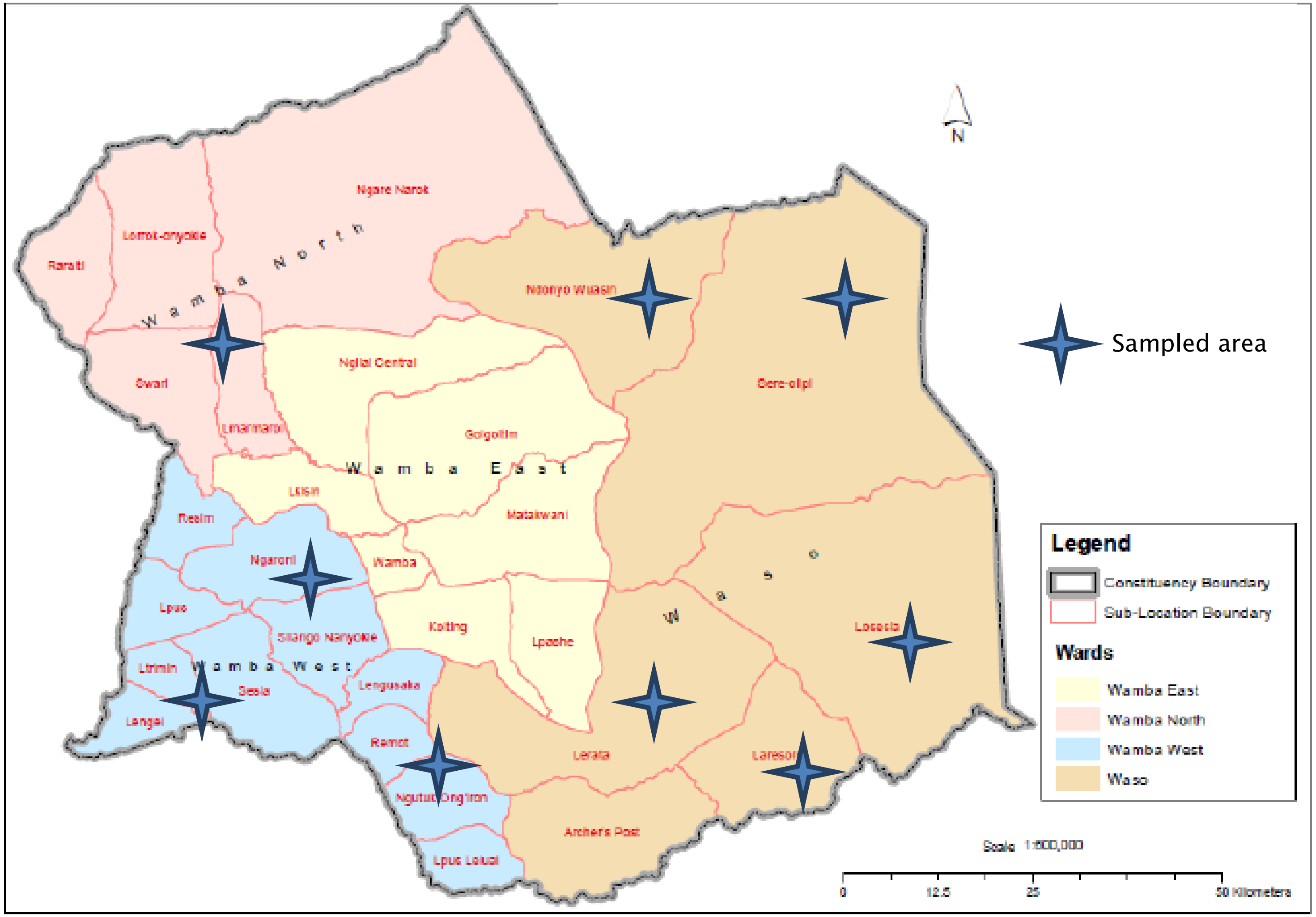
9.5 Future Work

The findings of this research opened avenues for prospects in policy evaluation in arid and pastoral rangelands affected by droughts. The contributions have already created areas to seek further data, debate and develop effective policies. The following are specific areas for future work:-

1. The iterative SD modelling process follows a six-step cycle. While this research has produced the SD model and recommended for effective strategies, further work need to be done to empirically test the actual outcome of the proposed risk mitigation strategies. This allows monitoring and subsequent changes in pastoral policies to mitigate the risk of vulnerability.
2. The panel data analysis and SD simulation models produced statistically significant results on the drivers of pastoral wellbeing in Samburu district. There is however need to test both the statistical and SD models in other arid areas similar in livelihood characteristics.
3. Managing pastoral vulnerability risk in a dynamic environment requires a comprehensive model incorporating input from conservation benefits, employment income, agricultural and trading income. It would be valuable to empirically explore the impacts of income levels and benefits arising from these sources affect the vulnerability risk.
4. The result of the study indicated insignificant effects of food relief supply and improved purchasing power on malnutrition and poverty rates. It would be interesting to conduct an empirical research to investigate the role of risk mitigation strategies such as relief food and market prices on pastoral wellbeing.

10 Appendices

Appendix I: Study Area and Sample Selection



Appendix II: Questionnaire for Chapter 5

A Household Demographics

1 Name of the respodent (....)

2 Gender Male ☐ Female ☐

3 Residence area (....)

4 How long have you lived in this residence? (....)

5 How many people live and supported by your household?

	Number	Main Activities Engaged: Stay at Home	Formal Work	Attending College	Primary School	Tending Livestock	Others (specify)
(a) Adults 15 years and over	( )	( )	( )	( )	( )	( )	( )
(b) Age 5-14 years	( )	( )	( )	( )	( )	( )	( )
(c) Children below 5 years	( )	( )	( )	( )	( )	( )	( )

B Financial Capital

I Livestock

1 Do you own any livestock? Yes ☐ No ☐

	Cattle	Camels	Shoats	Donkeys
If yes, how many of these species do your household own?	( )	( )	( )	( )
(a) How many herders are required to look after these livestock during wet season?	( )	( )	( )	( )
(b) How many herders are required to look after these livestock during dry season?	( )	( )	( )	( )

	Frequency	Cost
2 How many times do you replace livestock fencing in a year?	( )	( )

3 In the past year how many of these species have you treated against diseases?

	Number	Cost
(a) Cattle	( )	( )
(b) Sheep	( )	( )
(c) Goats	( )	( )
(d) Camels	( )	( )

4 Did your household own milk producing animals in the past year? Yes ☐ No ☐

If YES, What is the average milk produced per day in litres for every single species?

	Cattle	Camels	Shoats
During rainy season	( )	( )	( )
During dry season	( )	( )	( )

5 Milk distribution

	Wet season	Dry Season
(a) How many litres do you distribute to the market daily	( )	( )
(b) How many litres do you distribute to other households	( )	( )

6 Why do you keep livestock?

	Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 most Important Uses
(a) I keep livestock to provide household with meat	☐	☐	☐	☐
(b) I keep livestock to provide household with milk	☐	☐	☐	☐
(c) I keep livestock for status (social reasons)	☐	☐	☐	☐
(d) I keep livestock for sale	☐	☐	☐	☐
(e) I keep livestock to provide inheritance	☐	☐	☐	☐
(f) I keep livestock as insurance against animal diseases	☐	☐	☐	☐
(g) I keep livestock as insurance against drought losses	☐	☐	☐	☐
(h) I keep livestock as insurance against raids	☐	☐	☐	☐
(i) I keep livestock for emergencies such as human illnesses	☐	☐	☐	☐
(j) Others (specify)	☐	☐	☐	☐

7 Have your household livestock ownership reduced in the past 5 years? Yes ☐ No ☐

8 If YES, what do you associate the decline? Also rank the three highest causes

	Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank
(a) Consumption by slaughter	☐	☐	☐	☐
(b) Pasture shortage	☐	☐	☐	☐
(c) Water shortage	☐	☐	☐	☐
(d) Diseases	☐	☐	☐	☐
(e) Raids/stealing	☐	☐	☐	☐
(f) Wildlife Predation	☐	☐	☐	☐
(g) Accidents	☐	☐	☐	☐
(h) Others (specify)..	☐	☐	☐	☐

II Other Sources of Income

		Activity (Yes/No)	1-2000	2001-4000	Above 4000
9	Does your household engage in these activities and how much on average is the monthly income(Ksh.)?				
	(a) Livestock	( )	☐	☐	☐
	(b) Casual labour	( )	☐	☐	☐
	(c) Formal employment	( )	☐	☐	☐
	(d) Charcoal and firewood	( )	☐	☐	☐
	(e) Crops	( )	☐	☐	☐
	(f) Gifts and remittances	( )	☐	☐	☐
	(g) Others (trade and other Misc)	( )	☐	☐	☐

		Yes	No
10	Have you directly or indirectly benefited from conservation projects	☐	☐

		Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 main benefits
11	If Yes, to what extent have you directly/indirectly benefited from the conservancy? Rank three main benefits				
	(a) Transport	☐	☐	☐	☐
	(b) Medical care	☐	☐	☐	☐
	(c) Employment	☐	☐	☐	☐
	(d) Bursary	☐	☐	☐	☐
	(e) Water services	☐	☐	☐	☐
	(f) Cash benefits	☐	☐	☐	☐
	(g) Livestock marketing services	☐	☐	☐	☐

C Natural Capital

I Water sources

		Rainy Season Amimals	Rainy Season People	Dry Season Amimals	Dry Season People
1	What is the distance to water points? (KMs)	( )	( )	( )	( )
2	Tick three main water sources for animals and people during rainy and wet seasons				
	(a) Hand dug wells	☐	☐	☐	☐
	(b) Borehole	☐	☐	☐	☐
	(c) Ponds	☐	☐	☐	☐
	(d) Surface (rivers, lakes and depression)	☐	☐	☐	☐
	(e) Taps	☐	☐	☐	☐
	(f) Other (water tanks)	☐	☐	☐	☐

II Rangeland Productivity

		Yes	No
3	Has access to grazing land reduced?	☐	☐

From a scale of 1-3 where disagree=1 and agree=3, please state your level of agreement or disagreement to the following statements.

		Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 main causes of range reduction
4	According to your observation and past experience, what is your opinion on the following?				
	(a) Increased human population has accupied dry period grazing areas	☐	☐	☐	☐
	(b) Past grazing areas are producing less of pasture than before	☐	☐	☐	☐
	(c) Tribal conflicts have limited access to past grazing areas	☐	☐	☐	☐
	(d) Expansion of business centres have occupied grazing areas	☐	☐	☐	☐
	(e) Existence of pests have prevented access to past grazing areas	☐	☐	☐	☐
	(f) Enhanced wildlife conservation has denied access to grazing land	☐	☐	☐	☐
	(g) Wildlife predation has increased in areas used during dry seasons	☐	☐	☐	☐
	(h) Increased livestock population is causing competition on rangeland	☐	☐	☐	☐

		Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 most effective
5	In your opinion, which are the measures capable of improving productivity?				
	(a) Planting grass in dry areas will help improve land productivity	☐	☐	☐	☐
	(b) Rotational grazing to allow land recovery	☐	☐	☐	☐
	(c) Restricting previous dry period grazing areas will improve reserves	☐	☐	☐	☐
	(d) Reducing household livestock ownership allows rangeland to recover	☐	☐	☐	☐
	(e) Restricting settlements on grazing land improves rangeland utilization	☐	☐	☐	☐

D Drought Mitigation Strategies

1	In which way(s) did the household respond to the 2006 and 2009 droughts?	Agree (3)	Neither Agree nor	Disagree (1)	Rank 3 Most Applied
	(a) Shift livestock ONLY to areas where water and forage resource is available	☐	☐	☐	☐
	(b) Shift the ENTIRE household to areas where water and forage resource is available	☐	☐	☐	☐
	(c) Drop out school going children/students to herd livestock during drought period	☐	☐	☐	☐
	(d) Pay someone to herd livestock	☐	☐	☐	☐
	(e) Buy forage and other food supplements to feed livestock during stress period	☐	☐	☐	☐
	(f) Sell some of the herds to reduce herd-size to a manageable levels	☐	☐	☐	☐
	(g) Request for other relatives to herd on behalf without pay.	☐	☐	☐	☐

2	How did your household respond to food shortage caused by the droughts of 2006 and 2009? Rank the three main responses adopted by the household	Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 Main Responses
	(a) Slaughter small stocks (sheep and goats)	☐	☐	☐	☐
	(b) Slaughter large stock (cattle and camels)	☐	☐	☐	☐
	(c) Sell small stock for market products	☐	☐	☐	☐
	(d) Sell large stock for market products	☐	☐	☐	☐
	(e) Wild hunting	☐	☐	☐	☐
	(f) Exhange livestock with cereals	☐	☐	☐	☐
	(g) Draw blood from livestock	☐	☐	☐	☐
	(h) Engage in Charcoal/wood business	☐	☐	☐	☐
	(i) Migrate to towns for casual labour	☐	☐	☐	☐

3	What is your opinion on the following strategies on reducing droughts impact? Rank the three most effective	Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 Most Effective Strategies
	(a) Relief food supply	☐	☐	☐	☐
	(b) Livestock destocking for slaughter	☐	☐	☐	☐
	(c) Livestock destocking for cash	☐	☐	☐	☐
	(d) Water tankering/ mobile water supply to people and livestock	☐	☐	☐	☐
	(e) Permanent water supply to households and livestocks	☐	☐	☐	☐
	(f) Livestock veterinary services	☐	☐	☐	☐
	(g) School feeding program	☐	☐	☐	☐

4	To what extent do you agree or disagree with the following on the decision to sell livestock during drought period?	Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank
	(a) Destocking should be done prior to drought following failure in short rain (Dec)	☐	☐	☐	☐
	(b) Destocking programme prior to drought following failure in long rain (April)	☐	☐	☐	☐
	(c) Destocking programme during drought after the dry period grazing is degraded	☐	☐	☐	☐
	(d) Continous destocking regardless of the state of pasture (good and bad rain years)	☐	☐	☐	☐

5	In your opinion, to what extent do you agree or disagree with the following constraints towards livestock sales during droughts? Rank the three most impediments	Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank
	(a) Lack of buyers/market for livestock	☐	☐	☐	☐
	(b) Low livestock prices	☐	☐	☐	☐
	(c) Expectation of sudden rains	☐	☐	☐	☐
	(d) Poor animal body condition to treck	☐	☐	☐	☐
	(e) Lack of weather forecast	☐	☐	☐	☐
	(f) Inconsistent weather forecast information	☐	☐	☐	☐

		Yes	No
6	Have you received information in the past about forecasted weather condition?	☐	☐

If Yes, how did you respond to the information?

(a) Sell livestock ( )

(b) Move to dry land grazing areas ( )

(c) Drop school going children to look after livestock ( )

(d) Bought and stored pasture supplements ( )

(e) Other specify (eg. Did nothing) ( )

		Agree (3)	Neither Agree nor Disagree (2)	Disagree (1)	Rank 3 most effective
7	In your opinion, to what extent do you agree or disagree with these strategies in mantaining pastoral wellbeing? Rank the three most effective strategies				
	(a) Migration to areas of good pasture and water resources	☐	☐	☐	☐
	(b) Diversification of livestock species (eg mix small and large stock)	☐	☐	☐	☐
	(c) Herd accumulation	☐	☐	☐	☐
	(d) Grazing management: Herd split into satelite and home based	☐	☐	☐	☐
	(e) Livestock feed supplement	☐	☐	☐	☐
	(f) Livestock disease control	☐	☐	☐	☐
	(g) Social safety networks	☐	☐	☐	☐
	(h) Others, eg street livestock (Specify)	☐	☐	☐	☐

Appendix III (a): SD Variables Values and Description

Sub-System	Variable	Equation/Value	Source description
Human sub-system	Initial human population	59,094 people	Population census (GoK, 2010b)
	Annual mortality rate (above 5 years)	11.8/1000	Literature table 4.5 (IFAD, 2009)
	Average number per household	6 people	ALRMP panel data
	Average number of households	(human population/6)	Linear mathematical relationship between total population and average per household membership
	Annual birth rate	39.2/1000	Literature table 4.5 (IFAD, 2009)
	Annual infant mortality rate (under 12 months)	79.8/1000	Literature table 4.5 (IFAD, 2009)
	Annual under 5 years mortality rate	121.2/1000	Literature table 4.5 (IFAD, 2009)
	Annual KCPE rate (8 years primary school)	1/8	Assumption: Equal proportion of enrolled complete every year
	Annual KCSE rate (4 years secondary school)	1/4	Assumption: Equal proportion of enrolled complete every year
	Annual primary school dropout rate	5% (40% primary dropout in 8 years)	Kenya national statistics and literature (World Bank, 2011, Somerset, 2007)
	Annual secondary school dropout rate	3.125% (12.5% secondary dropout in 4 years)	Literature and national statistics (World Bank, 2011)
	Annual primary school	50%	Derived from literature on Samburu district primary

	enrolment rate		enrolment rates (Lesorogol, 2008b) and confirmed from cross-sectional data
	Annual college completion rate (4 years in college)	1/4	Assumption: Equal proportion of enrolled complete every year
Rangeland sub-system	Rangeland size	1,014,200 ha	Interim Independent Boundaries Review Commission (IIBRC) (GoK, 2010b)
	Initial core conservation area	55,855 ha	Literature on conservation in Northern Kenya table 4.4 (NRT, 2009)
	Household acreage	1 ha per household	Assumption based on the estimated size of kraals, houses, and fences
	Biomass production (Sinclair)	-201+7.67*Rain	Literature equation 16(a) (Sinclair, 1975)
	Biomass production (Braun)	-196+8.49*Rain	Literature equation 16 (b) (Braun, 1973)
	Pasture decay	50%	Assumption based on literature that 50% of pasture is annual grass damaged (Tefera et al., 2007a). 50% of the excess pasture is lost at the end of every season.
	Palatable pasture	50%	Assumption based on literature that between 45% and 50% of pasture produced is palatable (van Wijngaarden, 1985, Mulindwa et al., 2011)
	Initial degraded rangeland Initial productive rangeland	30% 70%	Assumption from literature estimated between 30% and

			45% of arid areas of east Africa to be degraded or unproductive (van Wijngaarden, 1985). Focus group discussion helped to find the common perceived degradation estimate for this region.
	Settlement area (ha)	(1* Number of households)	Linear mathematical relationship between acreage and households
	Annual degradation rate	1% and 0.5%	Assumption from literature indicating 1% annual degradation during highly intensified land use (Pickup et al., 1998), the SD assumed 50% degradation rate during period with less pasture exploitation caused by other factors.
	Average rainfall	500 millimetres	Literature review indicating 500mm on normal rainfall years and assumed rainfall decline by 25% during drought years(ALRMP, 2012, ALRMP, 2005, GoK, 2010a)
	Dry Matter (DM) per TLU	12.5 Kgs per day	Literature on biomass requirement for TLU assuming 50% efficiency utilization (Yacouba et al., 2009), also see equation 13.
Livestock sub-system	Initial cattle population	4.889 * Number of households	ALRMP panel data for January 2006
	Initial SSU population	29.87 * Number of	ALRMP panel data for January

		households	2006
	Initial Camels population	0.568 * Number of households	ALRMP panel data for January 2006
	Monthly birth rate-cattle	7%	ALRMP panel data
	Monthly birth rate-SSU	12%	
	Monthly birth rate- camels	4%	
	Monthly sales rates-cattle	1.28%	
	Monthly sales rate- SSU	4.06%	
	Monthly sales rate-camels	0.04%	
	Monthly slaughter rate-cattle	0.34%	
	Monthly slaughter rate-SSU	1.2%	
	Monthly slaughter rate-camels	0.16%	
	Monthly drought rate-cattle	7.77%	
	Monthly drought rate-SSU	5.8%	
	Monthly drought rate-camels	0.53%	
	Monthly disease rate-cattle	1.9%	
	Monthly disease rate-SSU	3.8%	
	Monthly disease rate-camels	2%	
	Monthly predation-Cattle	0.51%	
	Monthly predation-SSU	0.52%	
	Monthly predation-camels	0.55%	
	Monthly conflicts-cattle	0.077%	
	Monthly conflict-SSU	0.034%	
	Monthly conflict-camels	0.087%	

	Daily milk produced-cattle	0.94 litres	Literature (Dahl and Hjort, 1976, Sieff, 1999, Fratkin, 2004) and assumed 25% decline during drought period as the analysis of the cross sectional data showed (Chapter 5). Also see equation 9 for total milk production. Daily rate is multiplied by 30 days to get monthly milk produced
	Daily milk produced-SSU	0.3 litres	
	Daily milk produced-camel	1.3 litres	
	Milking rate	50%	
	Total milk per household	Equation 9	
	Weaning rate-Cattle	1/8	Assumption based on the gestation period of different species.
	Weaning rate-SSU	1/5	
	Weaning rate-Camels	1/12	

Appendix III (b): STELLA Complete Model Parameterisation

Human Population and Education

College_Education(t) = College_Education(t - dt) + (KCSE - Graduation - Natural_Attrition_College) * dt
INIT College_Education = Secondary_School*KCSERate
INFLOWS:
KCSE = if(Year_Count=1) then (Secondary_School-Secondary_Drop-Natral_Attrition__Secondary)*KCSERate else 0
OUTFLOWS:
Graduation = if (Year_Count=1) then (College_Education-Natural_Attrition_College)*CompletionRate else 0
Natural_Attrition_College = (College_Education/1000)*Above_5_MortRate

Pre_School_Pool(t) = Pre_School_Pool(t - dt) + (Children_Pool - Exit_Pool - Attrition_Preschool) * dt
INIT Pre_School_Pool = Human_Births*12*0.5

INFLOWS:
Children_Pool = Human_Births
OUTFLOWS:
Exit_Pool = if(Year_Count=1) then (Pre_School_Pool*2/3) else 0
Attrition_Preschool = (Pre_School_Pool/1000)*Under_5_Mortality_Rate

Primary_Pool(t) = Primary_Pool(t - dt) + (Preschool - Exit_Enrollment - Under_5_Decline) * dt
INIT Primary_Pool = Human_Births*12*.90
INFLOWS:
Preschool = Primary__Enrollment
OUTFLOWS:
Exit_Enrollment = if(Year_Count=1) then Primary_Pool else 0
Under_5_Decline = (Primary_Pool/1000)*Under_5_Mortality_Rate

Primary_School(t) = Primary_School(t - dt) + (Enroll - KCPE - Primary__Drop - Natural_Attrition_Primary) * dt
INIT Primary_School = Primary_Pool*Enrollment__Rate
INFLOWS:
Enroll = abs(if(Year_Count=1) then (Enrollment__Rate*Primary_Pool) else 0)
OUTFLOWS:
KCPE = if (Year_Count=1) then (Primary_School-Primary__Drop-Natural_Attrition_Primary)*KCPE_Rate else 0
Primary__Drop = (Primary_School*Primary_Drop_Rate*Pri_Drought_Drop_Out_Effect)
Natural_Attrition_Primary = (Primary_School/1000)*Above_5_MortRate

Secondary_School(t) = Secondary_School(t - dt) + (KCPE - KCSE - Secondary_Drop - Natral_Attrition__Secondary) * dt
INIT Secondary_School = Primary_School*KCPE_Rate
INFLOWS:
KCPE = if (Year_Count=1) then (Primary_School-Primary__Drop-Natural_Attrition_Primary)*KCPE_Rate else 0
OUTFLOWS:
KCSE = if(Year_Count=1) then (Secondary_School-Secondary_Drop-Natral_Attrition__Secondary)*KCSERate else 0
Secondary_Drop = (Secondary_School*Secondary_Drop_Rate*Sec_Drought_Drop_Out_Effect)
Natral_Attrition__Secondary = (Secondary_School/1000)*Above_5_MortRate

Semiskilled(t) = Semiskilled(t - dt) + (Primary__Drop + Secondary_Drop - SemiSkilled_Mortality) * dt
INIT Semiskilled = (Primary__Drop+Secondary_Drop)*120

INFLOWS:

- Primary__Drop = (Primary_School*Primary_Drop_Rate*Pri_Drought_Drop_Out_Effect)
- Secondary_Drop = (Secondary_School*Secondary_Drop_Rate*Sec_Drought_Drop_Out_Effect)

OUTFLOWS:

- SemiSkilled_Mortality = Semiskilled*(Above_5_MortRate/1000)

Skilled_Labour(t) = Skilled_Labour(t - dt) + (Graduation - Skilled_Mortality) * dt
INIT Skilled_Labour = College_Education*CompletionRate*12*.5

INFLOWS:

- Graduation = if (Year_Count=1) then (College_Education-Natural_Attrition_College)*CompletionRate else 0

OUTFLOWS:

- Skilled_Mortality = Skilled_Labour*(Above_5_MortRate/1000)

Total_Human_Population(t) = Total_Human_Population(t - dt) + (Human_Births - Under_5_Mortalities - Crude_Mortality) * dt
INIT Total_Human_Population = 59094

INFLOWS:

- Human_Births = (Total_Human_Population/1000)*Human_Birth_Rate-((Total_Human_Population/1000)*Human_Birth_Rate/1000)*Infant_Mortality

OUTFLOWS:

- Under_5_Mortalities = (Human_Births/1000)*Under_5_Mortality_Rate
- Crude_Mortality = ((Total_Human_Population-Under_5_Mortalities)/1000)*Above_5_MortRate

Above_5_MortRate = 11.8/12
Average_Household_Members = 6
CompletionRate = 1/4
Enrollment__Rate = if(MASS_ENROLMENT=1) and(Years>2012) then(0.74) else(0.5)
Human_Birth_Rate = 39.2/12
Infant_Mortality = 79.8/12
KCPE_Rate = 1/8
KCSERate = 1/4
MASS_ENROLMENT = 1
Number_of_Households = Total_Human_Population/Average_Household_Members
Population_growth_Model = 59094*(1+(0.026/12))^TIME
Primary_Drop_Rate = .40/(12*8)
Primary__Enrollment = Exit_Pool
Pri_Drought_Drop_Out_Effect = If(SCHOOL_FEEDING=1) and(Years>2012) then(0.5) else If(Drought_Cycle=1) then(1.5) else 1
SCHOOL_FEEDING = 1
Secondary_Drop_Rate = .125/(12*4)
Sec_Drought_Drop_Out_Effect = If(SCHOOL_FEEDING=1) and(Years>2012) then(0.5) else If(Drought_Cycle=1) then(1.3) else 1
Semi_Skilled_Labour_proportion = ((Semiskilled)/Total_Human_Population)*100
Skilled_and_Semiskilled_Human_Capital = Semi_Skilled_Labour_proportion+Skilled_Labour_Proportion

Skilled_Labour_Proportion = ((Skilled_Labour)/Total_Human_Population)*100
Under_5_Mortality_Rate = 121.2/12

Livelihoods Measurement

Project_Run_Time(t) = Project_Run_Time(t - dt) + (Run_Time) * dt
INIT Project_Run_Time = 0
INFLOWS:
Run_Time = 1
Lagged_NDVI_3_Months = DELAY(NDVI,3)
Lagged_NDVI_6_Months = DELAY(NDVI,6)
Mortality_Rate_Cattle = Cattle_Losses__Related_Offtake+Slaughter
MUAC__Percentage =
MAX(0,68.497-0.24609*(Calving_Rate*100)-0.16068*(Kidding_Rate*100)+0.07127*(Mortality_Rate_Cattle*100)+1.31428*(Cattle_Sales_Rate*100)-2.2548*(SSU_Rate_of_Sale*100)-31.668*NDVI-33.898*Lagged_NDVI_3_Months-6.184*Lagged_NDVI_6_Months-1.2849*TLU_Per_Household)
NDVI = if(Drought_Cycle=1) then(Max(0.29,normal(0.38-0.06,0.02))) else (Max(0.38,normal(0.40,0.02)))
Poor_Households =
max(0,91.811-13.24*Lagged_NDVI_6_Months+7.023*Lagged_NDVI_3_Months-5.095*NDVI-2.595*TLU_Per_Household+0.27*MUAC__Percentage)

Livestock Asset Dynamics

Camels_Owned(t) = Camels_Owned(t - dt) + (Camels_Birth - Camels_Offtake) * dt
INIT Camels_Owned = Number_of_Households*0.568
INFLOWS:
Camels_Birth = (Camels_Owned*Camels_Birth_Rate)+Claim_Camel
OUTFLOWS:
Camels_Offtake =
Camels_Owned*(Camels_Consumption_Rate+Camels_Loss_Rate)+Camels__Required
Cattle_Owned(t) = Cattle_Owned(t - dt) + (Cattle_Births - Cattle__Offtake) * dt
INIT Cattle_Owned = Number_of_Households*4.8888889
INFLOWS:
Cattle_Births = (Cattle_Owned*Calving_Rate)+Claim_Cattle+CATTLE_REPURCHASE
OUTFLOWS:
Cattle__Offtake =
Cattle_Owned*(Consumption_Related_Offtake+Cattle_Losses__Related_Offtake)+Cattle_Sales_Required+Cattle_Required_for_Insurance
CATTLE_SOLD_STRATEGY_SEVEN(t) = CATTLE_SOLD_STRATEGY_SEVEN(t - dt) + (CATTLE_SALES - CATTLE_REPURCHASE - CONSUMED) * dt
INIT CATTLE_SOLD_STRATEGY_SEVEN = 0
INFLOWS:
CATTLE_SALES = Cattle_Owned*EXTRA_CATTLE_SOLD_STRATEGY_SEVEN
OUTFLOWS:
CATTLE_REPURCHASE = if(Month_Count=1) Then(0.5*CATTLE_SOLD_STRATEGY_SEVEN) else(0)
CONSUMED = if(Month_Count=1) Then(CATTLE_SOLD_STRATEGY_SEVEN-CATTLE_REPURCHASE) else(0)
Drought_Camel(t) = Drought_Camel(t - dt) + (Mortalities_Camel - Claim_Camel) * dt
INIT Drought_Camel = 0

INFLOWS:
Mortalities_Camel = if(Years>2012) Then(Number_of_camels_Drought_Loss) Else(0)
OUTFLOWS:
Claim_Camel = if(Month_Count=1) Then(Drought_Camel)*STRATEGY_FIVE Else 0

Drought_Cattle(t) = Drought_Cattle(t - dt) + (Mortalities_Drought - Claim_Cattle) * dt
INIT Drought_Cattle = 0
INFLOWS:
Mortalities_Drought = if(Years>2012) Then(Number_of_Cattle_Drought_Loss) Else(0)
OUTFLOWS:
Claim_Cattle = if(Month_Count=1) Then(Drought_Cattle)*STRATEGY_FIVE Else 0

Drought_SSU(t) = Drought_SSU(t - dt) + (Mortalities_SSU - Claim_SSU) * dt
INIT Drought_SSU = 0
INFLOWS:
Mortalities_SSU = if(Years>2012) Then(Number_of_SSU_Drought_Loss) Else(0)
OUTFLOWS:
Claim_SSU = if(Month_Count=1) Then(Drought_SSU)*STRATEGY_FIVE Else 0

Small_Stock_Owned(t) = Small_Stock_Owned(t - dt) + (Small_Stock_Births - Small_Stock_Offtake) * dt
INIT Small_Stock_Owned = Number_of_Households*2.98694*10
INFLOWS:
Small_Stock_Births = (Small_Stock_Owned*Kidding_Rate)+Claim_SSU+SSU_REPURCHASED
OUTFLOWS:
Small_Stock_Offtake = Small_Stock_Owned*(SSU_Consumption_Rate+SSU__Loss_Rate)+SSU_Sales_Required+Vet_SSU

SSU_SOLD_STRATEGY_SEVEN(t) = SSU_SOLD_STRATEGY_SEVEN(t - dt) + (SSU_SALES - SSU_REPURCHASED - SSU_CONSUMED) * dt
INIT SSU_SOLD_STRATEGY_SEVEN = 0
INFLOWS:
SSU_SALES = Small_Stock_Owned*SSU_STRATEGY_SEVEN
OUTFLOWS:
SSU_REPURCHASED = if(Month_Count=1) Then(0.5*SSU_SOLD_STRATEGY_SEVEN) else(0)
SSU_CONSUMED = if(Month_Count=1) Then(SSU_SOLD_STRATEGY_SEVEN-SSU_REPURCHASED) else(0)

TLU_Drought(t) = TLU_Drought(t - dt) + (TLU_Lost - Insurance_Claim) * dt
INIT TLU_Drought = 0
INFLOWS:
TLU_Lost = Number_of_TLU_Drought_Loss
OUTFLOWS:
Insurance_Claim = if(Month_Count=1) Then(TLU_Drought) Else 0

Years(t) = Years(t - dt) + (Study_Period) * dt
INIT Years = 2006
INFLOWS:
Study_Period = Year_Count

Calving_Rate = if(STRATEGY_THREE=1) then(Cattle_Birth_Rate) else if(Deficit_or_Surplus_Biomass<0) then Cattle_Birth_Rate*0.75 else Cattle_Birth_Rate

- Camels_Birth_Rate = if(STRATEGY_THREE=1) then(0.04) else if(Deficit_or_Surplus_Biomass<0) then (0.04*.75) else 0.04
- Camels_Consumption_Rate = Camels_Rate_of_Sale+Camel_Rate_of_Slaughter
- Camels_Loss_Rate = Camels_Rate_of_Predation+Camels_Rate_of__Conflict_Loss+Camels_Rate_of__Disease_Loss+Camels_Rate_of__Drought_Loss
- Camels_Per_Household = Camels_Owned/Number_of_Households
- Camels_Rate_of_Predation = 0.0055
- Camels_Rate_of_Sale = 0.00041
- Camels_Rate_of__Conflict_Loss = (0.00087)*STRATEGY_SIX
- Camels_Rate_of__Disease_Loss = 0.02
- Camels_Rate_of__Drought_Loss = IF(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate*0.67) ELSE IF(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Camel_Drought_Rate*0.50) ELSE IF(STRATEGY_THREE=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate*0.50) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate*0.8) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Camel_Drought_Rate*0.8*0.8) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate*0.50) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate*0.67) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Camel_Drought_Rate*0.50) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate*0.50) ELSE IF(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Camel_Drought_Rate*0.75) ELSE IF(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Camel_Drought_Rate) ELSE(0)
- Camels__Required = IF(Cattle_Proportion<0.4) AND(Camel_Proportion>0.15) THEN(Cost_of_Supplementary_Livestock_Feeds*1/3)/(Camel_Prices/80) ELSE(0)
- Camel_Drought_Rate = 0.0053
- Camel_Proportion = (Camels_Owned*0.7)/Total_Livestock_Unit_TLU
- Camel_Rate_of_Slaughter = 0.0016
- Cattle_Birth_Rate = 0.07
- Cattle_Diseases = if(STRATEGY_FOUR=1) Then(0.01902*0.5) Else(0.01902)

- Cattle_Drought = IF(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss*0.67) ELSE IF(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Cattle_Drought_Loss*0.50) ELSE IF(STRATEGY_THREE=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss*0.50) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss*0.8) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Cattle_Drought_Loss*0.8*0.8) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss*0.50) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss*0.67) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Cattle_Drought_Loss*0.50) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss*0.50) ELSE IF(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(Cattle_Drought_Loss*0.75) ELSE IF(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(Cattle_Drought_Loss) ELSE(0)

- Cattle_Drought_Loss = 0.0777-EXTRA_CATTLE_SOLD_STRATEGY_SEVEN
- Cattle_Losses__Related_Offtake = Loss_arising_from_Conflicts+Cattle_Diseases+Cattle_Drought+Preditors_for_Cattle
- Cattle_Per_Household = Cattle_Owned/Number_of_Households
- Cattle_Proportion = (Cattle_Owned*1)/Total_Livestock_Unit_TLU
- Cattle_Required_for_Insurance = if(STRATEGY_FIVE=1) and(Month_Count=12) Then(Insurance_Expense/Cattle_Prices) Else 0
- Cattle_Sales_Rate = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then(0.01284*1.5) else(0.01284)
- Cattle_Sales_Required = if(Cattle_Proportion>0.4) then(Cost_of_Supplementary_Livestock_Feeds*2/3)/(Cattle_Prices/80) else(0)
- Consumption_Related_Offtake = Cattle_Sales_Rate+Slaughter
- Cost_of_Supplementary_Livestock_Feeds = (Supplementary_Feeds*((400)/80)/22.5)
- Deficit = if(Deficit_or_Surplus_Biomass<0) then(1) else(0)
- Deficit_or_Surplus_Biomass = Stocking_Capacity_Sinclair-Total_Livestock_Unit_TLU
- Drought_Cycle = if(Years=2006) then 1 else if(Years=2009) then 1 else if(Years=2012) then 1 else if(Years=2015) then 1 else if(Years=2018) then 1 else if(Years=2021) then 1 else if(Years=2024) then 1 else if(Years=2027) then 1 else if(Years=2030) then 1 else 0
- EXTRA_CATTLE_SOLD_STRATEGY_SEVEN = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then(Cattle_Sales_Rate*1/3) else(0)
- Insurable_Value = ((Camels_Owned*Camel_Prices)+(Cattle_Owned*Cattle_Prices)+(Small_Stock_Owned*Average_SSU_Price))
- Insurance_Expense = Insurable_Value*0.055
- KGs_Supplementary_feeds = Deficit_or_Surplus_Biomass*11.25
- Kidding_Rate = if(STRATEGY_THREE=1) then(SSU_Birth_Rate) else if(Deficit_or_Surplus_Biomass<0) then SSU_Birth_Rate*0.75 else SSU_Birth_Rate
- Labour = 0.69+0.07*TLU_Per_Household
- Loss_arising_from_Conflicts = (0.00077)*STRATEGY_SIX
- Month_Count = COUNTER(1,13)
- Number_of_camels_Drought_Loss = ABS((Camels_Owned*Camels_Rate_of__Drought_Loss))

- Number_of_Cattle_Drought_Loss = ABS(Cattle_Owned*Cattle_Drought)
- Number_of_SSU_Drought_Loss = ABS(Small_Stock_Owned*SSU_Rate_of__Drought_Loss)
- Number_of_TLU_Drought_Loss = ABS(Number_of_Cattle_Drought_Loss+(0.7*Number_of_camels_Drought_Loss)+(Number_of_SSU_Drought_Loss*0.1))
- Preditors_for_Cattle = 0.00514
- Slaughter = 0.0034
- SSU_Birth_Rate = 0.12
- SSU_Consumption_Rate = SSU_Rate_of_Sale+SSU_Rate_of_Slaughter
- SSU_Drought_Loss = 0.058-SSU_STRATEGY_SEVEN
- SSU_Per_Household = Small_Stock_Owned/Number_of_Households
- SSU_Proportion = (Small_Stock_Owned*.1)/Total_Livestock_Unit_TLU
- SSU_Rate_of_Predation = 0.00517
- SSU_Rate_of_Sale = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then(0.0406*1.5) else(0.0406)
- SSU_Rate_of_Slaughter = 0.012
- SSU_Rate_of__Conflict_Loss = (0.00034)*STRATEGY_SIX
- SSU_Rate_of__Disease_Loss = If(STRATEGY_FOUR=1) Then(0.038*0.5) Else(0.038)
- SSU_Rate_of__Drought_Loss = IF(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss*0.67) ELSE IF(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(SSU_Drought_Loss*0.50) ELSE IF(STRATEGY_THREE=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss*0.50) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss*0.8) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(SSU_Drought_Loss*0.8*0.8) ELSE IF(STRATEGY_FOUR=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss*0.50) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss*0.67) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(SSU_Drought_Loss*0.50) ELSE IF(STRATEGY_FOUR=1) AND(STRATEGY_THREE=1) AND(Drought_Cycle=0) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss*0.50) ELSE IF(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass>0) THEN(SSU_Drought_Loss*0.75) ELSE IF(Drought_Cycle=1) AND(Deficit_or_Surplus_Biomass<0) THEN(SSU_Drought_Loss) ELSE(0)
- SSU_Sales_Required = if(Cattle_Proportion>0.40) then(Cost_of_Supplementary_Livestock_Feeds*1/3)/(Average_SSU_Price/80) ELSE IF(Camel_Proportion>0.15) AND(Cattle_Proportion<0.4)THEN(Cost_of_Supplementary_Livestock_Feeds*2/3)/(Average_SSU_Price/80) ELSE(Cost_of_Supplementary_Livestock_Feeds)/(Average_SSU_Price/80)
- SSU_Sales_Required_Vet = Total_Veterinary_Expenses/(Average_SSU_Price/80)
- SSU_STRATEGY_SEVEN = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then(SSU_Rate_of_Sale*1/3) else(0)
- SSU__Loss_Rate = SSU_Rate_of_Predation+SSU_Rate_of__Conflict_Loss+SSU_Rate_of__Disease_Loss+SSU_Rate_of__Drought_Loss
- STRATEGY_FIVE = If(Years>2012) then(1) else(0)
- STRATEGY_FOUR = If(Years>2012) then(0) else(0)
- STRATEGY_SEVEN = If(Years>2012) then(0) else(0)

- STRATEGY_SIX = If(Years>2012) then(1) else(1)
- STRATEGY_THREE = If(Years>2012) then(0) else(0)
- Supplementary_Feeds = (if(Drought_Cycle=1) and(Deficit_or_Surplus_Biomass<0) Then(Deficit_or_Surplus_Biomass*-1*(22.5/0.5)) Else if(Drought_Cycle=0) and(Deficit_or_Surplus_Biomass<0) Then(Deficit_or_Surplus_Biomass*-1*(22.5/1)) else 0)*STRATEGY_THREE
- TLU_Per_Household = ABS(Total_Livestock_Unit_TLU/Number_of_Households)
- TLU_Price = (Camel_Prices*Camel_Proportion)+(Cattle_Prices*Cattle_Proportion)+(Average_SSU_Price*SSU_Proportion)
- Total_Insurance_Sum_Claimed_USD = Insurance_Claim*180
- Total_Livestock_Unit_TLU = Cattle_Owned+Camels_Owned*.7+Small_Stock_Owned*.1
- Total_Veterinary_Expenses = Veterinary_Expenses_Per_HH*Number_of_Households
- Veterinary_Expenses_Per_HH = if(STRATEGY_FOUR=1) then(10*Cattle_Per_Household+22.25*Camels_Per_Household+4.4*SSU_Per_Household)*3/80 Else(10*Cattle_Per_Household+22.25*Camels_Per_Household+4.4*SSU_Per_Household)/80
- Vet_SSU = STRATEGY_FOUR*SSU_Sales_Required_Vet
- Year_Count = if Month_Count=12 then 1 else 0

Livestock Milk Productivity

Lactating_Camels(t) = Lactating_Camels(t - dt) + (Lactation_for_Camels - Loss_of_Lactating__Camels - Weaning__Camels) * dt
INIT Lactating_Camels = Camels_Birth*12
INFLOWS:
- Lactation_for_Camels = Camels_Birth

OUTFLOWS:
- Loss_of_Lactating__Camels = Lactating_Camels*Camels_Loss_Rate
- Weaning__Camels = (Lactating_Camels-Loss_of_Lactating__Camels)*Weaning_Rate_Camels

Lactating_Cattle(t) = Lactating_Cattle(t - dt) + (Lactation_for_Cattle - Mortality_for__Lactating_Cattle - Weaning_Cattle) * dt
INIT Lactating_Cattle = Cattle_Births*9*.5
INFLOWS:
- Lactation_for_Cattle = Cattle_Births

OUTFLOWS:
- Mortality_for__Lactating_Cattle = Lactating_Cattle*Cattle_Losses__Related_Offtake
- Weaning_Cattle = (Lactating_Cattle-Mortality_for__Lactating_Cattle)*Weaning_Rate_Cattle

Lactating_SSU(t) = Lactating_SSU(t - dt) + (Lactaion_for_Small_STock - Weaning_Small_Stock - Mortality_for__Lactating_small_Stock) * dt
INIT Lactating_SSU = Small_Stock_Births*5*.5
INFLOWS:
- Lactaion_for_Small_STock = Small_Stock_Births

OUTFLOWS:
- Weaning_Small_Stock = (Lactating_SSU-Mortality_for__Lactating_small_Stock)*Weaning_Rate_SSU
- Mortality_for__Lactating_small_Stock = Lactating_SSU*SSU__Loss_Rate

- Camel_Milk_Rainy_Season = 1.3*Rainy_Season
- Camel__Milk_Dry_Season = 1.3*Dry_Season*0.75
- Cow_Milk_Production_Dry_Season = 0.94*0.75*Dry_Season

- Cow_Milk_Production_Rainy_Season = 0.94*Rainy_Season
- Dry_Season = if(Long_Drought>0) Or (Short_Drought>0) then 1 else 0
- Long_Drought = if(Month_Count>9) then 0 else(if(Month_Count>5) then 1 else (if(Month_Count>3) then 0 else 0))
- Long_Rain = if(Month_Count>9) then 0 else(if(Month_Count>5) then 0 else (if(Month_Count>3) then 1 else 0))
- Milking_Strategy_One = 0.75
- Milking_Strategy_Two = 0.50
- Milk_Produced_Camels = Lactating_Camels*Milk_Production_Per_Camel
- Milk_Produced_Cattle = Lactating_Cattle*Milk_Production_Per_Cow
- Milk_Produced_HH_Strategy_One = Milk_Produced_Strategy_One/Number_of_Households
- Milk_Produced_HH_Strategy_Two = Milk_Produced_Strategy_Two/Number_of_Households
- Milk_Produced_Strategy_One = Milking_Strategy_One*(Milk_Produced_Camels+Milk_Produced_Cattle+Milk_Produced__SSU)
- Milk_Produced_Strategy_Two = Milking_Strategy_Two*(Milk_Produced_Camels+Milk_Produced_Cattle+Milk_Produced__SSU)
- Milk_Produced_Total = Milk_Produced_Camels+Milk_Produced_Cattle+Milk_Produced__SSU
- Milk_Produced__SSU = Lactating_SSU*Milk_Production_Per_SSU
- Milk_Production_Per_Camel = If(STRATEGY_THREE=1) then(RANDOM(1.5,3,2)) else if(Drought_Cycle=1) then(Camel_Milk_Rainy_Season+Camel__Milk_Dry_Season)*0.5 else (Camel_Milk_Rainy_Season+Camel__Milk_Dry_Season)
- Milk_Production_Per_Cow = If(STRATEGY_THREE=1) then(RANDOM(0.94,1.2,1.0)) else if(Drought_Cycle=1) then(Cow_Milk_Production_Rainy_Season+Cow_Milk_Production_Dry_Season)*0.5 else (Cow_Milk_Production_Rainy_Season+Cow_Milk_Production_Dry_Season)
- Milk_Production_Per_SSU = If(STRATEGY_THREE=1) then(RANDOM(0.3,0.4,0.35)) else if(Drought_Cycle=1) then(SSU_Milk_Rainy_Season+SSU_Milk_Dry_Season)*0.5 else (SSU_Milk_Rainy_Season+SSU_Milk_Dry_Season)
- Rainy_Season = if(Long_Rain>0) Or (Short_Rain>0) then 1 else 0
- Short_Drought = if(Month_Count>9) then 0 else(if(Month_Count>5) then 0 else (if(Month_Count>3) then 0 else 1))
- Short_Rain = if(Month_Count>9) then 1 else(if(Month_Count>5) then 0 else (if(Month_Count>0) then 0 else 0))
- SSU_Milk_Dry_Season = 0.2*Dry_Season
- SSU_Milk_Rainy_Season = 0.3*Rainy_Season
- Weaning_Rate_Camels = 1/12
- Weaning_Rate_Cattle = 1/8
- Weaning_Rate_SSU = 1/5

Livestock Revenue Productivity

- Average_SSU_Price = Small_Stock_Prices*1/3+SSU_Lagged_one_Prices*1/3+SSU_Lagged_two_Prices*1/3
- Camels_Sold = Camels_Owned*Camels_Rate_of_Sale
- Camel_Prices = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then(normal(8000,1267))*0.90 Else if(Drought_Cycle=1) then(normal(8000,1267))*0.75 else(normal(8000,1267))
- CAMEL__WORTH = Camels_Owned*Camel_Prices
- Cattle_Prices = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then((normal(8000,250))*0.90) Else if(Drought_Cycle=1) then(normal(8000,250))*0.75 else(normal(8000,250))
- Cattle_Sold = Cattle_Owned*Cattle_Sales_Rate

- CATTLE_WORTH = Cattle_Owned*Cattle_Prices
- Finacial_Capital_Cattle_HH = CATTLE_WORTH/Number_of_Households
- FINANCIAL_CAPITAL = CAMEL__WORTH+CATTLE_WORTH+SMALL_STOCK_WORTH
- Financial_Capital_Camel_HH = CAMEL__WORTH/Number_of_Households
- Financial_Capital_Per_Households = FINANCIAL_CAPITAL/Number_of_Households
- Financial_Capital_SSU_HH = SMALL_STOCK_WORTH/Number_of_Households
- Livestock_Revenue_Per_Household = Total_Livestock_Revenues/Number_of_Households
- Revenues_from_Camel_Sales = Camels_Sold*Camel_Prices
- Revenues_from_Cattle = Cattle_Prices*Cattle_Sold
- Revenues_from_Small_Stock = Small_Stock_Prices*Small_Stock_Sold
- Small_Stock_Prices = if(STRATEGY_SEVEN=1) and(Drought_Cycle=1) then((normal(900,25))+(SSU_Price_Trend*Project_Run_Time))*.90 Else if(Drought_Cycle=1) then((normal(900,25))+(SSU_Price_Trend*Project_Run_Time))*.75 else((normal(900,25))+(SSU_Price_Trend*Project_Run_Time))
- Small_Stock_Sold = Small_Stock_Owned*SSU_Rate_of_Sale
- SMALL_STOCK_WORTH = Small_Stock_Owned*Average_SSU_Price
- SSU_Lagged_one_Prices = delay(Small_Stock_Prices,1)
- SSU_Lagged_two_Prices = delay(SSU_Lagged_one_Prices,1)
- SSU_Price_Trend = 5.4
- Total_Livestock_Revenues = Revenues_from_Camel_Sales+Revenues_from_Cattle+Revenues_from_Small_Stock

Rangeland Subsystem

Braun_Resource_Stock(t) = Braun_Resource_Stock(t - dt) + (Pasture_Prod_Rate - Pasture_Consumed - Braun_Decay) * dt
INIT Braun_Resource_Stock = (Productive_Rangeland*512)

INFLOWS:

- Pasture_Prod_Rate = Biomass_Production_Braun

OUTFLOWS:

- Pasture_Consumed = Pasture_Demand_Braun
- Braun_Decay = if(Month_Count=2) or (Month_Count=9) then(Braun_Resource_Stock*Decay) else 0

Core_Conservation__Areas(t) = Core_Conservation__Areas(t - dt) + (Conservation) * dt
INIT Core_Conservation__Areas = 55855

INFLOWS:

- Conservation = (Degraded_Rangeland+Productive_Rangeland)*Conservation_Rate*STRATEGY_EIGHT

Degraded_Rangeland(t) = Degraded_Rangeland(t - dt) + (Land_Degradation - Settlement_On_Degraded_Land - Reclamation_of_Degraded_Land) * dt
INIT Degraded_Rangeland = (Land_Size-Core_Conservation__Areas-Initial_Settlement_Area_ha)*0.3

INFLOWS:

- Land_Degradation = if((Pasture__Demand_Sinclair)/1000>Stocking_Capacity_Sinclair) then (Productive_Rangeland*Degradation_Factor) else (Productive_Rangeland*Degradation_Factor)*0.5

OUTFLOWS:

- Settlement_On_Degraded_Land = if(STRATEGY_TWO=1) and(Years>2012) then(MIN((Household_Acreage*Number_of_Households)-Lag_One_Settlement+(0.5*Initial_Settlement_Area_ha)/(15*12), 0.5*Degraded_Rangeland)) else(0)

Reclamation_of_Degraded_Land = if(Drought_Cycle=1) then 0 else (INIT(Degraded_Rangeland)*Reclamation)

DESIRED_SECLUSION(t) = DESIRED_SECLUSION(t - dt)
INIT DESIRED_SECLUSION = INIT(Productive_Rangeland)

Initial_Settlement_Area_ha(t) = Initial_Settlement_Area_ha(t - dt)
INIT Initial_Settlement_Area_ha = (Total_Human_Population/Average_Household_Members)*Household_Acreage

Land_For_Settlement(t) = Land_For_Settlement(t - dt) + (Settlement_on__Productive_Land + Settlement_On_Degraded_Land) * dt
INIT Land_For_Settlement = 0

INFLOWS:

Settlement_on__Productive_Land = if(STRATEGY_TWO=0) then((Household_Acreage*Number_of_Households)-Land_For_Settlement-Initial_Settlement_Area_ha) else((Household_Acreage*Number_of_Households)-Settlement_On_Degraded_Land-Land_For_Settlement-Initial_Settlement_Area_ha)

Settlement_On_Degraded_Land = if(STRATEGY_TWO=1) and(Years>2012) then(MIN((Household_Acreage*Number_of_Households)-Lag_One_Settlement+(0.5*Initial_Settlement_Area_ha)/(15*12), 0.5*Degraded_Rangeland)) else(0)

Productive_Rangeland(t) = Productive_Rangeland(t - dt) + (Reclamation_of_Degraded_Land - Land_Degradation - Settlement_on__Productive_Land - Conservation) * dt
INIT Productive_Rangeland = (Land_Size-Core_Conservation__Areas-Land_For_Settlement-Degraded_Rangeland)

INFLOWS:

Reclamation_of_Degraded_Land = if(Drought_Cycle=1) then 0 else (INIT(Degraded_Rangeland)*Reclamation)

OUTFLOWS:

Land_Degradation = if((Pasture__Demand_Sinclair)/1000>Stocking_Capacity_Sinclair) then (Productive_Rangeland*Degradation_Factor) else (Productive_Rangeland*Degradation_Factor)*0.5

Settlement_on__Productive_Land = if(STRATEGY_TWO=0) then((Household_Acreage*Number_of_Households)-Land_For_Settlement-Initial_Settlement_Area_ha) else((Household_Acreage*Number_of_Households)-Settlement_On_Degraded_Land-Land_For_Settlement-Initial_Settlement_Area_ha)

Conservation = (Degraded_Rangeland+Productive_Rangeland)*Conservation_Rate*STRATEGY_EIGHT

Sinclair_Resource_Stock(t) = Sinclair_Resource_Stock(t - dt) + (Sinclair_Pasture_Production - Sinclair_Decay - Pasture_Consumed_Sinclair) * dt
INIT Sinclair_Resource_Stock = Productive_Rangeland*400

INFLOWS:

Sinclair_Pasture_Production = Biomass_Production_Sinclair

OUTFLOWS:

Sinclair_Decay = if(Month_Count=2) or (Month_Count=9) then(Sinclair_Resource_Stock*Decay) else 0

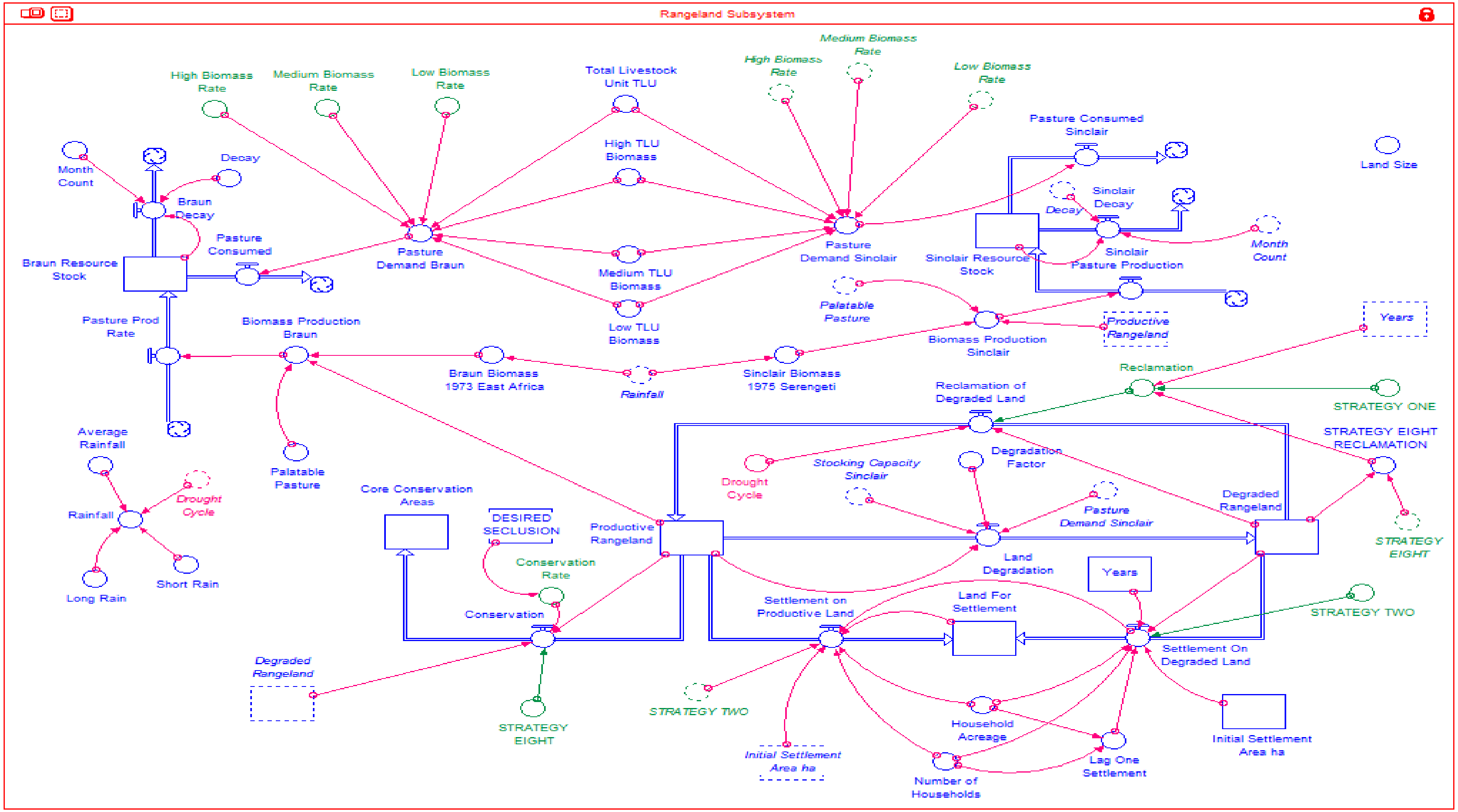
Pasture_Consumed_Sinclair = Pasture__Demand_Sinclair

Average_Rainfall = 500

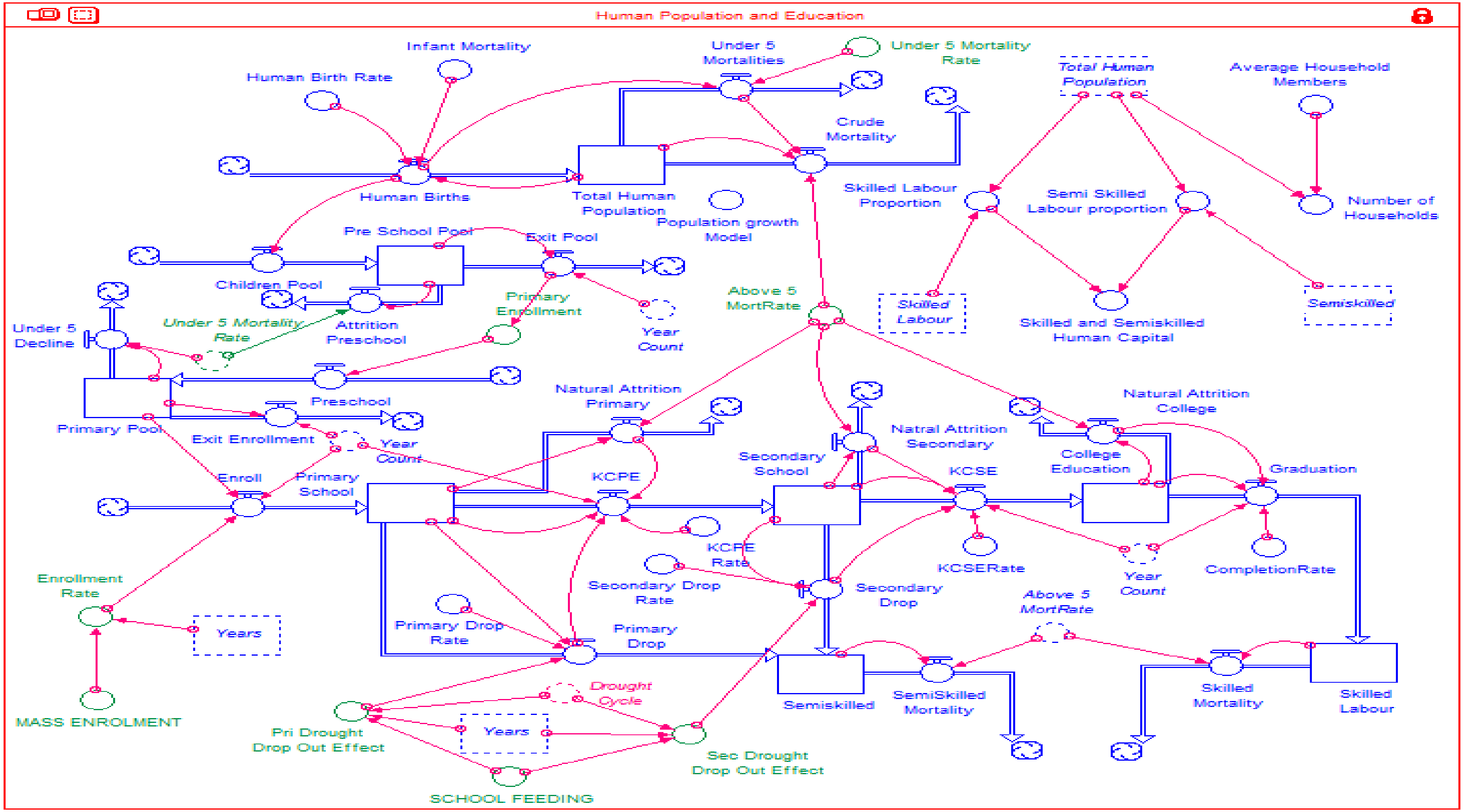
Biomass_Production_Braun = (Braun_Biomass_1973_East_Africa*Productive_Rangeland)*Palatable_Pasture

- Biomass_Production_Sinclair = (Productive_Rangeland*Sinclair_Biomass_1975_Serengeti)*Palatable_Pasture
- Braun_Biomass_1973_East_Africa = Max(0,8.488*Rainfall -195.768)
- Conservation_Rate = ((DESIRED_SECLUSION*0.3)/DESIRED_SECLUSION)/216
- Decay = 0.5
- Degradation_Factor = 0.01/12
- High_Biomass_Rate = 1
- High_TLU_Biomass = 12.5*30
- Household_Acreage = 1
- Lag_One_Settlement = DELAY((Household_Acreage*Number_of_Households),1)
- Land_Size = (21000*100*0.3333)
- Low_Biomass_Rate = 0
- Low_TLU_Biomass = 250*0.025*30
- Medium_Biomass_Rate = 0
- Medium_TLU_Biomass = 10*30
- Palatable_Pasture = 0.50
- Pasture_Demand_Braun = (Low_TLU_Biomass*Total_Livestock_Unit_TLU)*Low_Biomass_Rate+(Medium_TLU_Biomass*Total_Livestock_Unit_TLU)*Medium_Biomass_Rate+(High_TLU_Biomass*Total_Livestock_Unit_TLU)*High_Biomass_Rate
- Pasture__Demand_Sinclair = (Low_TLU_Biomass*Total_Livestock_Unit_TLU)*Low_Biomass_Rate+(Medium_TLU_Biomass*Total_Livestock_Unit_TLU)*Medium_Biomass_Rate+(High_TLU_Biomass*Total_Livestock_Unit_TLU)*High_Biomass_Rate
- Rainfall = IF(Drought_Cycle=1) then(Average_Rainfall*0.75*Long_Rain*1/6)+(Average_Rainfall*0.75*Short_Rain*1/6) Else(Average_Rainfall*Long_Rain*1/6)+(Average_Rainfall*Short_Rain*1/6)
- Reclamation = if(Years>2012) then((0.05/12)*STRATEGY_ONE+STRATEGY_EIGHT_RECLAMATION) else(0)
- Sinclair_Biomass_1975_Serengeti = Max(0,7.67*Rainfall -201)
- Stocking_Capacity_Braun = (Braun_Resource_Stock/High_TLU_Biomass)*High_Biomass_Rate+(Braun_Resource_Stock/Medium_TLU_Biomass)*Medium_Biomass_Rate+(Braun_Resource_Stock/Low_TLU_Biomass)*Low_Biomass_Rate
- Stocking_Capacity_Sinclair = ((Sinclair_Resource_Stock+Biomass_Production_Sinclair)/High_TLU_Biomass)*High_Biomass_Rate+((Sinclair_Resource_Stock+Biomass_Production_Sinclair)/Medium_TLU_Biomass)*Medium_Biomass_Rate+((Sinclair_Resource_Stock+Biomass_Production_Sinclair)/Low_TLU_Biomass)*Low_Biomass_Rate
- STRATEGY_EIGHT = 0
- STRATEGY_EIGHT_RECLAMATION = (((INIT(Degraded_Rangeland)*0.5))/(INIT(Degraded_Rangeland))/216)*STRATEGY_EIGHT
- STRATEGY_ONE = 0
- STRATEGY_TWO = 0
- Total_Biomass = Sinclair_Resource_Stock+Biomass_Production_Sinclair

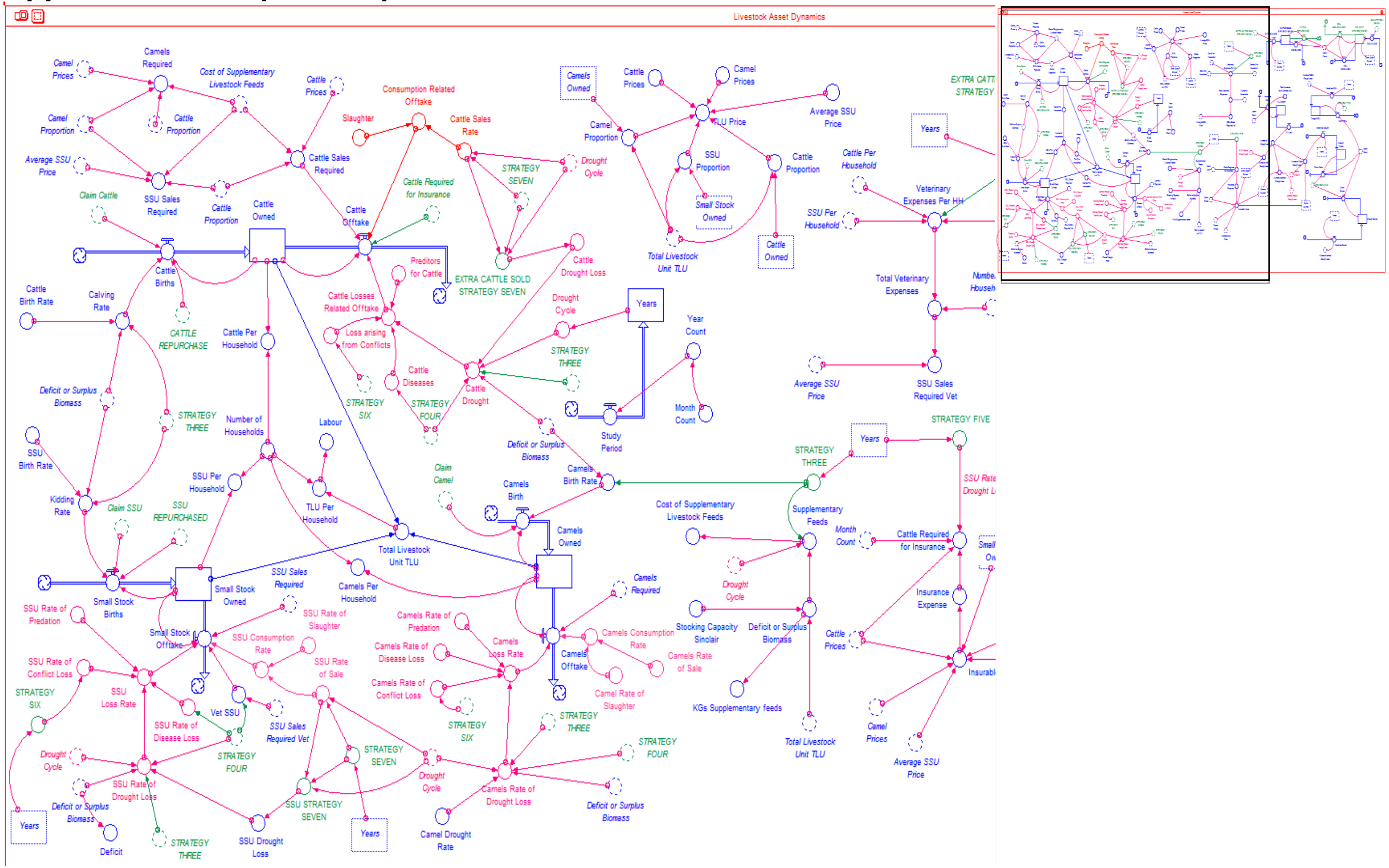
Appendix IV (a): System Dynamics Model for Rangeland Sub-Model



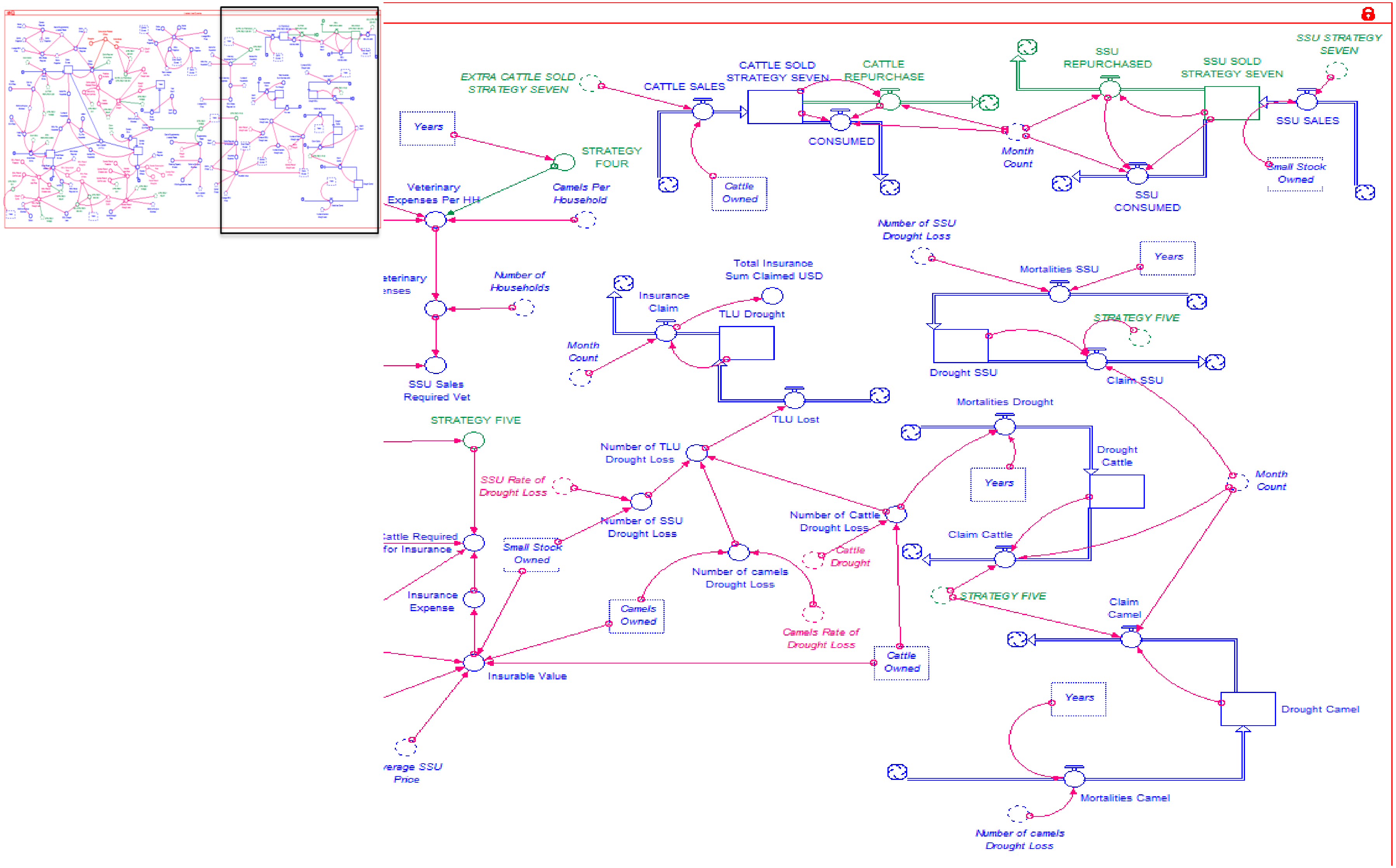
Appendix IV (b): System Dynamics Human Population Sub-Model



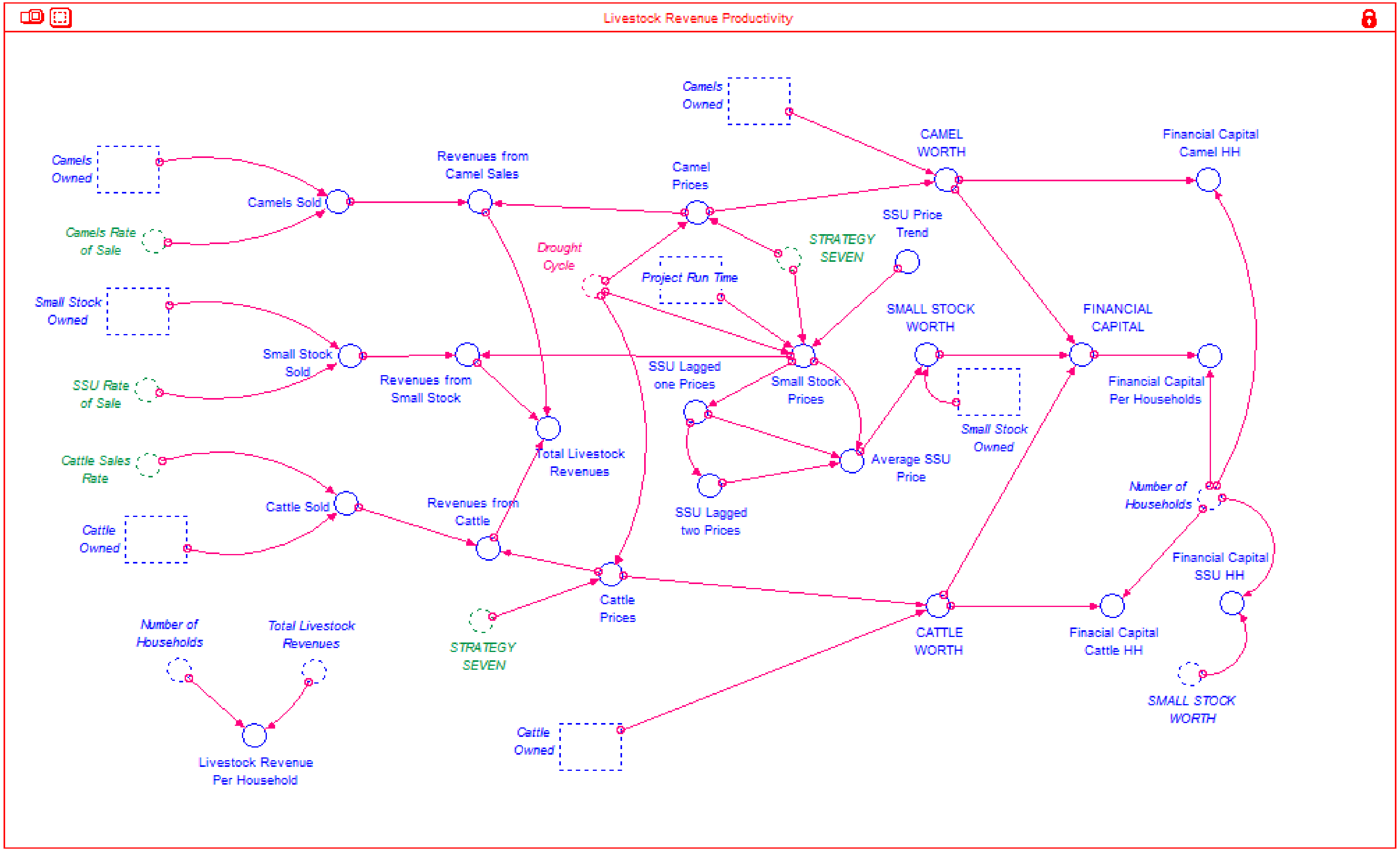
Appendix IV (c): System Dynamics Livestock Sub-Model 1



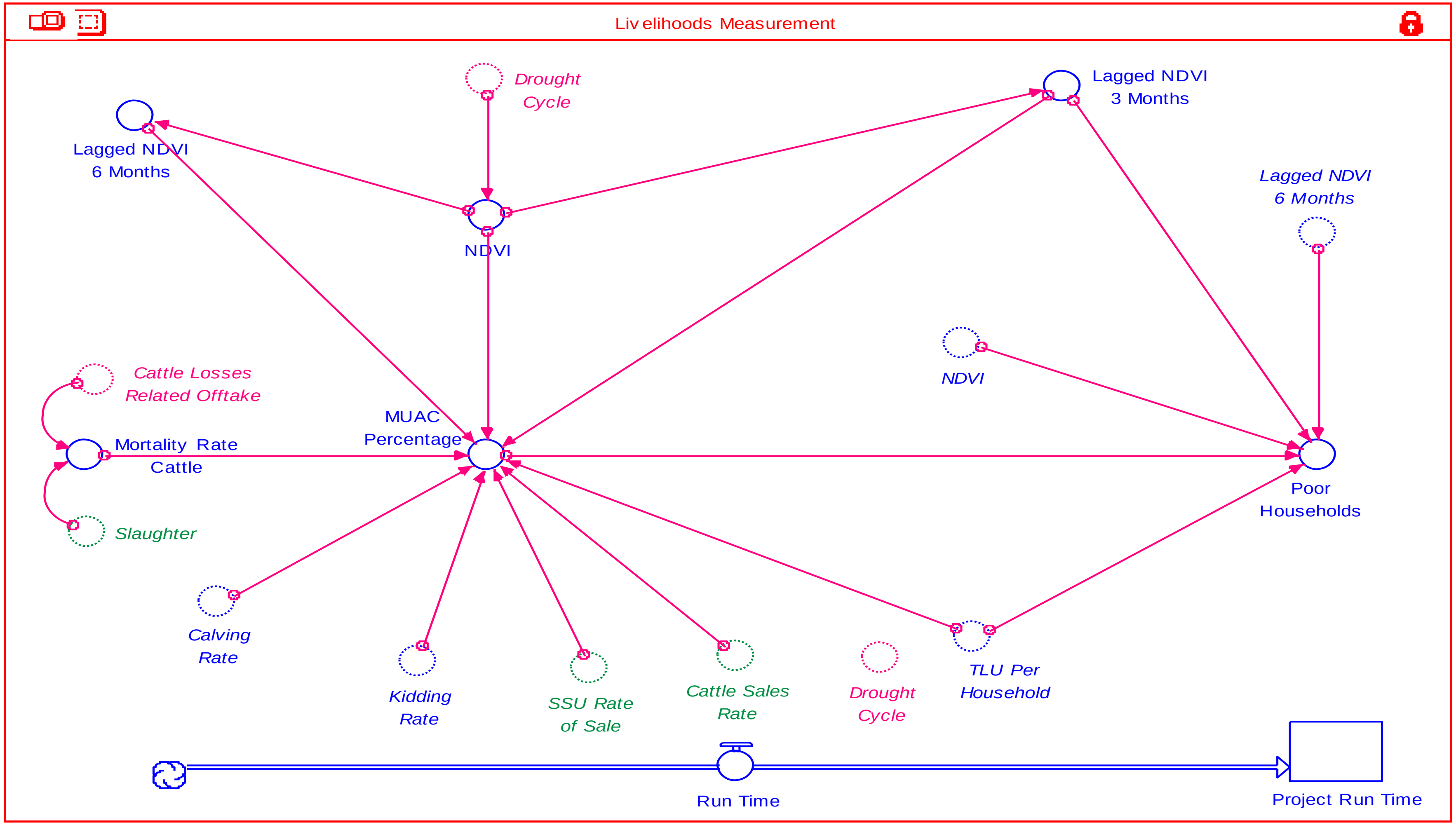
Appendix IV (d): System Dynamics Livestock Sub-Model 2



Appendix IV (e): System Dynamics Livestock Production Sub-Model



Appendix IV (f): System Dynamics Livelihood Measurement Sub-Model



Appendix V: Risk Mitigation Strategies and Policy Options

Strategy	Strategy Details
Baseline	Baseline scenario and the rules set
1	Reclaim 5% of degraded rangeland for every good rainfall year
2	Relocate 50% of households and all new households to degraded rangeland
3	Purchase of supplementary feeds (commercial feeding).
4	Veterinary services
5	Restocking through livestock insurance policy
6	Bolster security and minimise insecurity related livestock losses
7	Destocking livestock prior to drought by increasing normal sales rate by 50%
8	Increase conservation areas by 30% in exchange of 50% reclamation of degraded rangeland
9	Reclamation and planned settlements
10	Reclamation, planned settlement and supplementary feeding
11	Reclamation, planned settlement, supplementary feeding and veterinary services
12	Reclamation, planned settlement, veterinary services and restocking program
13	Reclamation, planned settlement, veterinary services , restocking program and bolster security
14	Reclamation, planned settlement, veterinary services , supplementary feeding and bolster security
15	Reclamation, planned settlement, veterinary services , supplementary feeding, bolster security and destocking
16	Reclamation, planned settlement, veterinary services , restocking, bolster security and destocking
17	Reclamation, planned settlement, veterinary services , supplementary feeding, bolster security, destocking and enhanced conservation
18	Reclamation, planned settlement, veterinary services , restocking, bolster security, destocking and enhanced conservation
19	Increase school retention by school feeding programs
20	Increase enrolment rate to match the national level (50% to 74%)
21	Combined education strategy of increased enrolment and retention

Appendix VI: System Dynamics Simulation Results Comparison

Strategy	Strategy Details	Percentage Change in the 5C's Compared with Baseline Scenario						
		Human Capital		Natural Capital	Financial Capital			Social Capital
		Skilled labour	Malnutrition	Biomass	Household TLU	Household Milk	Livestock Worth (US$)	Poverty rates
Baseline	Baseline Scenario	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	Reclaim 5% of degraded rangeland for every good rainfall year		1.41	10.07	3.60	4.22	4.56	1.05
2	Relocate 50% of households and all new households to degraded rangeland		-1.30	1.14	0.08	0.07	-0.23	-0.15
3	Purchase of supplementary feeds		1.80	0.25	3.80	32.68	-2.40	1.15
4	Veterinary services		-5.50	-0.35	-12.95	25.52	25.78	-3.90
5	Restocking through livestock insurance policy		3.76	-0.51	8.90	64.35	54.79	2.65
6	Bolster security and minimise insecurity related livestock losses		15.38	-0.04	36.70	0.73	1.41	10.92
7	Destocking livestock prior to drought by increasing normal sales rate by 50%		1.25	-0.08	3.05	8.38	10.98	0.90
8	Increase conservation areas by 30% in exchange of 50% reclamation of degraded rangeland		5.82	-21.44	5.07	-14.63	-14.84	1.78
9	Reclamation and planned settlements		-6.17	11.23	-13.02	4.47	4.46	-3.94
10	Reclamation, planned settlement and supplementary feeding		-2.13	11.41	-6.01	45.45	7.16	-1.78
11	Reclamation, planned settlement, supplementary feeding and veterinary services		3.03	10.96	4.97	93.36	38.26	1.53
12	Reclamation, planned settlement, veterinary services and restocking program		45.50	10.31	130.10	213.62	192.49	36.61
13	Reclamation, planned settlement, veterinary services , restocking program and bolster security		47.11	10.28	143.00	219.71	198.83	38.71
14	Reclamation, planned settlement, veterinary services , supplementary feeding and bolster security		3.55	10.94	6.53	96.31	40.18	1.98
15	Reclamation, planned settlement, veterinary services , supplementary feeding, bolster security and destocking		10.30	10.82	12.76	112.07	55.07	4.16
16	Reclamation, planned settlement, veterinary services , restocking, bolster security and destocking		48.18	10.29	128.41	181.51	173.71	36.37
17	Reclamation, planned settlement, veterinary services , supplementary feeding, bolster security, destocking and enhanced conservation		2.51	-10.37	-5.41	73.08	26.73	-1.26
18	Reclamation, planned settlement, veterinary services , restocking, bolster security, destocking and enhanced conservation		41.24	-10.83	99.87	129.16	123.88	29.39
19	Increase school retention by school feeding programs	8.41						
20	Increase enrolment rate to match the national level (50% to 74%)	12.62						
21	Combined education strategy of increased enrolment and retention	22.90						

Appendix VII: Education strategies and human skills

Year	Percentage of Skilled labour				Percentage of skilled and semi-skilled labour			
	Baseline	Enrolment	Dropout	Combined	Baseline	Enrolment	Dropout	Combined
2006	0.1	0.1	0.1	0.1	1.5	1.5	1.5	1.5
2007	0.1	0.1	0.1	0.1	1.6	1.6	1.6	1.6
2008	0.1	0.1	0.1	0.1	1.7	1.7	1.7	1.7
2009	0.1	0.1	0.1	0.1	2.0	2.0	2.0	2.0
2010	0.2	0.2	0.2	0.2	2.3	2.3	2.3	2.3
2011	0.3	0.3	0.3	0.3	2.5	2.5	2.5	2.5
2012	0.4	0.4	0.4	0.4	2.9	2.9	2.9	2.9
2013	0.5	0.5	0.5	0.5	3.4	3.4	3.3	3.3
2014	0.7	0.7	0.7	0.7	3.8	3.8	3.6	3.6
2015	0.9	0.9	0.9	0.9	4.3	4.4	3.9	3.9
2016	1.2	1.2	1.2	1.2	4.9	5.1	4.2	4.2
2017	1.4	1.4	1.4	1.4	5.4	5.6	4.5	4.7
2018	1.7	1.7	1.7	1.8	6.0	6.4	4.9	5.1
2019	2.0	2.1	2.1	2.1	6.6	7.2	5.4	5.6
2020	2.3	2.4	2.4	2.5	7.1	7.9	5.8	6.2
2021	2.7	2.8	2.8	3.0	7.8	8.7	6.3	6.8
2022	3.0	3.2	3.2	3.4	8.4	9.6	6.8	7.5
2023	3.3	3.6	3.6	3.9	8.9	10.4	7.2	8.1
2024	3.7	4.1	4.0	4.5	9.5	11.3	7.7	8.8
2025	4.0	4.6	4.4	5.0	10.2	12.2	8.2	9.5
2026	4.3	5.0	4.8	5.6	10.7	12.9	8.7	10.3
2027	4.6	5.5	5.2	6.1	11.2	13.8	9.2	11.0
2028	5.0	6.0	5.6	6.7	11.8	14.7	9.7	11.7
2029	5.3	6.4	6.0	7.3	12.3	15.4	10.2	12.5
2030	5.6	6.9	6.4	7.9	12.8	16.3	10.6	13.2

Appendix VIII: Livestock Insurance Paid

Years	Livestock insurance expenses ('000' US$)				
	Strategy 5	Strategy 12	Strategy 13	Strategy 16	Strategy 18
2013	699	745	764	717	668
2014	854	988	1,033	989	835
2015	448	644	661	759	666
2016	1,145	1,467	1,487	1,455	1,231
2017	1,409	1,816	1,821	1,787	1,516
2018	659	1,115	1,111	1,281	1,048
2019	1,647	2,364	2,312	2,349	1,742
2020	1,850	2,531	2,399	2,440	1,781
2021	789	1,726	1,684	1,908	1,485
2022	2,044	3,055	3,104	2,776	2,180
2023	2,168	3,437	3,455	3,154	2,375
2024	867	2,250	2,421	2,389	1,964
2025	2,190	4,218	4,272	3,621	2,851
2026	2,258	4,718	4,884	4,055	3,165
2027	919	3,243	3,304	3,182	2,491
2028	2,209	5,869	6,030	4,645	3,717
2029	2,263	6,490	6,746	5,199	4,121
2030	854	4,473	4,660	4,134	3,253
Average	1,404	2,842	2,897	2,602	2,061

11 References

ABULE, E., SNYMAN, H. A. & SMIT, G. N. 2005. Comparisons of pastoralists perceptions about rangeland resource utilisation in the Middle Awash Valley of Ethiopia. *Journal of Environmental Management,* 75**,** 21-35.

ABULE, E., SNYMAN, H. A. & SMIT, G. N. 2007. Rangeland evaluation in the middle Awash valley of Ethiopia: I. Herbaceous vegetation cover. *Journal of Arid Environments,* 70**,** 253-271.

ADANO, W. & WITSENBURG, K. 2005. Once Nomads Settle: assessing the process, motives and welfare changes of settlements on Mount Marsabit. *As pastoralists settle: social, health, and economic consequences of the pastoral sedentarization in Marsabit District, Kenya.* Springer.

ADGER, W. N. 2006. Vulnerability. *Global Environmental Change,* 16**,** 268-281.

AGRAWAL, A. 2001. Common property institutions and sustainable governance of resources. *World Development,* 29**,** 1649-1672.

AKLILU, Y. & CATLEY, A. 2010. Livestock Exports from Pastoralist Areas: An Analysis of Benefits by Wealth Group and Policy Implications. *IGAD LPI Working Paper No. 01-10.* FAO.

AKLILU, Y. & WEKESA, M. 2002. Drought, livestock and livelihoods: lessons from the 1999-2001 emergency response in the pastoral sector in Kenya. *In:* HUMANITARIAN PRACTICE NETWORK (ed.). London: Overseas Development Institute (ODI).

ALRMP 2005. Samburu District Vision and Strategy: 2005-2015. *In:* OFFICE OF THE PRESIDENT: MINISTRY OF SPECIAL PROGRAMMES (ed.). Nairobi: Arid Lands Resource Management Project (ALRMP).

ALRMP 2007. Samburu District annual progress report for 2006/2007 financial year. Arid Land Resource Management Project II.

ALRMP 2012. Samburu District Profile. Arid Lands Resource Management Project (http://www.aridland.go.ke/arid_profiles/samburu_profile.pdf).

ANDERSON, D. & GROVE, R. 1990. *Conservation in Africa: peoples, policies and practice*, Cambridge Univ Pr.

ANGASSA, A. & OBA, G. 2007. Relating long-term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in southern Ethiopia. *Agricultural Systems,* 94**,** 715-725.

ANGASSA, A. & OBA, G. 2009. Effects of grazing pressure, age of enclosures and seasonality on bush cover dynamics and vegetation composition in southern Ethiopia. *Journal of Arid Environments,* 74**,** 111-120.

BAARS, R., CHILESHE, E. & KALOKONI, D. 1997. Technical note: Range condition in high cattle density areas in the Western Province of Zambia. *Tropical Grasslands,* 31**,** 569-573.

BABBIE, E. 1990. Survey research methods . Belmont, CA: Wadsworth. Inc.

BAGCHI, S., NAMGAIL, T. & RITCHIE, M. E. 2006. Small mammalian herbivores as mediators of plant community dynamics in the high-altitude arid rangelands of Trans-Himalaya. *Biological Conservation,* 127**,** 438-442.

BAKER, R. 1981. *Land Degradation in Kenya: Economic Or Social Crisis?*, University of East Anglia.

BALINT, Z. & MUTUA, F. 2011. Drought Monitoring with the Combined Drought Index. Nairobi: FAO-SWALIM

BALTAGI, B. & BOOZER, M. 1997. Econometric analysis of panel data. *Econometric Theory,* 13**,** 747-754.

BALTAGI, B. & SONG, S. 2006. Unbalanced panel data: A survey. *Statistical Papers,* 47**,** 493-523.

BARLAS, Y. 1996. Formal aspects of model validity and validation in system dynamics. *System Dynamics Review,* 12**,** 183-210.

BARN, D. 2002. An appraisal of Pastoral Production Potential in Relation to Continued Interventions by the Ereto Ngorongoro Pastoralist Project. *Environmental Research Group Oxford, Oxford, UK.*

BARRETT, C., CHABARI, F., BAILEY, D., LITTLE, P. & COPPOCK, D. 2003. Livestock pricing in the northern Kenyan rangelands. *Journal of African Economies,* 12, 127.

BARRETT, C. & LUSENO, W. 2004. Decomposing producer price risk: a policy analysis tool with an application to northern Kenyan livestock markets. *Food Policy,* 29, 393-405.

BARRETT, C. & MCPEAK, J. 2006. Poverty traps and safety nets. *Poverty, Inequality and Development*, 131-154.

BAULCH, B. 1996. Editorial. The new poverty agenda: a disputed consensus'. *IDS Bulletin,* 27, 1-10.

BEBE, B., UDO, H., ROWLANDS, G. & THORPE, W. 2003. Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification. *Livestock Production Science,* 82, 211-221.

BEGZSUREN, S., ELLIS, J. E., OJIMA, D. S., COUGHENOUR, M. B. & CHULUUN, T. 2004. Livestock responses to droughts and severe winter weather in the Gobi Three Beauty National Park, Mongolia. *Journal of Arid Environments,* 59, 785-796.

BEHNKE, R. & KERVEN, C. 1994. *Redesigning for risk: tracking and buffering environmental variability in Africa's rangelands*, ODI Inc.

BEHNKE, R. H., SCOONES, I. & KERVEN, C. 1993. *Range ecology at disequilibrium : new models of natural variability and pastoral adaptation in African savannas,* London, Overseas Development Institute.

BEKURE, S. 1991. *Maasai herding: an analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya*, International Livestock Centre for Africa.

BEKURE, S. & CHABARI, F. 1991. An economic analysis of Maasai livestock production. *Maasai Herding: An analysis of the Livestock Production System of Maasai Pastoralists in eastern Kajiado District, Kenya. ed. by S. Bekure, PN de Leeuw, BE Grandin and PJH Neate. pp115-125. Nairobi: International Livestock Centre for Africa.*

BEKURE, S. & DE LEEUW, P. 1991. The potential for improving the livestock production and welfare of the pastoral Maasai Herding. An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya. *International Livestock Center for Africa (ILCA), ILCA Systems Study,* 4, 141-154.

BILSBORROW, R. & OGENDO, H. 1992. Population-driven changes in land use in developing countries. *Ambio*, 37-45.

BIRCH, I. & GRAHN, R. 2007. Pastoralism–Managing Multiple Stressors and the Threat of Climate Variability and Change. *UNDP Human Development Report Office Occasional Paper, UNDP: New York*.

BIRCH, I. & SHURIA, H. 2002. *Taking charge of the future: pastoral institution building in Northern Kenya*, Drylands Programme, International Institute for Environment and Development.

BLAIKIE, P., BROOKFIELD, H. & ALLEN, B. 1987. *Land degradation and society*, Routledge Kegan & Paul.

BLAIKIE, P. M. 1994. *At risk: natural hazards, people's vulnerability, and disasters*, Psychology Press.

BOLLIG, M. 2006. *Risk management in a hazardous environment: a comparative study of two pastoral societies*, Springer Verlag.

BOONE, R., BURNSILVER, S., THORNTON, P., WORDEN, J. & GALVIN, K. 2005. Quantifying declines in livestock due to land subdivision. *Rangeland Ecology & Management,* 58, 523-532.

BOONE, R., GALVIN, K., THORNTON, P., SWIFT, D. & COUGHENOUR, M. 2006. Cultivation and conservation in Ngorongoro conservation area, Tanzania. *Human Ecology,* 34, 809-828.

BOONE, R. B. & WANG, G. 2007. Cattle dynamics in African grazing systems under variable climates. *Journal of Arid Environments,* 70, 495-513.

BORODZICZ, E. 2005. *Risk, crisis and security management*, John Wiley & Sons, West Sussex.

BRAUN, H. 1973. Primary production in the Serengeti: purpose, methods and some results of research. *Ann. Univ. Abidjan, ser. E (Ecologie),* 6, 171-88.
BRESLOW, N. 1970. A generalized Kruskal-Wallis test for comparing K samples subject to unequal patterns of censorship. *Biometrika,* 57, 579-594.
BROWMAN, D. L. 1987. Agro-pastoral risk management in the Central Andes. *Research in economic anthropology,* 8, 171-200.
BURRA, S., JIJJI, S., REGAN-SACHS, R. & TIWAR, K. 2009. Strategic Business Plan: Scaling up the "linking livestock markets to wildlife conservation" programme. *Strategic Consulting Project for Ol Pajeta.* Laikipia district,: Oxford Said Business School, MBA Team.
BURTON, I. & WHITE, G. F. 1993. *The environment as hazard*, The Guilford Press.
BUTT, B. 2010. Seasonal space-time dynamics of cattle behavior and mobility among Maasai pastoralists in semi-arid Kenya. *Journal of Arid Environments,* 74, 403-413.
CAMPBELL, B., DORÉ, D., LUCKERT, M., MUKAMURI, B. & GAMBIZA, J. 2000a. Economic comparisons of livestock production in communal grazing lands in Zimbabwe. *Journal Title: Ecological Economics,* 33, 3.
CAMPBELL, B., DORÉ, D., LUCKERT, M., MUKAMURI, B. & GAMBIZA, J. 2000b. Special Section: Land use options in dry tropical woodland ecosystem in Zimbabwe; Economic comparisons of livestock production in communal grazing lands in Zimbabwe. *Ecological Economics,* 33, 413-438.
CAMPBELL, B. M., GORDON, I. J., LUCKERT, M. K., PETHERAM, L. & VETTER, S. 2006. In search of optimal stocking regimes in semi-arid grazing lands: One size does not fit all. *Ecological Economics,* 60, 75-85.
CAMPBELL, D. 1999. Response to drought among farmers and herders in southern Kajiado District, Kenya: A comparison of 1972-1976 and 1994-1995. *Human Ecology,* 27, 377-416.
CARTER, M. & BARRETT, C. 2006. The economics of poverty traps and persistent poverty: An asset-based approach. *Journal of Development Studies,* 42, 178-199.
CARTER, M. & MAY, J. 2001. One kind of freedom: poverty dynamics in post-apartheid South Africa. *World Development,* 29, 1987-2006.
CHANDRASEKHAR, K., RAO, K. S., MAIKHURI, R. K. & SAXENA, K. G. 2007. Ecological implications of traditional livestock husbandry and associated land use practices: A case study from the trans-Himalaya, India. *Journal of Arid Environments,* 69, 299-314.
CHANTARAT, S., MUDE, A. & BARRETT, C. 2009a. Willingness to pay for index based livestock insurance: results from a field experiment in northern Kenya. *Ithaca, NY (USA): Cornell University.*
CHANTARAT, S., MUDE, A., BARRETT, C. & CARTER, M. 2009b. Designing Index Based Livestock Insurance for Managing Asset Risk in Northern Kenya. Working Paper, Cornell University.
CHAPMAN, C. & WARD, S. 2002. *Managing Project Risk and Uncertainty: A constructively simple approach to decision making,* Chichester, UK, John Wiley & Sons.
CHEN, Y., LEE, G., LEE, P. & OIKAWA, T. 2007. Model analysis of grazing effect on above-ground biomass and above-ground net primary production of a Mongolian grassland ecosystem. *Journal of Hydrology,* 333, 155-164.
COENRAADS, R. R. 2006. *Natural disasters and how we cope*, Millennium House.
COLLIS, J. & HUSSEY, R. 2003. Business research: A practical guide for undergraduate and postgraduate students.
COLSON, E. 1979. The Harvey Lecture Series. In Good Years and in Bad: Food Strategies of Self-Reliant Societies. *Journal of Anthropological Research,* 35, 18-29.
COPPOCK, D. 1994. *The Borana Plateau of southern Ethiopia: synthesis of pastoral research, development, and change, 1980-91*, International Livestock Centre for Africa.
COPPOCK, D., ELLIS, J. & SWIFT, D. 1986. Livestock feeding ecology and resource utilization in a nomadic pastoral ecosystem. *Journal of Applied Ecology,* 23, 573-583.

COSSINS, N. J. & UPTON, M. 1987. The Borana pastoral system of southern Ethiopia. *Agricultural Systems,* 25, 199-218.
COSSINS, N. J. & UPTON, M. 1988. Options for improvement of the Borana Pastoral System. *Agricultural Systems,* 27, 251-278.
COUGHENOUR, M. 2004. The Ellis paradigm humans, herbivores and rangeland systems. *African Journal of Range and Forage Science,* 21, 191-200.
COWLING, R. 2000. Challenges to the 'new'rangeland science. *Trends in Ecology & Evolution,* 15, 303-304.
CRERAND, A. 2005. Risk management the bow-tie way. *Chemical engineer(London)*, 18-20.
CRESWELL, J. 2003. *Research design: Qualitative, quantitative, and mixed methods approaches*, Sage Publications, Inc.
D'AGOSTINO, R. B., BELANGER, A. & D'AGOSTINO JR, R. B. 1990. A suggestion for using powerful and informative tests of normality. *American Statistician,* 44, 316-321.
DAHL, G. & HJORT, A. 1976. *Having herds: pastoral herd growth and household economy*, Dept. of Social Anthropology, University of Stockholm.
DE LEEUW, J., WAWERU, M. N., OKELLO, O. O., MALOBA, M., NGURU, P., SAID, M. Y., ALIGULA, H. M., HEITKÖNIG, I. M. A. & REID, R. S. 2001. Distribution and diversity of wildlife in northern Kenya in relation to livestock and permanent water points. *Biological Conservation,* 100, 297-306.
DE LEEUW, P., SEMENYE, P., PEACOCK, C. & GRANDIN, B. 1991. Productivity of cattle and smallstock. *Maasai herding: analysis of the livestock production system of Maasai pastoralists in Eastern Kajiado district, Kenya. Addis Ababa, ILCA*, 83-101.
DE LEEUW, P. N., MCDERMOTT, J. J. & LEBBIE, S. H. B. 1995. Monitoring of livestock health and production in sub-Saharan Africa. *Preventive Veterinary Medicine,* 25, 195-212.
DESHMUKH, I. 1984. A common relationship between precipitation and grassland peak biomass for east and southern Africa. *African Journal of Ecology,* 22, 181-186.
DESHMUKH, I. 1986. Primary production of a grassland in Nairobi National Park, Kenya. *Journal of Applied Ecology,* 23, 115-123.
DESHMUKH, I. 2008. A common relationship between precipitation and grassland peak biomass for east and southern Africa. *African Journal of Ecology,* 22, 181-186.
DESTA, S. & COPPOCK, D. 2002a. Cattle population dynamics in the southern Ethiopian rangelands. *Journal of Range Management,* 55, 439–51.
DESTA, S. & COPPOCK, D. 2002b. Cattle population dynamics in the southern Ethiopian rangelands, 1980-97. *Journal of Range Management,* 55, 439-451.
DESTA, S. & COPPOCK, D. 2004. Pastoralism under pressure: tracking system change in southern Ethiopia. *Human Ecology,* 32, 465-486.
DEWAAL, A. 1988. Famine Early Warning Systems and the Use of Socio-Economic Data. *Disasters,* 12, 81-91.
DEWI, S. & CHESSON, P. 2004. Age-structured population growth rates in constant and variable environments: a near equilibrium approach. *Theoretical population biology,* 65, 75-88.
DFID 1999. Sustainable livelihoods. *Lessons from early experience.* London: Department for International Development.
DOSS, C., MCPEAK, J. & BARRETT, C. Perceptions of Risk within Pastoralist Households in Northern Kenya and Southern Ethiopia. 2005. American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association).
DOUGLAS, M. 1992. *Risk and blame: essays in cultural theory*, Routledge London.
DRACUP, J. A., LEE, K. S. & PAULSON JR, E. G. 1980. On the definition of droughts. *Water Resources Research,* 16, 297-302.
DREGNE, H. E. 1995. Desertification control: A framework for action. *Environmental Monitoring and Assessment,* 37, 111-122.
DYSON-HUDSON, R. & MCCABE, J. 1985. *South Turkana nomadism: Coping with an unpredictably varying environment*, Human Relations Area Files, New Haven, Conn.

DYSON HUDSON, N. 1991. Pastoral production systems and livestock development projects: an East African perspective. World Bank.

ELLIS, A. W., GOODRICH, G. B. & GARFIN, G. M. 2010. A hydroclimatic index for examining patterns of drought in the Colorado River Basin. *International Journal of Climatology,* 30**,** 236-255.

ELLIS, F. 2000. The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics,* 51**,** 289-302.

ELLIS, F. & MDOE, N. 2003. Livelihoods and rural poverty reduction in Tanzania. *World Development,* 31**,** 1367-1384.

ELLIS, J., COUGHENOUR, M. & SWIFT, D. 1993. Climate variability, ecosystem stability, and the implications for range and livestock development. *Range ecology at disequilibrium. New models of natural variability and pastoral adaptation in African savannas***,** 31–41.

ELLIS, J. & SWIFT, D. 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. *Journal of Range Management***,** 450-459.

FAFCHAMPS, M. & GAVIAN, S. 1996. The spatial integration of livestock markets in Niger. *Journal of African Economies,* 5**,** 366.

FAO 2009. The State of Agricultural Commodity Markets 2009. Food and Agricultural Organization.

FAY, M. P. & PROSCHAN, M. A. 2010. Wilcoxon-Mann-Whitney or t-test? On assumptions for hypothesis tests and multiple interpretations of decision rules. *Statistics surveys,* 4**,** 1.

FORRESTER, J. 1994. System dynamics, systems thinking, and soft OR. *System.*

FORRESTER, J. & SENGE, P. 1980. Tests for building confidence in system dynamics models. *TIMS studies in the management sciences,* 14**,** 209-228.

FRATKIN, E. 2004. Ariaal Pastoralists of Northern Kenya: Studying Pastoralism, Drought, and Development in Africa's Arid Lands. Needham Heights MA: Allyn and Bacon.

FRATKIN, E. & ROTH, E. 1990. Drought and economic differentiation among Ariaal pastoralists of Kenya. *Human Ecology,* 18**,** 385-402.

FRATKIN, E. & ROTH, E. 2005. *As pastoralists settle: social, health, and economic consequences of the pastoral sedentarization in Marsabit District, Kenya*, Kluwer Academic/Plenum Publishers, New York.

FRATKIN, E., ROTH, E. & NATHAN, M. 1999. When Nomads Settle: The Effects of Commoditization, Nutritional Change, and Formal Education on Ariaal and Rendille Pastoralists 1. *Current Anthropology,* 40**,** 729-735.

FRATKIN, E. & SMITH, K. 1995. Women's changing economic roles with pastoral sedentarization: varying strategies in alternate Rendille communities. *Human Ecology,* 23**,** 433-454.

FREEMAN, H., ELLIS, F. & ALLISON, E. 2004. Livelihoods and rural poverty reduction in Kenya. *Development Policy Review,* 22**,** 147-171.

FRIEDEL, M. 1991. Range condition assessment and the concept of thresholds: a viewpoint. *Journal of Range Management,* 44**,** 422-426.

FYNN, R. & O'CONNOR, T. 2000. Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. *Journal of Applied Ecology,* 37**,** 491-507.

GALATY, J. G. 2005. Time, terror, and pastoral inertia: sedentarization and conflict in Northern Kenya. *In:* FRATKIN, E. & ROTH, E. (eds.) *As pastoralist settle: social, health, and economic consequences of pastoral sedentarization in Marsabit district, Kenya.* Kluwer Academic Publishers New York.

GALVIN, K. 1992. Nutritional ecology of pastoralists in dry tropical Africa. *American Journal of Human Biology,* 4**,** 209–221.

GALVIN, K., BOONE, R., SMITH, N. & LYNN, S. 2001. Impacts of climate variability on East African pastoralists: linking social science and remote sensing. *Climate Research,* 19**,** 161-172.

GALVIN, K., THORNTON, P., BOONE, R. & SUNDERLAND, J. 2004. Climate variability and impacts on east African livestock herders: the Maasai of Ngorongoro Conservation Area, Tanzania. *African Journal of Range and Forage Science,* 21**,** 183-189.

GALVIN, K., THORNTON, P., DE PINHO, J., SUNDERLAND, J. & BOONE, R. 2006. Integrated modeling and its potential for resolving conflicts between conservation and people in the rangelands of East Africa. *Human Ecology,* 34, 155-183.
GAREDEW, E., SANDEWALL, M., SÖDERBERG, U. & CAMPBELL, B. 2009. Land-Use and Land-Cover Dynamics in the Central Rift Valley of Ethiopia. *Environmental management,* 44, 683-694.
GEORGIADIS, N., HACK, M. & TURPIN, K. 2003. The influence of rainfall on zebra population dynamics: implications for management. *Journal of Applied Ecology,* 40, 125-136.
GHULAM, A., QIN, Q., TEYIP, T. & LI, Z. L. 2007. Modified perpendicular drought index (MPDI): a real-time drought monitoring method. *ISPRS journal of photogrammetry and remote sensing,* 62, 150-164.
GOK 2005. Kenya Economic Recovery Strategy for Wealth and Employment
Creation (2003 - 2007). Nairobi: Ministry of Planning and National Development, Government Printers.
GOK 2009. National Policy on Peacebuilding and Conflict Management. *In:* PRESIDENT., O. O. T. (ed.). Nairobi: Republic of Kenya.
GOK 2010a. District Livestock Production Annual Report Year 2010; Samburu North. *In:* MINISTRY OF LIVESTOCK DEVELOPMENT (ed.). Republic of Kenya: District Livestock Production Officer.
GOK 2010b. Interim Independent Bounderies Review Commission (IIBRC). *In:* DELIMITATION OF CONSTITUENCIES AND RECOMMENDATION ON LOCAL AUTHORITY ELECTORAL UNITS AND ADMINISTRATIVE BOUNDARIES FOR DISTRICTS AND OTHER UNITS (ed.). Nairobi Kenya: Parliament Report.
GRANDIN, B. 1988. Wealth and pastoral dairy production: A case study from Maasailand. *Human Ecology,* 16, 1-21.
GRANDIN, B., BEKURE, S. & NESTEL, P. 1991. Livestock transactions, food consumption and household budgets. *Maasai Herding. An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado Dsitrict, Kenya. International Livestock Center for Africa (ILCA), ILCA Systems Study,* 4, 103-114.
GUBA, E. & LINCOLN, Y. 1994. Competing paradigms in qualitative research. *Handbook of qualitative research,* 2, 163-194.
HAMBLER, C., CANNEY, S. M., COE, M. J., HENDERSON, P. A. & ILLIUS, A. W. 2007. Grazing and "degradation". *Science,* 316, 1564-7; author reply 1564-7.
HANSEN, C. B. 2007. Generalized least squares inference in panel and multilevel models with serial correlation and fixed effects. *Journal of Econometrics,* 140, 670-694.
HARDIN, G. 1998. Extensions of the tragedy of the commons. *Science,* 280, 682-683.
HARO, G. O., DOYO, G. J. & MCPEAK, J. G. 2005. Linkages between community, environmental, and conflict management: experiences from Northern Kenya. *World Development,* 33, 285-299.
HIGGINS, S. I., KANTELHARDT, J., SCHEITER, S. & BOERNER, J. 2007. Sustainable management of extensively managed savanna rangelands. *Ecological Economics,* 62, 102-114.
HJORT, A. & DAHL, G. 1991. Responsible man. The Atmaan Beja of North-eastern Sudan. *Stockholm Studies in Social Anthropology (Sweden).*
HOCKING, D. & MATTICK, A. 1993. Dynamic carrying capacity analysis as tool for conceptualizing and planning range management improvements, with a case study from India. *Paper-Pastoral Development Network.*
HOFSTEDE, G. 1991. *Cultures and organizations*, McGraw-Hill New York.
HOGG, R. 1986. The new pastoralism: poverty and dependency in northern Kenya. *Africa,* 56, 319-333.
HOLTZMAN, J. 2001. The food of elders, the" ration" of women: brewing, gender, and domestic processes among the Samburu of northern Kenya. *American anthropologist*, 1041-1058.

HOLTZMAN, J. 2007. Eating time: Capitalist history and pastoralist history among Samburu herders in northern Kenya. *Journal of Eastern African Studies,* 1, 436-448.

HOMEWOOD, K. 2004. Policy, environment and development in African rangelands. *Environmental Science & Policy,* 7, 125-143.

HOMEWOOD, K., LAMBIN, E., COAST, E., KARIUKI, A., KIKULA, I., KIVELIA, J., SAID, M., SERNEELS, S. & THOMPSON, M. 2001. Long-term changes in Serengeti-Mara wildebeest and land cover: Pastoralism, population, or policies? *Proceedings of the National Academy of Sciences,* 98, 12544.

HOMEWOOD, K. & LEWIS, J. 1987. Impact of drought on pastoral livestock in Baringo, Kenya 1983-85. *Journal of Applied Ecology,* 24, 615-631.

HOPE, K. R. 2009. Climate change and poverty in Africa. *International Journal of Sustainable Development & World Ecology,* 16, 451-461.

HUSSEY, J. & HUSSEY, R. 1997. *Business Research: A practical guide for undergraduate and postgraduate students*, Macmillan, Basingstoke.

HUTCHINSON, C. 1991. Uses of satellite data for famine early warning in sub-Saharan Africa. *International Journal of Remote Sensing,* 12, 1405-1421.

IFAD. 2009. *Rural poverty in Kenya statistics; social indicators* [Online]. International Fund for Agricultural Development. [Accessed 15 March 2010].

ILLIUS, A. & O'CONNOR, T. 2000. Resource heterogeneity and ungulate population dynamics. *Oikos,* 89, 283-294.

ILRI 2010. An evaluation of the response to the 2008 – 2009 drought in Kenya. Nairobi: International Livestock Research Institute (ILRI).

IMF 2012. Kenya: Poverty Reduction Strategy Paper-Progress Report. *January 2012 IMF Country Report No. 12/10* Washington DC: International Monitoring Fund: Publication Services.

IMF 2010. Kenya: Poverty Reduction Strategy Paper (PRSP). *July 2010, IMF Country Report No. 10/22.* Washington, D.C.: International Monetary Fund.

IPCC 2007. Climate Change 2007:Synthesis report. Intergovermental Panel on Climate Change,.

JAHNKE, H. E. 1982. *Livestock production systems and livestock development in tropical Africa*, Kieler Wissenschaftsverlag Vauk Kiel.

JAMES, A. & CARLES, A. 1996. Measuring the productivity of grazing and foraging livestock. *Agricultural Systems,* 52, 271-291.

JOHNSON, P. & GILL, J. 1997. *Research methods for Managers,* London, UK, Paul Chapman.

JOLLY, C. & TORREY, B. 1993. Population and land use in developing countries: Report of a Workshop. Washington, DC: National Academy Press.

JUSTICE, C. 1986. Monitoring the grasslands of semi-arid Africa using NOAA-AVHRR data. *International Journal of Remote Sensing,* 7, 1383-1622.

KAITHO, R., STUTH, J., ANGERER, J., JAMA, A., MNENE, W. & KINGAMKONO, M. 2003. A new system to forecast near-term forage conditions for early warning systems in pastoral regions of East Africa. *Research Brief*, 03-02.

KANE, S., REILLY, J. & TOBEY, J. 1992. An empirical study of the economic effects of climate change on world agriculture. *Climatic change,* 21, 17-35.

KAPLAN, H. & HILL, K. 2008. Food sharing among Ache foragers: Tests of explanatory hypotheses. *SOCIAL STUDIES.*

KAPLAN, H., HILL, K. & HURTADO, A. 1990. Risk, foraging, and food sharing among the Ache. *Risk and uncertainty in tribal and peasant economies*, 107–44.

KASSAHUN, A., SNYMAN, H. A. & SMIT, G. N. 2008. Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia. *Journal of Arid Environments,* 72, 1265-1281.

KASSAS, M. 1995. Desertification: a general review. *Journal of Arid Environments,* 30, 115-128.

KERE, J., LESENI, B., KITILIT, R. & ADIEMA, C. 2008. Samburu district 2008 long rains assessment report. Arid Lands Resource Management Project II (ALRMP).

KHAN, M. M., MOCK, N. B. & BERTRAND, W. B. 1992. Composite Indicators for Famine Early Warning Systems. *Disasters,* 16, 195-206.

KIMANI, K. & PICKARD, J. 1998. Recent Trends and Implications of Group Ranch Sub-Division and Fragmentation in Kajiado District, Kenya. *The Geographical Journal,* 164.

KING, J., SAYERS, A., PEACOCK, C. & KONTROHR, E. 1984. Maasai herd and flock structures in relation to livestock wealth, climate and development. *Agricultural Systems,* 13, 21-56.

KONAKA, S. 1997. The Samburu livestock market in northcentral Kenya. *African Study Monographs,* 18, 137-155.

KONCZACKI, Z. 1978. *The economics of pastoralism: a case study of sub-Saharan Africa*, Routledge.

LAMBIN, E., GEIST, H. & LEPERS, E. 2003. Dynamics of land-use and land-cover change in tropical regions.

LAMPREY, R. & REID, R. 2004. Expansion of human settlement in Kenya's Maasai Mara: what future for pastoralism and wildlife? *Journal of Biogeography,* 31, 997-1032.

LEGGETT, K., FENNESSY, J. & SCHNEIDER, S. 2003. Seasonal vegetation changes in the Hoanib River catchment, north-western Namibia: a study of a non-equilibrium system. *Journal of Arid Environments,* 53, 99-113.

LESOROGOL, C. 2008a. *Contesting the commons: privatizing pastoral lands in Kenya*, Univ of Michigan Pr.

LESOROGOL, C. K. 2008b. Land privatization and pastoralist well-being in Kenya. *Development and Change,* 39, 309-331.

LESOROGOL, C. K. 2009. Asset building through community participation: restocking pastoralists following drought in northern Kenya. *Soc Work Public Health,* 24, 178-86.

LINCOLN, Y. & GUBA, E. 2000. Paradigmatic controversies, contradictions, and emerging confluences. *Handbook of qualitative research,* 2, 163-188.

LITTLE, P. 1992. The elusive granary: herder, farmer and state in northern Kenya.

LITTLE, P., MAHMOUD, H. & COPPOCK, D. 2001a. When deserts flood: risk management and climatic processes among East African pastoralists. *Climate Research,* 19, 149-159.

LITTLE, P., MCPEAK, J., BARRETT, C. & KRISTJANSON, P. Challenging Stereotypes: The Multiple Dimensions of Poverty in Pastoral Areas of East Africa. 2008.

LITTLE, P., SMITH, K., CELLARIUS, B., COPPOCK, D. & BARRETT, C. 2001b. Avoiding disaster: diversification and risk management among East African herders. *Development and Change,* 32, 401-433.

LOW, B., SUNDARESAN, S. R., FISCHHOFF, I. R. & RUBENSTEIN, D. I. 2009. Partnering with local communities to identify conservation priorities for endangered Grevy's zebra. *Biological Conservation,* 142, 1548-1555.

LUSENO, W., MCPEAK, J., BARRETT, C., LITTLE, P. & GEBRU, G. 2003. Assessing the value of climate forecast information for pastoralists: Evidence from Southern Ethiopia and Northern Kenya. *World Development,* 31, 1477-1494.

LUSIGI, W. 1984. Integrated resource assessment and management Plan for western Marsabit District, northern Kenya. *Integrated Project in Arid Lands (IPAL) Technical Report No A-6.* Nairobi: UNESCO.

LYBBERT, T., BARRETT, C., DESTA, S. & COPPOCK, D. 2004a. Pastoral risk and wealth-differentiated herd accumulation patterns in southern Ethiopia. *Economic Journal,* 114, 750-777.

LYBBERT, T., BARRETT, C., DESTA, S. & COPPOCK, D. 2004b. Stochastic wealth dynamics and risk management among a poor population. *Economic Journal,* 114, 750-777.

LYBBERT, T., BARRETT, C., MCPEAK, J. & LUSENO, W. 2007. Bayesian herders: Updating of rainfall beliefs in response to external forecasts. *World Development,* 35, 480-497.

MAINGUET, M. 1994. *Desertification: Natural background and human mismanagement*, Berlin.

MBURU, N. & KIRITI-NGANGA, T. 2007. Poverty in Kenya, 1974-1997: A stochastic dominance approach. *Global economic integration and inequality*, 121.

MCCABE, J. 1987. Drought and recovery: livestock dynamics among the Ngisonyoka Turkana of Kenya. *Human Ecology,* 15, 371-389.
MCCABE, J. 1990. Turkana pastoralism: a case against the tragedy of the commons. *Human Ecology,* 18, 81-103.
MCCABE, J. 1997. Risk and uncertainty among the Maasai of the Ngorongoro conservation area in Tanzania: A case study in economic change. *Nomadic Peoples,* 1, 54-65.
MCCABE, J. 2003. Sustainability and livelihood diversification among the Maasai of northern Tanzania. *Human Organization,* 62, 100-111.
MCCARTHY, J. J. 2001. *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*, Cambridge Univ Pr.
MCCARTHY, N. & SWALLOW, B. Managing the natural capital of African rangelands: rights, risk and responses. 1999. 1002-1007.
MCPEAK, J. 2003. Fuelwood Gathering and Use in Northern Kenya: Implications for Food Aid and Local Environments. *USAID Global Livestock CRSP Research Brief*, 03-01.
MCPEAK, J. 2004. Contrasting income shocks with asset shocks: Livestock sales in northern Kenya. *Oxford Economic Papers,* 56, 263.
MCPEAK, J. 2005. Individual and collective rationality in pastoral production: evidence from northern Kenya. *Human Ecology,* 33, 171-197.
MCPEAK, J. & BARRETT, C. 2001. Differential risk exposure and stochastic poverty traps among East African pastoralists. *American Journal of Agricultural Economics*, 674-679.
MCPEAK, J. & LITTLE, P. 2003. Research Brief 03-02-PARIMA May 2003.
MCPEAK, J. & LITTLE, P. (eds.) 2005. *Cursed if you do, cursed if you don't*: Springer.
MINSON, D. & MCDONALD, C. 1987. Estimating forage intake from the growth of beef cattle. *Tropical Grasslands,* 21, 116-122.
MIZUTANI, F., MUTHIANI, E., KRISTJANSON, P. & RECKE, H. 2005. Impact and value of wildlife in pastoral livestock production systems in Kenya: Possibilities for healthy ecosystem conservation and livestock development for the poor. *Conservation and Development Interventions at the Wildlife/livestock Interface: Implications for Wildlife, Livestock and Human Health*, 121-132.
MOGUES, T. 2004. Shocks, livestock asset dynamics and social capital in Ethiopia. *University of Wisconsin-Madison, mimeo.*
MOORE, D. S. 2009. *The basic practice of statistics*, WH Freeman & Co.
MORTON, J., BARTON, D., COLLINSON, C., HEATH, B., DISTRICT, M. & DISTRICT, S. 2006. Comparing Drought Mitigation Interventions in the Pastoral Livestock Sector. *University of Greenwich, Natural Resource Institute. Chatham, UK Processed.*
MUDE, A., BARRETT, C., MCPEAK, J., KAITHO, R. & KRISTJANSON, P. 2009a. Empirical forecasting of slow-onset disasters for improved emergency response: An application to Kenya's arid north. *Food Policy,* 34, 329-339.
MUDE, A., CHANTARAT, S., BARRETT, C., CARTER, M., IKEGAMI, M. & MCPEAK, J. 2009b. Index-based livestock insurance for northern Kenya's arid and semi-arid lands: the Marsabit pilot. *Nairobi, Kenya: Project document, ILRI.*
MULINDWA, H., GALUKANDE, E., WURZINGER, M., OJANGO, J., OKEYO, A. M. & SÖLKNER, J. 2011. Stochastic simulation model of Ankole pastoral production system: Model development and evaluation. *Ecological Modelling,* 222, 3692-3700.
MUNYUA, P., MURITHI, R., WAINWRIGHT, S., GITHINJI, J., HIGHTOWER, A., MUTONGA, D., MACHARIA, J., ITHONDEKA, P., MUSAA, J. & BREIMAN, R. 2010. Rift Valley Fever Outbreak in Livestock in Kenya, 2006-2007. *The American Journal of Tropical Medicine and Hygiene,* 83, 58.
MUORIA, P. K., MURUTHI, P., KARIUKI, W. K., HASSAN, B. A., MIJELE, D. & OGUGE, N. O. 2007. Anthrax outbreak among Grevy's zebra (Equus grevyi) in Samburu, Kenya. *African Journal of Ecology,* 45, 483-489.
MURIUKI, H. 2001. Smallholder dairy production and marketing in Kenya. *In:* MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT (ed.). Nairobi: Government of Kenya,.

NIAMIR, M. 1991. Traditional African range management techniques: implications for rangeland development. *ODI, Pastoral Development Network,* 31.
NKEDIANYE, D., DE LEEUW, J., OGUTU, J. O., SAID, M. Y., SAIDIMU, T. L., KIFUGO, S. C., KAELO, D. S. & REID, R. S. 2011. Mobility and livestock mortality in communally used pastoral areas: the impact of the 2005-2006 drought on livestock mortality in Maasailand. *Pastoralism: Research, Policy and Practice,* 1, 17.
NKOMO, J., NYONG, A. & KULINDWA, K. 2006. The impacts of climate change in Africa. *The Stern Review on the Economics of Climate Change*.
NORDÅS, R. & GLEDITSCH, N. P. 2007. Climate change and conflict. *Political Geography,* 26, 627-638.
NRT. 2009. *About Northern Rangelands Trust; NRT area of operation* [Online]. [Accessed 15 th March 2010].
NRT. 2010. *Tourism* [Online]. Nairobi: Northern Rangeland Trust. Available: http://www.nrt-kenya.org/tourism.html [Accessed 12-01-2011 2010].
NRT. 2011. *Development Model; Livestock* [Online]. Northern Rangeland Trust. [Accessed 1st November 2011].
NYAMONGO, I. 2000. Factors Influencing Education and Age at First Marriage in an Arid Region: The Case of the Borana of Marsabit district, Kenya. *African Study Monographs*.
O'CONNOR, T. 1995. Transformation of a savanna grassland by drought and grazing. *African Journal of Range and Forage Science,* 12, 53-60.
OBA, G. 2001. The effect of multiple droughts on cattle in Obbu, Northern Kenya. *Journal of Arid Environments,* 49, 375-386.
ODHIAMBO, W., NYANGITO, H. O. & NZUMA, J. 2004. Sources and determinants of agricultural growth and productivity in Kenya. *Institute for Public Policy Research and Analysis (KIPPRA), Nairobi.*
OFFICE OF GOVERENEMENT COMMERCE 2002. Management of Risk: guidance for practitioners. London: The stationery office.
OGUTU, J. 2000. Herbivore dynamics in the Mara area of Kenya: the effects of land use change, climate, and predators. Shaker Verlag.
OGUTU, J., BHOLA, N. & REID, R. 2005. The effects of pastoralism and protection on the density and distribution of carnivores and their prey in the Mara ecosystem of Kenya. *Journal of Zoology,* 265, 281-293.
OLSSON, P., FOLKE, C. & BERKES, F. 2004. Adaptive comanagement for building resilience in social–ecological systems. *Environmental management,* 34, 75-90.
OSTERLOH, S., MCPEAK, J., MAHMOUD, H., LUSENO, W., LITTLE, P., GEBRU, G. & BARRETT, C. 2003. Pastoralist Livestock Marketing Behavior in Northern Kenya and Southern Ethiopia: An Analysis of Constraints Limiting Off-take Rates.
OYUGI, L. 2008. *Effects of Economic Growth on Poverty Reduction: Experiences from Botswana, Kenya and Namibia* [Online].
PALMER, W. C. 1965. Meteorological drought research paper no. 45. *US Weather Bureau, Washington, DC,* 58.
PEDEN, D. 1987. Livestock and wildlife population distributions in relation to aridity and human populations in Kenya. *Journal of Range Management,* 40, 67-71.
PICARDI, A. C. 1976. Practical and ethical issues of development in traditional societies. *Simulation,* 26, 1-9.
PICKUP, G. 1995. A simple model for predicting herbage production from rainfall in rangelands and its calibration using remotely-sensed data. *Journal of Arid Environments,* 30, 227-245.
PICKUP, G. 1996. Estimating the effects of land degradation and rainfall variation on productivity in rangelands: an approach using remote sensing and models of grazing and herbage dynamics. *Journal of Applied Ecology,* 33, 819-832.
PICKUP, G., BASTIN, G. & CHEWINGS, V. 1998. Identifying trends in land degradation in non-equilibrium rangelands. *Journal of Applied Ecology,* 35, 365-377.
PKALYA, R., ADAN, M. & MASINDE, I. 2003. Conflict in Northern Kenya; A focus on the internally dispaced conflict victims in Northern kenya. ITDG practical answers to poverty.

PLUMB, G. E., WHITE, P. J., COUGHENOUR, M. B. & WALLEN, R. L. 2009. Carrying capacity, migration, and dispersal in Yellowstone bison. *Biological Conservation,* 142, 2377-2387.

POTTER, H. 1985. *Aspects of climate, herbage growth and animal production in a semi-arid area of Kenya.* PhD thesis, University of Nairobi, Nairobi, Kenya.

PRATT, D., GWYNNE, M. & BLACKIE, J. 1977. *Rangeland management and ecology in East Africa*, Hodder and Stoughton London.

PUIGDEFÁBREGAS, J. 1998. Ecological impacts of global change on drylands and their implications for desertification. *Land degradation & development,* 9, 393-406.

RAVALLION, M. 2010. Poverty Lines across the World. *Policy Research Working*

REID, R., KRUSKA, R., MUTHUI, N., TAYE, A., WOTTON, S., WILSON, C. & MULATU, W. 2000. Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. *Landscape Ecology,* 15, 339-355.

REPUBLIC OF KENYA 2010. Delimination of Constituencies and Recommendations on Local Electoral Units and Administrative Boundaries for District and Other Units. *In:* INTERIM INDEPENDENT BOUNDERIES REVIEW COMMISSION (IIBRC) (ed.). Nairobi, Kenya.

RETZER, V. & REUDENBACH, C. 2005. Modelling the carrying capacity and coexistence of pika and livestock in the mountain steppe of the South Gobi, Mongolia. *Ecological Modelling,* 189, 89-104.

REYNOLDS, J., SMITH, D., LAMBIN, E., TURNER, B., MORTIMORE, M., BATTERBURY, S., DOWNING, T., DOWLATABADI, H., FERNÁNDEZ, R. & HERRICK, J. 2007. Global desertification: building a science for dryland development. *Science,* 316, 847.

RIDDER, N. & BREMAN, H. 1993. A new approach to evaluation rangeland productivity in Sahelian Countries. *In: Range ecology at disequilibrium, RH Behnke et al.(eds.). ODI, London (1993) 104-117.*

ROBSON, C. 2002. *Real world research,* Oxford, UK, Blackwell publishers.

ROTH, E. 1991. Education, tradition, and household labor among Rendille pastoralists of northern Kenya. *Human Organization,* 50, 136-141.

ROTH, E., NATHAN, M. & FRATKIN, E. 2005. The Effects of Pastoral Sedentarization on Children's Growth and Nutrition among Ariaal and Rendille in Northern Kenya. *As Pastoralists Settle*, 173-191.

ROTH, E. A. 1990. Modeling Rendile household herd composition. *Human Ecology,* 18, 441-455.

RUTTEN, M. 1992. Selling wealth to buy poverty: the process of the individualization of land ownership among the Maasai pastoralists of Kajiado District, Kenya, 1890–1990. *Nijmegen Studies in Development and Cultural Change,* 10.

SANDFORD, S. 1980. Pastoral Production and Society - Proceedings of the International Meeting on Nomadic Pastoralism, Paris 1-3 December 1976 - Equipe-Ecologie-Et-Anthropologie-Des-Societes-Pastorales. *Third World Quarterly,* 2, 580-581.

SANDFORD, S. 1983. Management of pastoral development in the Third World. *Chichester/New York.*

SANDFORD, S. 2004. Factors affecting the economic assessment of opportunistic and conservative stocking strategies in African livestock systems. *equilibrium,* 56.

SANDFORD, S. & SCOONES, I. 2006. Opportunistic and conservative pastoral strategies: Some economic arguments. *Ecological Economics,* 58, 1-16.

SAUNDERS, M., THORNHILL, A. & LEWIS, P. 2009. *Research methods for business students*, Financial Times/Prentice Hall.

SAYER, R. 2000. *Realism and social science*, Sage Publications Ltd.

SCHWARTZ, J. H. 2005. Ecological and economic consequences of reduced mobility in pastoral livestock production systems. *In:* FRATKIN, E. & ROTH, E. (eds.) *As pastoralist settle: social, health, and economic consequences of pastoral sedentarization in Marsabit district, Kenya.* Kluwer Academic Publishers New York.

SCOONES, I. 1995. Exploiting heterogeneity: habitat use by cattle in dryland Zimbabwe. *Journal of Arid Environments,* 29, 221-237.

SCOONES, I. 1998. *Sustainable rural livelihoods: a framework for analysis*, Institute of Development Studies Brighton.

SCOONES, I. & GRAHAM, O. 1994. New directions for pastoral development in Africa. *Development in Practice*, 188-198.
SELLEN, D. 1996. Nutritional status of sub-Saharan African pastoralists: a review of the literature. *Nomadic Peoples,* 39, 107-134.
SELLEN, D. 2000. Seasonal ecology and nutritional status of women and children in a Tanzanian pastoral community. *American Journal of Human Biology,* 12, 758-781.
SELLEN, D. 2003. Nutritional consequences of wealth differentials in East African pastoralists: the case of the Datoga of northern Tanzania. *Human Ecology,* 31, 529-570.
SEN, A. K. 1981. *Poverty and famines: an essay on entitlement and deprivation*, Clarendon Press Oxford.
SERE, C., STEINFELD, H. & GROENEWOLD, J. 1995. World livestock production systems: current status, issues and trends.
SHAPIRO, S. S. & WILK, M. B. 1965. An analysis of variance test for normality (complete samples). *Biometrika,* 52, 591.
SHIKLOMANOV, I. A. Appraisal and assessment of world water resources. Water International, 2000. 11-32.
SIEFF, D. 1999. The effects of wealth on livestock dynamics among the Datoga pastoralists of Tanzania. *Agricultural Systems,* 59, 1-25.
SINCLAIR, A. 1975. The resource limitation of trophic levels in tropical grassland ecosystems. *The Journal of Animal Ecology,* 44, 497-520.
SMITH, K. (ed.) 2001. *Environmental hazards: assessing risk and reducing disaster*: Taylor & Francis.
SMITH, K. 2004. *Environmental hazards: assessing risk and reducing disaster*, Routledge, London.
SMITH, K. (ed.) 2005. *From Milk to Maize: the transition to agriculture for Rendille and Ariaal pastoralists.*: Springer.
SNELDER, D. & BRYAN, R. 1995. The use of rainfall simulation tests to assess the influence of vegetation density on soil loss on degraded rangelands in the Baringo District, Kenya. *Catena,* 25, 105-116.
SNYMAN, H. & DU PREEZ, C. 2005. Rangeland degradation in a semi-arid South Africa—II: influence on soil quality. *Journal of Arid Environments,* 60, 483-507.
SOINI, E. 2005. Land use change patterns and livelihood dynamics on the slopes of Mt. Kilimanjaro, Tanzania. *Agricultural Systems,* 85, 306-323.
SOLOMON, T. B., SNYMAN, H. A. & SMIT, G. N. 2007. Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management,* 82, 481-494.
SOMERSET, A. 2007. A preliminary note on Kenya primary school enrolment trends over four decades. *In:* TRANSITIONS AND EQUITY (CREATE) (ed.) *Consortium for Research on Education Access.* Falmer, UK.
SPENCER, P. 1973. *Nomads in alliance: symbiosis and growth among the Rendille and Samburu of Kenya*, School of Oriental & African Studies University of London.
STEINFELD, H., WASSENAAR, T. & JUTZI, S. 2006. Livestock production systems in developing countries: status, drivers, trends. *Revue Scientifique et Technique de l'Office International des Epizooties,* 25, 505-516.
STERMAN, J. D. 2000. *Business dynamics: systems thinking and modeling for a complex world*, Irwin McGraw-Hill.
STEWART, J. & HASH, C. 1982. Impact of Weather Analysis on Agricultural Production and Planning Decisions for the Semiarid Areas of Kenya. *Journal of Applied Meteorology,* 21, 477-494.
STUTH, J., KAITHO, R. & ANGERER, J. 2003. Integrating Information and Communication Technology for the Livestock Early Warning System (LEWS) in East Africa. *Research Brief*, 03-01.
SULLIVAN, S. & ROHDE, R. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography,* 29, 1595-1618.
SWIFT, J. 1989. Why are rural people vulnerable to famine? *IDS Bulletin,* 20, 8-15.

SWIFT, J., BARTON, D. & MORTON, J. 2002. Drought Management for Pastoral Livelihoods-Policy Guidelines for kenya. *Natural Resources Institute, Kent, UK.*
TAINTON, N. 1981. Veld and pasture management in South Africa. *Shuter and Shooter, Pietermaritzburg, South Africa.*
TAINTON, N. 2007. Recent trends in grazing management philosophy in South Africa. *African Journal of Range and Forage Science,* 2, 4.
TEFERA, S., SNYMAN, H. A. & SMIT, G. N. 2007a. Rangeland dynamics in southern Ethiopia: (1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management,* 85, 429-442.
TEFERA, S., SNYMAN, H. A. & SMIT, G. N. 2007b. Rangeland dynamics of southern Ethiopia: (2). Assessment of woody vegetation structure in relation to land use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management,* 85, 443-452.
THE GUARDIAN 2010. Kenyan herders to be offered livestock insurance against drought: Pioneering scheme uses satellite imagery which shows when available forage is so scarce that animals are likely to starve. Friday 22 January 2010 ed.: The Guardian.
THORNTON, P., BURNSILVER, S., BOONE, R. & GALVIN, K. 2006. Modelling the impacts of group ranch subdivision on agro-pastoral households in Kajiado, Kenya. *Agricultural Systems,* 87, 331-356.
THORNTON, P., FAWCETT, R., GALVIN, K., BOONE, R., HUDSON, J. & VOGEL, C. 2004. Evaluating management options that use climate forecasts: modelling livestock production systems in the semi-arid zone of South Africa. *Climate Research,* 26, 33-42.
THORNTON, P., GALVIN, K. & BOONE, R. 2003. An agro-pastoral household model for the rangelands of East Africa. *Agricultural Systems,* 76, 601-622.
THORNTON, P. K., BOONE, R. B., GALVIN, K. A., BURNSILVER, S. B., WAITHAKA, M. M., KUYIAH, J., KARANJA, S., GONZÁLEZ-ESTRADA, E. & HERRERO, M. 2007. Coping strategies in livestock-dependent households in East and southern Africa: a synthesis of four case studies. *Human Ecology,* 35, 461-476.
TOFT, B. & REYNOLDS, S. 1994. *Learning from disasters*, Butterworth-Heinemann Oxford, UK.
TUCKER, C., PINZÓN, J., BROWN, M., SLAYBACK, D., PAK, E., MAHONEY, R., VERMOTE, E. & EL SALEOUS, N. 2005. An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data. *International Journal of Remote Sensing,* 26, 4485-4498.
TURNER, B. & PIDGEON, N. 1978. Man-made Disasters: The Failure of Foresight. *London: Wykeham.(1994)" Causes of disaster: sloppy management." British Journal of Management,* 5, 215-220.
TURNER, B. L., KASPERSON, R. E., MATSON, P. A., MCCARTHY, J. J., CORELL, R. W., CHRISTENSEN, L., ECKLEY, N., KASPERSON, J. X., LUERS, A. & MARTELLO, M. L. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences,* 100, 8074.
TURNER, M. & WILLIAMS, T. 2002. Livestock market dynamics and local vulnerabilities in the Sahel. *World Development,* 30, 683-705.
UNITED NATIONS CHILDREN'S FUND 2010. Kenya: Statistics; Basic Indicators. UNICEF.
UPTON, M. 1986. Production policies for pastoralists: the Borana case. *Agricultural Systems,* 20, 17-35.
VAN DEN BRINK, R., BROMLEY, D. & CHAVAS, J. 1995. The economics of Cain and Abel: Agro-pastoral property rights in the Sahel. *JOURNAL OF DEVELOPMENT STUDIES-LONDON-,* 31, 373-373.
VAN KOOTEN, G., BULTE, E. & KINYUA, P. 1997. Game cropping and wildlife conservation in Kenya: a dynamic simulation model with adaptive control. *Agricultural Systems,* 54, 439-462.
VAN WIJNGAARDEN, W. 1985. *Elephants, Trees, Grass, Grazers: Relationships Between Climate, Soils, Vegetation and Large Herbivores in a Semi-arid Savanna Ecosystem (Tsavo, Kenya).*

VETTER, S. 2005. Rangelands at equilibrium and non-equilibrium: recent developments in the debate. *Journal of Arid Environments,* 62, 321-341.
WALKER, B., HOLLING, C. S., CARPENTER, S. R. & KINZIG, A. 2004. Resilience, Adaptability and Transformability in Social--ecological Systems. *Ecology and society,* 9, 5.
WALSH, T. & HEALY, R. 1987. Protection of Assets Manual. *Santa Monica.*
WAMBUA, F., NGIGE, G., MOGAKA, D. & CHEBOI, D. 2009. Samburu District long rains food security assessment report 23rd-31st July 2009.
WANG, P. & LI, X. 2004. Using MODIS land surface temperature and normalized difference vegetation index products for monitoring drought in the southern Great Plains, USA. *International Journal of Remote Sensing,* 25, 61-72.
WARD, S. 1999. Assessing and managing important risks. *International Journal of Project Management,* 17, 331-336.
WARD, S. 2005. *Risk Management: Organisation and Context,* London, Witherby Publishing.
WARD, S. & CHAPMAN, C. 2003. Transforming project risk management into project uncertainty management. *International Journal of Project Management,* 21, 97-105.
WEICHSELGARTNER, J. 2001. Disaster mitigation: the concept of vulnerability revisited. *Disaster Prevention and Management,* 10, 85-94.
WESTOBY, M., WALKER, B. & NOY-MEIR, I. 1989. Opportunistic management for rangelands not at equilibrium. *Journal of Range Management*, 266-274.
WILDE, G. 1976. The risk compensation theory of accident causation and its practical consequences for accident prevention. *Osterreichische Gesellschaft fur Unfallchirurgie, Salzburg.*
WILSON, R. T. 2007. Perceptions, practices, principles and policies in provision of livestock water in Africa. *Agricultural Water Management,* 90, 1-12.
WITTEMYER, G., RASMUSSEN, B. & DOUGLAS-HAMILTON, I. 2007. Breeding phenology in relation to NDVI variability in free-ranging African elephant. *Ecography,* 30, 42-50.
WOLSTENHOLME, E. F. & COYLE, R. G. 1983. The development of system dynamics as a methodology for system description and qualitative analysis. *Journal of the Operational Research Society*, 569-581.
WORLD BANK 2011. World Development Indicators; Population Growth (annual %). Available online at: http://data.worldbank.org/indicator/SP.POP.GROW.
XU, Z., TAKEUCHI, K., ISHIDAIRA, H. & ZHANG, X. 2002. Sustainability analysis for Yellow River water resources using the system dynamics approach. *Water Resources Management,* 16, 239-261.
YACOUBA, D., GUANGDAO, H. & ABDULAHI, A. 2009. Simulation Planning for Sustainable Use of Land Resources: Case study in Diamou. *Journal of Mathematics and Statistics,* 5, 15-23.