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Pastoral Practices, Economics, and Institutions of Sustainable Rangeland Management in Kenya

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Abstract

Rangelands contribute greater value than is generally acknowledged. The ecosystems provide a significant portion of the world's biodiversity and culturally diverse habitats and are also of great ecological and economic importance. In spite of their significance, rangeland resources continue to be degraded, especially in the arid and semi-arid environments of Africa and Asia. This study seeks to contribute to the formulation of strategies for taking action against rangeland degradation. The study examines the dynamics, causes, and methods of promoting sustainable management of the terrestrial ecosystems with possible positive feedback on improved livelihoods of the majority of the rural poor who depend on these resources.

Dynamics of land use/land cover changes in global livestock grazing systems over the last six decades are identified in this work through comprehensive literature searches, remotely sensed global satellite images, remotely sensed data, and relevant secondary statistics. The analysis shows that native grazing systems are declining, with significant losses to other land uses/covers. Although some conversions are related to biophysical factors such as climatic factors, the key driving forces behind native grazing lands conversions are related to human activities. Many of the land use/land cover changes consist mostly of the conversion of grazing vegetation to agricultural uses, invasive bush vegetation, bare cover, and persistent decreases in productivity of static grazing vegetation.

In Kenya, the estimated adoption rates of sustainable land management (SLM) practices in rangelands are alarmingly low (14.2%), despite the declining productivity of the ecosystems. This necessitates the identification of factors conditioning the adoption of SLM practices. The econometric approach chosen in the analysis accounts for potential endogeneity of explanatory variables. The estimation shows SLM adoption highly occurs in response to land degradation as an intervention measure to reverse and restore degrading lands. Additional factors influencing adoption of SLM practices include access to extension services, agro-ecological and land characteristics, access to output markets, capacity of a household to invest in sustainable practices, and human capital endowments.

The analysis of the influence of livestock market access on land use decisions and productivity of rangelands fails to reject the hypothesis that market inefficiencies characterizing livestock markets represent a major risk that rangelands face. By employing a positive mathematical programming model and a dynamic ecological-economic rangeland model, the study reveals that improved livestock market access will likely lead to higher livestock producer margins and fewer conversions of rangelands to other land uses/land covers.

The assessment of basic capabilities, among other factors, on households' decisions to participate in collective management of pasture using a Zero-inflated beta model confirms the key role of the capability concept in explaining the management of natural resources. While increased capabilities reduce cooperation levels in collective management of pastoral resources, they liberate participants to pursue their individual interests. In addition, increased capabilities reduce the problem of interdependency and transaction costs of monitoring and the adherence to the rules associated with collective action. On the other hand, increased basic capabilities are likely to weaken the social cohesion, cultural values, and customs of the communities involved.

Findings from this study suggest that key policy actions to achieve sustainable management of rangelands include facilitating sustainable intensification of livestock production; empowering livestock producers to participate in value-added livestock production and access to high value product markets and market opportunities; raising awareness of, promoting, and training on best practices for SLM in rangelands; creating policies enhancing extension services through appropriate training of trainers and research initiatives; and creating policies promoting collective action through capacity building and economic benefits associated with cooperation.

Zusammenfassung

Weideland stellt eine größere Bedeutung dar, als allgemein anerkannt. Die Ökosysteme liefern einen erheblichen Anteil der Artenvielfalt und kulturell abwechslungsreicher Lebensräume auf der Welt, und sind somit von großer ökologischer und wirtschaftlicher Bedeutung. Trotz ihres Stellenwerts werden Weideländer immer weiter abgebaut, besonders in den ariden und semi-ariden Gebieten Afrikas und Asiens. Diese Studie versucht zur Formulierung von Strategien beizutragen, um gegen den Abbau von Weideland vorzugehen. Die Studie untersucht die Dynamiken, Ursachen und Methoden, die nachhaltige Bewirtschaftung der terrestrischen Ökosysteme mit möglicher positiver Resonanz, im Hinblick auf eine verbesserte Lebensgrundlage der Mehrheit der armen Landbevölkerung, die von diesen Ressourcen abhängig sind, fördern.

Die Dynamiken der Landnutzung/Landnutzungsänderung (LULCC) bei Weidesystemen von Nutztieren weltweit, über die letzten sechs Jahrzehnte, werden in dieser Arbeit durch umfangreiche Literaturrecherchen, Fernerkundungssatellitenbilder, Fernerkundungsdaten und entsprechende Sekundärstatistiken ermittelt. Die Analyse zeigt, dass naturbedingte Weidesysteme zurückgehen, und zwar mit erheblichen Verlusten bei anderen Landnutzungen/Landnutzungsänderungen. Obwohl einige Umwandlungen auf biophysikalische Faktoren, zum Beispiel Klimafaktoren, zurückzuführen sind, steht die wesentliche Triebkraft hinter den Umwandlungen naturbedingter Weidesysteme im Zusammenhang mit den menschlichen Aktivitäten. Vieles in der LULCC setzt sich hauptsächlich zusammen aus der Umwandlung der Weidelandvegetation zur landwirtschaftlichen Nutzung, invasiver Strauchvegetation, kahler Bedeckung und dem anhaltenden Rückgang in der Produktivität statischer Weidelandvegetation.

In Kenia sind die geschätzten Übernahmeraten nachhaltiger Landbewirtschaftungspraktiken (SLM) auf Weideländern alarmierend niedrig (14,2%), trotz der sinkenden Produktivität der Ökosysteme. Dies macht die Identifikation von Faktoren erforderlich, welche die Übernahme von SLM-Praktiken bedingen. Der ökonometrische Ansatz, der in der Analyse gewählt wurde, erklärt die potentielle Endogenität erläuternder Variablen. Die Einschätzung zeigt, dass die SLM-Übernahme als Reaktion des Abbaus des Lands als Interventionsmaßnahme, um degradierte Länder rückgängig zu machen und zu regenerieren, auftritt. Zusätzliche Faktoren, die eine Übernahme von SLM-Praktiken beeinflussen, schließen den Zugriff auf Beratungsdienste, agrar-ökologische Merkmale und Landmerkmale, Zugriff auf Produktionsmärkte, die Leistungsfähigkeit eines Haushalts, der in nachhaltige Praktiken investieren soll, und die Humankapitalausschüttungen, ein.

Die Analyse des Einflusses eines Viehmarktzugangs auf die Landnutzungsentscheidungen und die Produktivität von Weideländern versäumt der Hypothese zu widersprechen, dass Marktunwirtschaftlichkeiten, welche die Viehmärkte kennzeichnen, eine große Gefahr darstellen, der die Weideländer gegenüberstehen. Indem man ein positives, mathematisches Programmiermodell und ein dynamisches, ökologisch-wirtschaftliches Weidelandmodell einsetzt, enthüllt die Studie, dass ein verbesserter Zugang zum Viehmarkt wahrscheinlich zu höheren Vieherzeuger-Margen und weniger Umwandlungen von Weideländern in Landnutzungen/Landnutzungsänderungen führt.

Die Beurteilung der Grundressourcen, neben anderen Faktoren, bei den Haushaltsentscheidungen, an einer kollektiven Bewirtschaftung von Weideländern mittels eines nicht überteuerten Betamodells teilzunehmen, bestätigt die Schlüsselrolle des Leistungsfähigkeitskonzepts bei der Erklärung der Verwaltung von natürlichen Ressourcen. Während erhöhte Ressourcen die Kooperationsbereitschaft bei der kollektiven Bewirtschaftung von Weidelandressourcen senken, geben sie den Teilnehmern die Freiheit, ihre individuellen Interessen zu verfolgen. Außerdem senken erhöhte Ressourcen das Problem von Interdependenzen und Transaktionskosten für die Überwachung und Einhaltung der Regeln, die mit dieser kollektiven Maßnahme einhergehen. Andererseits besteht die Wahrscheinlichkeit, dass erhöhte Grundressourcen den sozialen Zusammenhalt, die kulturellen Werte und die Gewohnheiten der beteiligten Gemeinden schwächen.

Ergebnisse dieser Studie legen nahe, dass das Kernkonzept, um eine nachhaltige Bewirtschaftung von Weideländern zu erzielen, folgendes beinhaltet: Das Erleichtern einer nachhaltigen Steigerung der Nutztierhaltung; die Ermächtigung der Vieherzeuger, an der Wertschöpfungsnutztierhaltung teilzunehmen, und ihnen einen Zugang zu hochwertigen Produktmärkten und Marktgelegenheiten zu geben; das Steigern des Bewusstseins für das Fördern und die Ausbildung in den besten Verfahren für die SLM bei Weideländern; das Erstellen von Richtlinien, welche die Beratungsdienste durch eine geeignete Schulung von Ausbildern und Forschungsinitiativen verbessern; und das Erstellen von Richtlinien, welche die kollektive Maßnahme durch Leistungsbildung und wirtschaftliche Vorteile, die mit dieser Kooperation einhergehen, fördern.

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List of Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
ASALs	Arid and Semi-Arid Lands
ANPP	Aboveground Net Primary Production
CES	Constant Elasticity of Substitution
CH_4	Methane
CO_2	Carbon Dioxide
CRS	Constant Returns to Scale
FAOSTAT Database	Food and Agriculture Organization Corporate Statistical Database
FFS	Farmer Field Schools
FGLM	Fractional Generalized Linear Model
GDP	Gross Domestic Production
GIS	Geographical Information System
GOK	Government of Kenya
GPS	Geographical Positioning System
HILDA	Historic Land Dynamics Assessment
IBLI	Index-Based Livestock Insurance
IV	Instrumental Variables
KARI	Kenya Agricultural Research Institute
KIHBS	Kenya Integrated Household Budget Survey
KMO	Kaiser–Meyer–Oklin
KNBS	Kenya National Bureau of Statistics
LDSF	Land Degradation Sampling Framework
LULC	Land use/Land Cover
LULCC	Land Use/Land Cover Changes
MODIS	Moderate Resolution Imaging Spectroradiometer
NALCMS	North American Land Change Monitoring System
NDVI	Normalized Difference Vegetation Index
NPP	Net Primary Production
PCA	Principal Component Analysis
PMP	Positive Mathematical Programming
SLM	Sustainable Land Management
SRM	Society for Range Management
RUE	Rainfall Use Efficiency
TLU	Tropical Livestock Units
USSR	Union of Soviet Socialist Republics
VCM	Vicious Circle Model

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Chapter One

1 Introduction

1.1 Background and motivation

Rangeland ecosystems are among the earth's largest terrestrial ecosystems and are found in all continents of the world (Kreutzmann et al., 2011; Lund, 2007; Mannetje, 2002; Blench and Sommer, 1999; Fig. 1.1). The various definitions of rangelands that have been proposed can possibly be attributed to the huge variety of rangelands that cover diverse vegetation types (Sayre et al., 2013; Lund, 2007). This study adopts the general definition provided by Mannetje (2002), in which rangelands refer to "ecosystems which carry a vegetation consisting of native and/or naturalized species of grasses and dicotyledonous herbs, trees and shrubs, used for grazing or browsing by wild and domestic animals, on which management is restricted to grazing, burning and control of woody plants". A similar definition of rangelands is given by the Society for Range Management (SRM) (2005), in which rangelands are defined as the land managed as a natural ecosystem with natural vegetation including grasslands, shrub-lands, savannas, tundra, and woodlands.

Global estimates of rangelands also vary widely and range from 18% to 80% (Lund, 2007; Mannetje 2002; Mitchell and Joyce, 2000) of the earth's land surface. The estimates vary depending on the definition of rangelands and data sources. SRM provides estimates of the global extent of major rangeland vegetation types as follows: grassland 42%, shrubland 23% and woodland 12%, with the other vegetation types forming 23% of the earth's land surface. Similar estimates are cited in Suttie et al. (2005), who give an estimated figure of 77% for the global extent of rangeland vegetation cover.

Rangelands, like other natural resources, provide essential ecosystem services for human welfare, both directly and indirectly (Costanza et al., 1997). The main recognized direct service provided by rangelands is their contribution as a source of feed and habitat for livestock and wildlife (Mannetje, 2002; Larbi et al., 2009, Sayre et al., 2013). Livestock production is found in approximately two thirds of rangelands worldwide, with about 1 billion people mainly depending on livestock for their livelihoods and about 70 percent of the rural poor households partially depending on livestock as a source of income (Ashley et al., 1999; Neely et al., 2009). These ecosystems are of high value, particularly in developing countries, where they provide the main feed resource for traditional livestock production systems and are a main source of livelihood for millions of rural households (Mannetje, 2002; Fig.1.2).

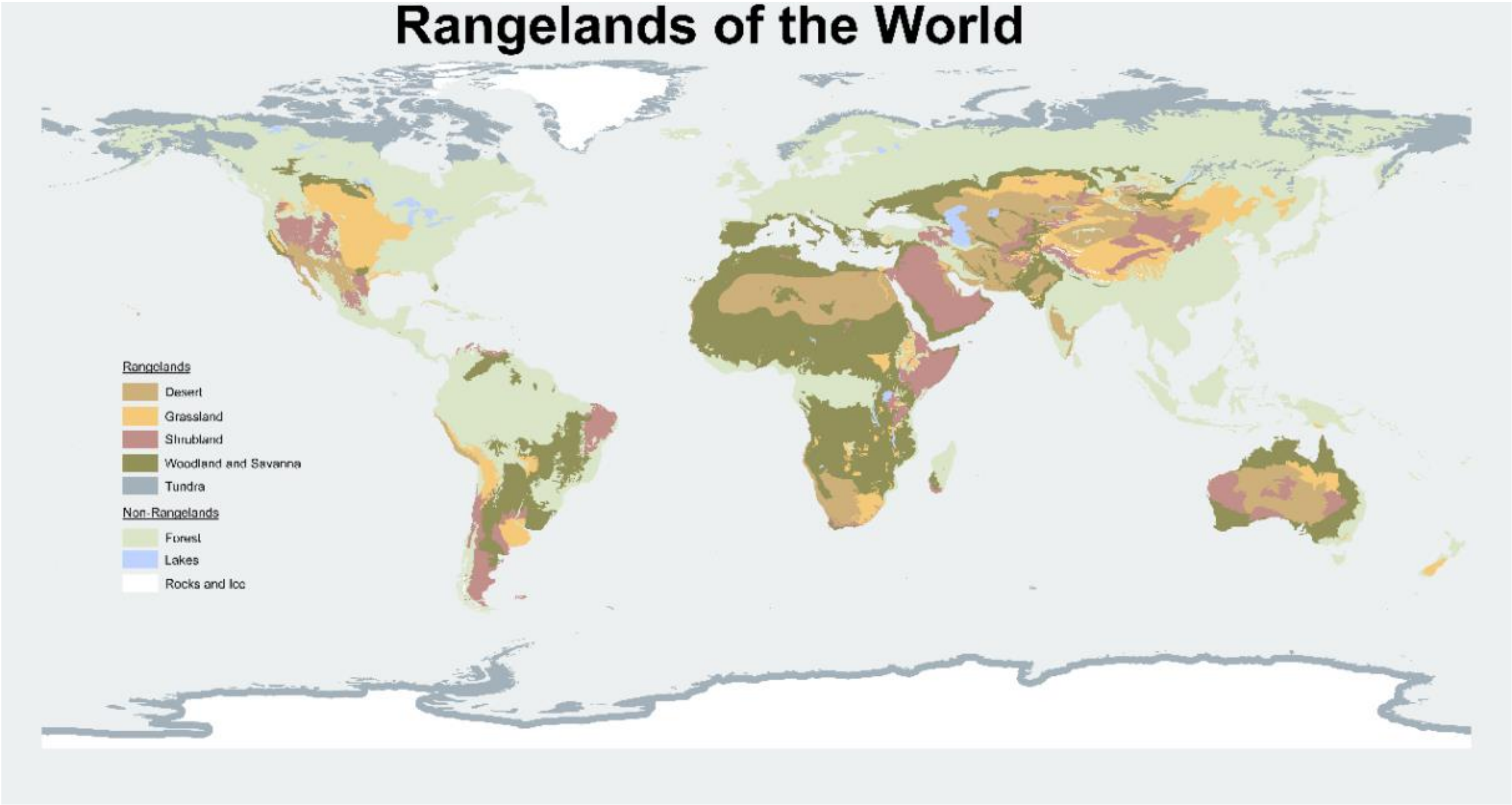


Figure 1.1: Rangelands of the world
Source: http://www.webpages.uidaho.edu/what-is-range/rangelands_map.htm

Overall, traditional pastoral systems are estimated to occupy about two thirds of global rangelands and host a large share of the world's poor (Neely et al., 2009).

Rangelands also offer important ecological services ranging from protecting fragile soils, providing carbon dioxide (CO_2) sequestration, forming a habitat for wild fauna and flora, and acting as watersheds (Blench and Sommer, 1999; Mannetje, 2002; Thornton and Herrero, 2010; Jianli et al., 2011; Shaoliang and Muhammad, 2011; Kreutzmann et al., 2011; Booker et al., 2013; Dabasso et al., 2014). Other benefits include supply of cultural services such as aesthetic beauty and intellectual stimulation, provide military training grounds, and provide religious sites and recreational venues amongst other uses (Mannetje, 2002; SRM, 2005; Shaoliang and Muhammad, 2011).

Despite the value of rangelands terrestrial ecosystem services, their stewardship is undermined by various factors leading to considerable rangeland degradation around the world (Hatfield and Davies, 2006; Neely et al., 2009). Among the key factors driving land degradation processes in rangelands is unprecedented land-use changes increasing pressure on the rangeland resources (Lambin et al., 2001; Lambin et al., 2003; Hobbs et al., 2008). Degraded rangelands lead to declining productivity and loss of ecosystems resilience. This, in most cases, is followed by a collapse in social resilience and adaptive capacity, increasing the vulnerability of individuals and communities that rely on the degrading rangeland resources (Vogel and Smith, 2002). Moreover, it is not only important to improve rangeland management for productivity purposes but also to reduce emission of greenhouse gases such as methane (CH_4) (Mannetje, 2002).

Globally, sustainable rangeland use practices are undermined by limited knowledge of the importance of rangelands in the provision of environmental services and the economic potential of the ecosystems. The awareness of the consequences of rangeland degradation is relatively weak, especially compared to the much more widespread preoccupation with land degradation problems in arable crop production. This presents a significant gap against the backdrop of the crucial environmental benefits provided by the ecosystems, not to mention their provision of a considerable share of agricultural output and rural incomes, especially in developing countries. In addition, to ensure the continued flow of the identified ecosystem goods and services from the resources, there is a need for policy actions to arrest rangeland degradation, improve productivity of the ecosystems in both quantity and quality, and reclaim degraded rangelands (Mannetje, 2002).

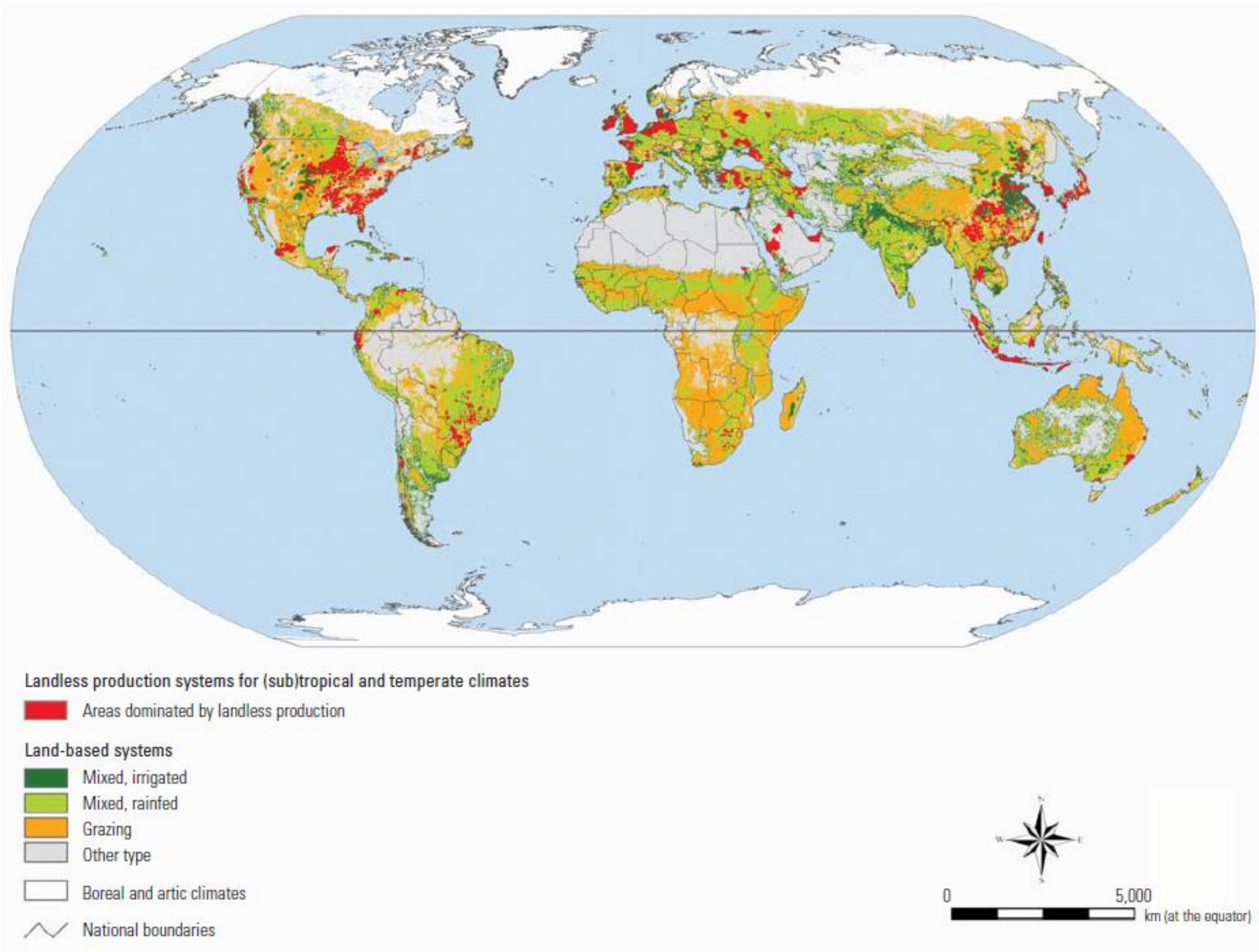


Figure 1.2: Map of world livestock production systems
Source: Steinfeld et al. (2006a)

1.2 Research questions

This study seeks to help fill the identified gap by examining causes and ways to arrest rangeland degradation with possible positive feedback on improved productivity and services provided by the ecosystems such as provisioning and regulatory services. The general objective of the study is to identify trends and related drivers of land use/land cover changes in rangelands and the resulting effects on the capacity of the ecosystems to provide goods and services in the long term, evaluate possible factors promoting sustainable management practices and their effects on rural livelihoods, and analyse the performance of institutions that support sustainable rangeland management of policy relevance in developing countries like Kenya. To be more specific, the study seeks to achieve four objectives. The guiding research questions for each of the objectives are as follows:

1. What major changes in the global livestock grazing systems have taken place over the last six decades?
    a. What are the global trends of land use/land cover changes in grazing areas?
    b. What are the key factors driving the transformation of grazing systems?
    c. What are the related effects of land use/land cover changes globally?
2. What are the key determinants of the adoption of sustainable land management (SLM) practices in Kenyan rangelands?
3. How does livestock market access influence land use decisions and productivity of rangelands?
4. What are the key factors facilitating or hindering participation in collective provision and appropriation of pasture resources?

Fig 1.3 presents a broad conceptualization of the relationships between the different research questions in the study. The conceptual framework starts with evidence of the existing proximate and underlying factors influencing land use/land cover changes (LULCC) in rangelands. The framework also highlights the influence of incentive structures on institutions governing use rights and control of pasture resources. The effects of the factors driving land use/land cover changes, coupled with the existing property rights governing rangeland management, could lead to maintenance, conversion, or modification of the natural ecosystems.

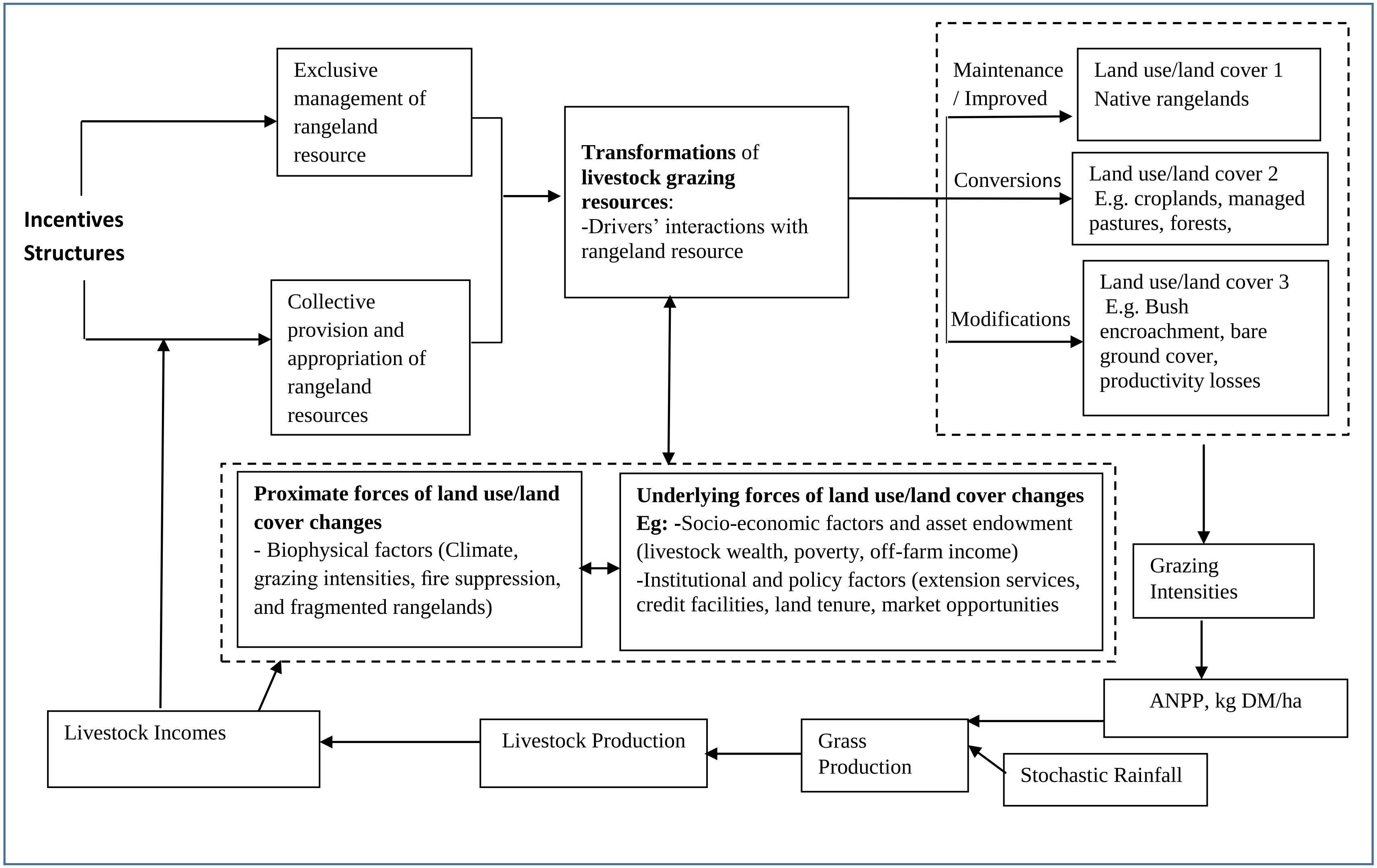


Figure 1.3: Conceptual framework
Source: Compiled by author.

This would subsequently lead to either degradation or the sustenance of the ecosystems with important ecological, social, cultural and economic consequences, including the productivity of grazing lands and impacts on food security and economic welfare. The study narrows its focus to the productive capacity of rangelands and evaluates the effects of LULCC on livestock production and livestock incomes, which, as shown in Fig 1.3, further influence the drivers of LULCC and incentives affecting rangeland institutions. Detailed descriptions of the various sections of the conceptual framework are discussed in their respective chapters.

1.3 Organization of the thesis

The study is organized into six chapters. The current chapter presents the introductory section of the study. The preceding part of the chapter presented the background information on the research topic by discussing rangelands, their functions and challenges facing the ecosystems. The relevance of the research topic is also emphasized in the previous section. These are aimed at familiarizing the reader with the topic and objectives of the study chapter. The approach and methods employed in the study and the relevance of the rangeland ecosystems in economic development and poverty reduction are discussed in the remaining part of the introductory chapter.

Chapter two reviews the transformations of livestock grazing systems at the global level. In this chapter, the dynamics of land use/land cover changes in grazing areas, the associated factors, and the related effects are assessed. In Chapter three, the study narrows its focus to Kenya and reviews the drivers of rangeland degradation and the associated costs and effects. The chapter then evaluates the determinants of SLM adoption on Kenyan rangelands. In Chapter four, the potential role of livestock markets in influencing land use decisions and subsequently the productivity of rangelands is assessed within a dynamic ecological-economic model and positive mathematical programming (PMP) model. The chapter presents policy conclusions on efforts made towards increasing the returns associated with grazing lands on the sustenance of the ecosystems. In Chapter five, the study assesses the effects of basic capabilities, among other factors, on participation in the collective management of pastoral resources among pastoral and agro pastoral communities. The chapter identifies situations in which joint provision and exploitation of rangeland resources is least likely to occur and ways in which SLM practices may be enhanced in such situations. Finally, Chapter six concludes by providing an overall summary of the study. The chapter also highlights the key policy implications and areas of potential future research.

1.4 Approach and methods

The studies in this thesis are conducted at three levels: at the global, national, and local levels. At the global level, the study is conducted in six regions, namely Africa, North America, Latin America, Asia, Europe, and Australia. The analysis is carried out through comprehensive desktop-based literature searches, remotely sensed global satellite images, and secondary statistics relevant for rangeland areas around the world.

At the national level, the study is conducted in thirteen counties in Kenya located in the dry lands (arid and semi-arid lands (ASALs)) of the country. These counties include Turkana, Marsabit, Mandera, West Pokot, Samburu, Isiolo, Wajir, Garissa, Baringo, Laikipia, Narok, Kajiado, and Tana River. The production system in these counties is either largely pastoralism or agro-pastoralism (Fig. 1.4). These counties are endowed with a variable climate and are found in agro climatic zones IV, V, and VI (Orodho, 2006; Sombroek et al., 1982). These counties also have the highest incidence of poverty in the country whereby the key contributing factors are vulnerability to drought, marginalization, poor infrastructure, and long distances to markets (GOK, 2012a; Campbell et al., 2003). Livestock production remains the key component of agricultural production in these areas, with pastures forming the main feed for livestock. The data set used in the analysis comes from a national survey conducted in 2005/06 over a period of 12 months (KNBS, 2005/06a; KNBS, 2005/06b). The extensive dataset covers all possible seasons and all of the districts in Kenya, including the drylands (ASALs) (KNBS, 2005/06a; KNBS, 2005/06b). The last national survey of this nature was conducted in the early 1980s (KNBS, 2005/06a).

At the local level, two studies have been conducted in Narok County, a semi-arid agro-pastoral region located in the southwestern Kenya (Fig. 1.4). The first study is conducted for the whole of Narok County, employing data from the national survey discussed above. The second study is purposively conducted in 6 divisions in Narok County based on the presence of pastoral activities. The selected divisions are, namely, the Mau, Mara, Ololulunga, Osupuko, Central, and Loita divisions. These divisions are located in the central and lower parts of the region and are either too dry with unreliable rainfall, or the soils are too infertile and shallow (Jaetzold et al., 2009). The production systems include pastoral/tourism, agro-pastoral, and pastoral leasing and largely pastoral, thus making a good representation of the pastoral systems present in the country as well as in many other developing countries (Fig. 1.5). The data set used in the analysis comes from primary cross-sectional data collected during a household survey conducted between November 2013 and February 2014.

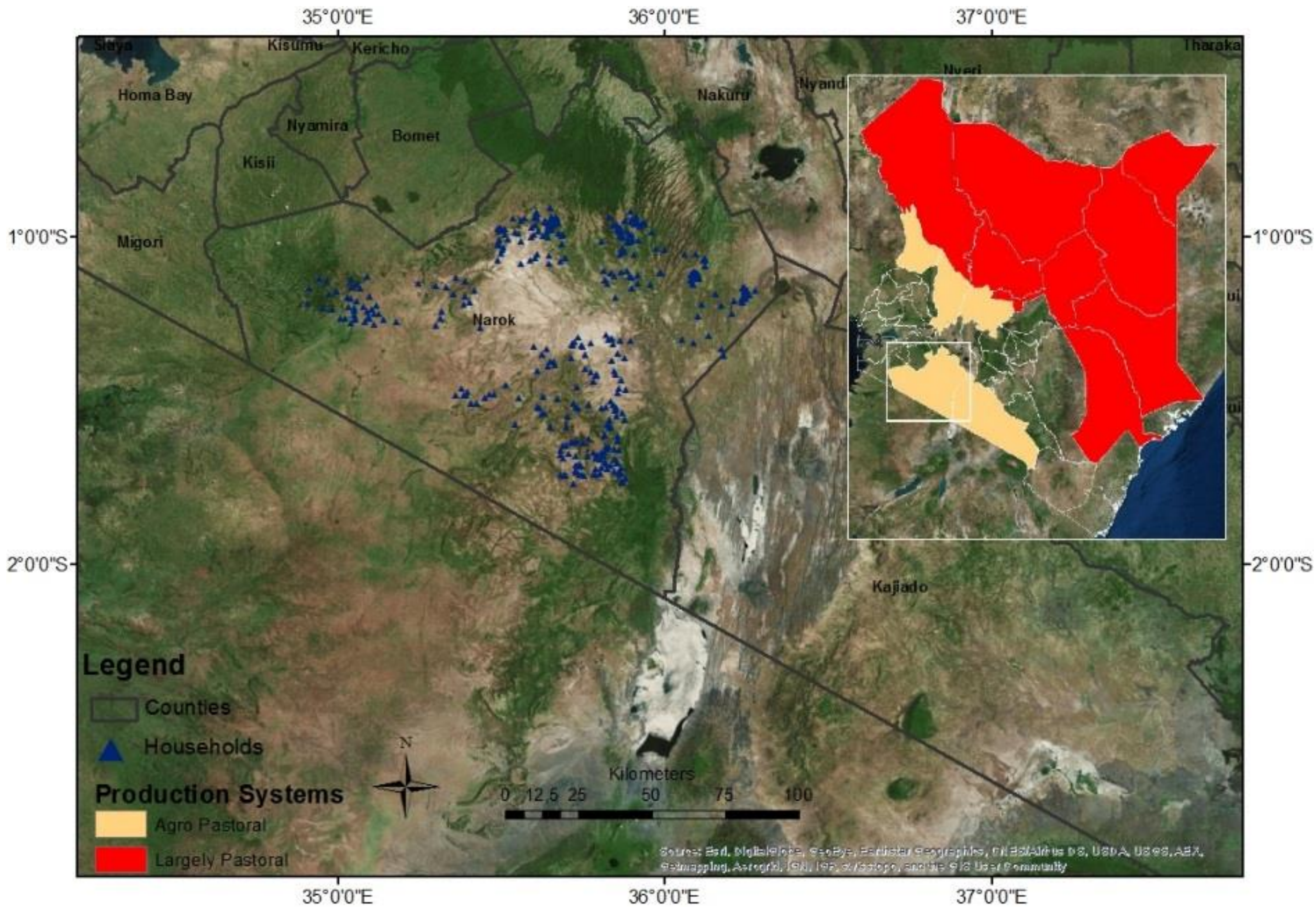


Figure 1.4: Location of the study areas in Kenya
Cartography: Author

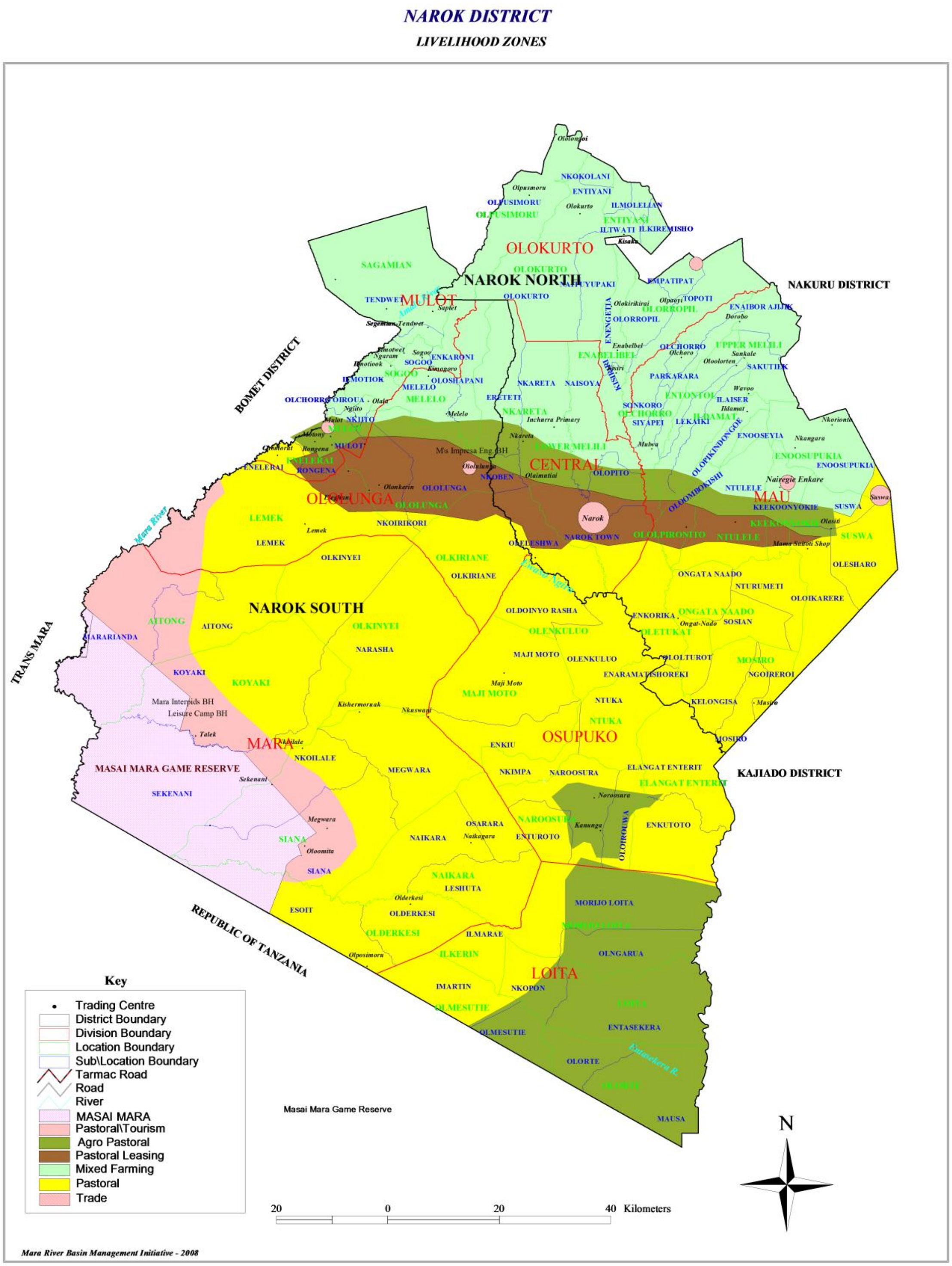


Figure 1.5: Narok County, Livelihood Zones
Source: Kenya National Bureau of Statistics

1.5 Relevance of rangeland resources in economic development and poverty reduction in developing countries

As highlighted earlier, rangelands provide various ecosystem goods and services including provisioning, supporting, regulating, and cultural services. However, the most important function of rangelands in developing countries such as Kenya is its great economic and social role in the production of livestock, which is a key source of livelihood for millions of poor people (Mannetje, 2002; Larbi et al., 2009; Sayre et al., 2013). The subsequent section highlights the relevance of livestock production in economic development and poverty reduction in developing countries.

1.5.1 Relevance of the livestock sector in economic development

Agriculture continues to play a key role in the economic development and welfare of nations in the developing world, with over 50 per cent of the population depending on agriculture (Upton, 2004). Recent estimates indicate that, in the year 2010, approximately 65 percent of the population in the least developed countries depended on agriculture (FAOSTAT Database). Livestock production is fundamental for global food security, as is crop production. Livestock production is estimated to account for 40 percent of the global gross value of agricultural production (Bruinsma, 2003). In developing countries, the contribution of livestock production is estimated to be about one-third of agricultural production; however, this share is rapidly increasing (Bruinsma, 2003; Upton, 2004). For instance, in Kenya, rangelands support approximately 70 percent of the national livestock and are a home to about 14 million people who are mainly pastoral and agro-pastoral communities (GoK, 2012a). The contribution of the livestock sector to the Kenyan economy has, however, been understated for several years due to products being traded informally or directly consumed by households. Recent estimates indicate that the value added by livestock to the agricultural GDP was about $4.54 billion US dollars in 2009, only slightly less than that from arable agriculture, with a contribution of $5.25 billion US dollars (Behnke and Muthami, 2011). The new estimates indicate the need for the government to give more attention to the livestock sector in designing future agricultural policies (Behnke and Muthami, 2011).

1.5.2 Livestock Production and Poverty reduction

Agriculture development in the developing world is essential, as it presents the potential to promote significant pro-poor growth and thus reduce poverty (Ashley et al., 1999; Bruinsma, 2003; Upton, 2004). Livestock production contributes to the sustainable livelihoods and security of millions of the world's rural poor households and especially of women in the developing world (Von Braun, 2010). It is estimated that livestock production constitutes the livelihoods of at least 70 percent of the world's rural poor (Ashley et al., 1999; Neely et al., 2009). The livestock systems provide these rural household fully or partially with incomes, food, wool, hides, transportation, draft power, the possibility to accumulate capital, and risk diversification mechanisms that can prevent the marginalized rural poor from falling further into poverty (Ashley et al., 1999; Mannetje, 2002).

The above are in support of observations made at the country levels, particularly in developing countries. In Kenya, rangelands are characterized by chronic poverty traps, and they face multiple and interlocking forms of shortcomings. The areas host a large share of the country's poor, with 18 of the 20 poorest constituencies in Kenya situated in these areas, where 74 percent to 97 percent of people live below the poverty line (GOK, 2012a; GOK, 2012b; Ndeng'e et al., 2008; Fig. 1.6). Households residing in these areas face high levels of risk and vulnerability, and the main contributing factors include isolation, weak economic integration, limited political leverage, insecurity, and a challenging natural environment (GOK, 2012a). Livestock could therefore play an important role in improving the welfare of the rural livelihoods and providing poverty relief for the country.

1.5.3 Livestock Trade

Livestock output is either consumed by farmers or traded. In recent years, agriculture markets have expanded in both developed and developing countries with the growth of international trade. Trade in livestock products has also been on the increase, with developing countries changing from being net exporters to net importers of livestock products (Upton, 2004; Fig. 1.7).

However, markets for livestock and livestock products in the majority of developing countries are characterized by market failures (Markelova et al., 2009; Ahuya et al., 2005; Aklilu, 2002; Hurrissa & Eshetu, 2002). There exist numerous challenges that hinder smooth trade in livestock and livestock product markets. In Kenya, while the country is self-sufficient regarding most livestock products, it is not able to supply its own meat sufficiently, since domestic beef consumption has more than doubled over the past two decades (Makokha et al., 2013; Muthee, 2006). Beef consumption accounts for about 73 percent of the total meat consumed in the country, and the shortage is bridged through informal cross-border trade of cattle across porous borders from neighboring countries (Makokha et al., 2013).

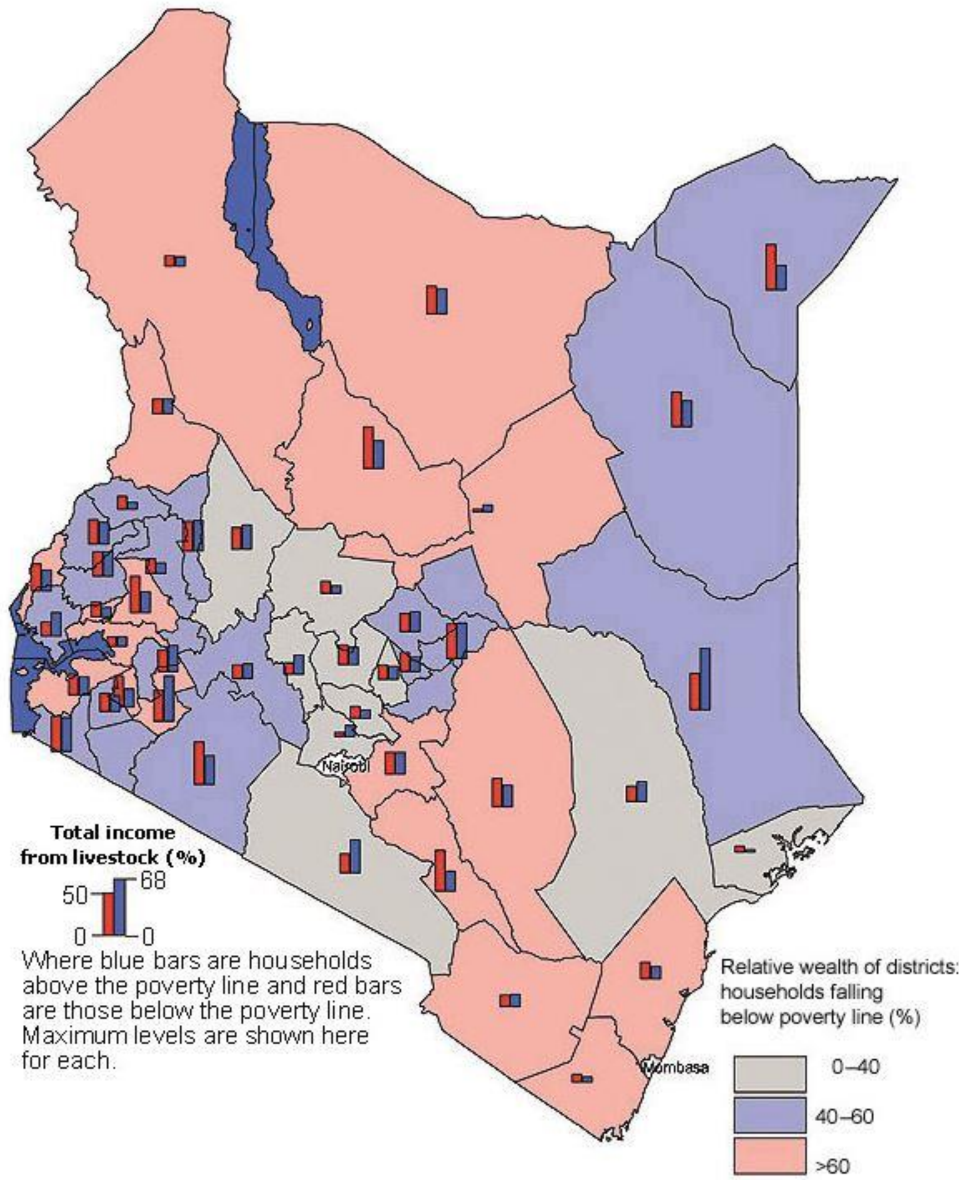


Figure 1.6: Kenya: Contribution (%) of livestock to total household income for households above and below the poverty line
Source: Thorton et al. (2002)

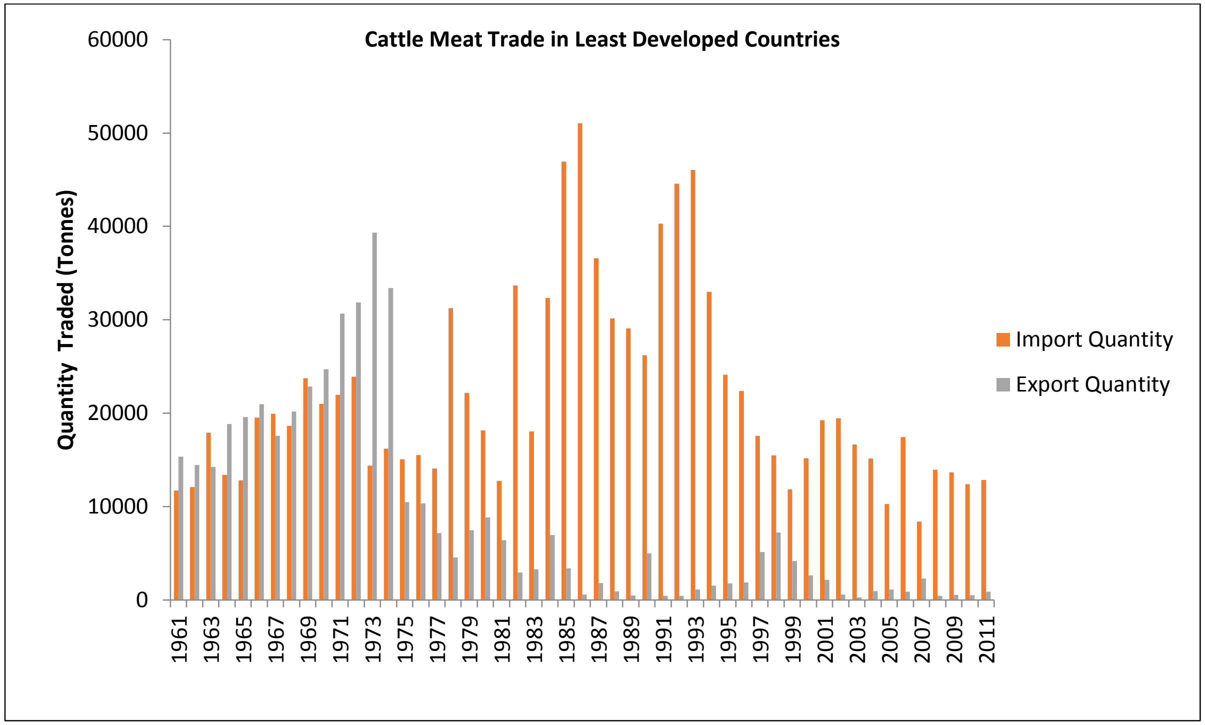


Figure 1.7: Cattle meat trade in least developed countries
Source: FAOSTAT Database

Despite the potential for livestock production in the country, livestock producers, especially those in grassland-based systems, generally receive market price disincentives (Fig. 1.8). These arise from issues related to market inefficiencies such as traders' rent-seeking behavior, government taxes and fees imposed on cattle trekkers, high transport costs, lack of market infrastructure, and lack of capital among others (Makokha et al., 2013; Muthee, 2006). Market price disincentives are also likely to have negative effects on the sustenance of the grazing ecosystems. With the erratic rainfall characterizing rangelands in ASALs, livestock marketing systems should be such that they facilitate the destocking of animals during periods of low rainfall, such as drought years (Turner and Williams, 2002). Efficient livestock production, marketing and sustenance of the grazing ecosystems is of significant importance to the country and other developing countries, in light of the following: (1) the rapidly growing demand of livestock products, (2) the strategic role the sector plays in the welfare of rural poor households, (3) the burden of increased imports, and (4) the strategic role the sector plays in the economy (Upton, 2004; Mannetje, 2002).

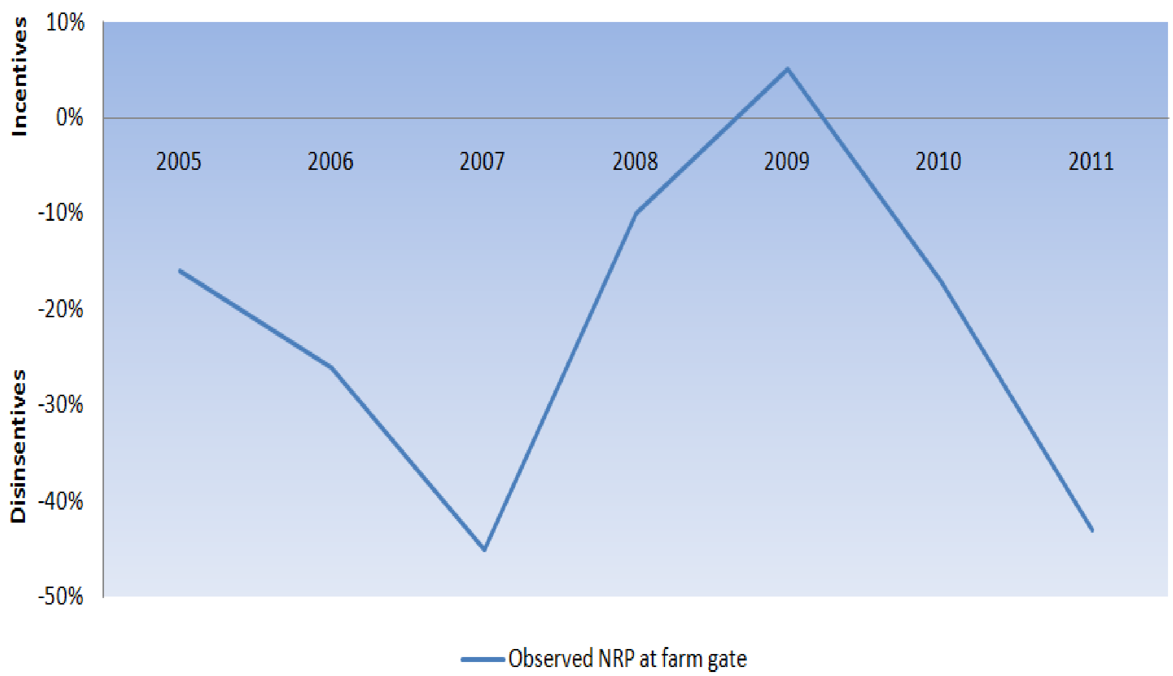


Figure 1.8: Incentives and Disincentives for Cattle Marketing in Kenya
Source: Makokha et al., 2013.

Chapter Two

2 Land Use/Land Cover Changes on Global Livestock Grazing Ecosystems : A review of the natural rangelands systems dynamics

2.1 Introduction

Natural rangeland systems are mainly used as native grazing pastures and are defined here as "ecosystems which carry a vegetation consisting of native and/or naturalized species of grasses and dicotyledonous herbs, trees and shrubs, used for grazing or browsing by wild and domestic animals, on which management is restricted to grazing, burning, and control of woody plants" (Mannetje, 2002). In addition to providing 50% of the world's livestock, the ecosystems encompass a significant portion of the world's biodiversity and culturally diverse habitats and are also of great ecological significance (Davies et al., 2015; Kreutzmann et al., 2011; Mannetje, 2002). The ecosystems are also vast and estimated to occupy about 50% of the world's total land area (Kiage, 2013; Friedel et al., 2000; Mathews, 1986; Davies et al., 2015; Mannetje, 2002).

Despite providing crucial ecosystem services, rangeland areas are being degraded, particularly in the arid and semi-arid environments of Africa and Asia (Steinfeld et al., 2006b; UNEP, 2007; Neely et al., 2009). Understanding rangeland dynamics and the paths of degradation is critical in the design of sustainable rangeland use. Numerous factors, as discussed later in the chapter, have been identified to contribute to the degradation of rangeland areas. A critical review of the drivers supports the current emerging views acknowledging the presence and interaction of both equilibrium and non-equilibrium factors in explaining the dynamics of the productivity of rangelands (Vetter, 2005; Domptail, 2011). The equilibrium model theory, which is mostly used in studying rangeland dynamics, centers on density-dependent factors such as stocking rates and the feedback of grazing pressure on vegetation composition, cover, and productivity. This theory stresses the importance of carrying capacity of rangelands resulting in interventions of maximum stock numbers to be allowed in an attempt to halt degradation and sustain rangelands (Vetter, 2005). In contrast, the disequilibrium theory views the ecology of rangelands as being best conceptualized in terms of non-equilibrium dynamics.

According to the theory, rangeland productivity is constrained by density-independent factors such as climatic variability and other external shocks to the system rather than by density-dependent factors (Boyd et al., 1999; Ramankutty et al., 2006). The disequilibrium theory implies that stocking strategies are less damaging to rangeland ecosystems and have negligible ecological effects (Kiage, 2013). However, an analysis of the literature on drivers of rangeland degradation illustrates that both density-dependent factors and density-independent factors, such as climate and anthropogenic factors, are responsible for rangeland degradation. This paper unfolds the existence of density-independent factors on native rangelands, their emergence, how they modify the ecosystems, and their possible interactions with density-dependent factors.

The literature review reveals that a large share of the identified drivers of rangeland degradation, as it is the case with other terrestrial ecosystems in the world, relates to land use/land cover changes. Significant environments in the world are experiencing land use/land cover changes, a density-independent factor, which in most cases is often associated with loss of natural vegetation, biodiversity loss, long-term productivity capacity losses, and ecological services losses among others (Foley et al., 2005; Kiage et al., 2007; Maitima et al., 2009). In addition, land use/land cover changes in rangelands are likely to interact with density dependent factors, resulting in either positive or negative consequences for the environment (Fig 2.1). For instance, as observed in extensive rangeland systems, land use/land cover changes resulting in the loss of pasture areas are likely to lead to restricted livestock mobility and access to pastoral resources which are necessary for sustainable rangeland use (Homewood et al., 2012; Flintan, 2011; Eva et al., 2006; Campbell et al., 2003; Campbell et al., 2005; Butt, 2010).

This chapter reviews the evidence on land use/land cover changes in global native rangelands over the last six decades. It first shows the trend of land use/land cover changes in rangelands and demonstrates that the processes are global. The analysis over an extended period of time offers more support of the trends compared to analyses over specific short-term periods, such as changes over a period of five years (Nickerson et al., 2011). Second, the dynamics of the land use/land cover changes are explored, indicating sources and destinations of rangelands losses/gains. Third, the chapter makes an evaluation to determine the related effects of native rangeland dynamics on the health of the ecosystems. This paper presents a balanced picture by demonstrating that not all losses of native rangelands are pessimistic and neither are all gains associated with better-managed systems.

2.2 Resource use/cover changes on native grazing lands – Area

Large environments of the world have experienced significant land cover changes. Comprehensive studies carried out all over the world identify significant landscape changes on rangelands associated with human activities. Land use/land cover changes are either associated with land cover conversions, which in our case would involve the complete replacement of grazing vegetation by another land cover type, or land cover modifications whereby the overall classification of the land cover is maintained but the character of the land cover is affected (Lambin et al., 2001; Lambin et al., 2003; Maitima et al., 2009; Reid et al., 2004). Figure 2.1 shows the possible transformations of grazing lands.

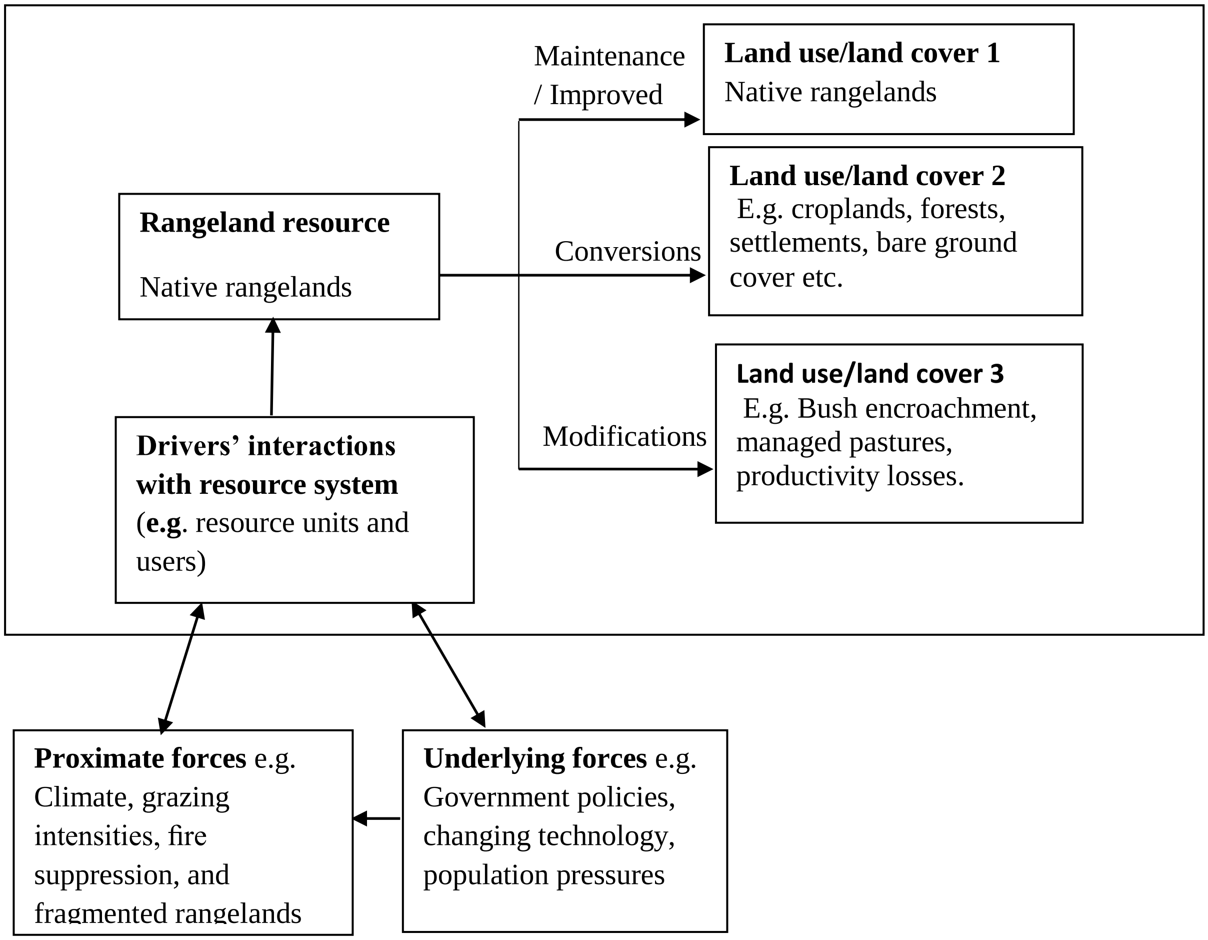


Figure 2.1: Linkages between land/land cover changes, the causes and the effects
Source: Author's conceptualization.

Fig. 2.1 indicates the existence of both proximate and underlying factors influencing land use/land cover of rangelands in the country. The resultant effect of these drivers could either be maintenance, conversion or modification of natural grazing ecosystems. Whereas maintained grazing land is clear, land cover conversions, as explained by Lambin et al. (2003), refer to complete replacement of grazing cover with another land-cover category, such as with cropping. On the other hand, land modifications refer to changes that affect the character of the vegetation without changing its classification, such as with the expansion of woody shrubs. Among the resulting effects of land cover conversions and modifications on grazing areas is the fragmentation of landscapes which have significant negative effects on sustenance and productivity of ecosystems. On the basis of the literature and case studies reviewed, we quantify land use/land cover changes on rangelands in various parts of the world.

Global

The area of native grazing lands, defined by Lambin et al. (2003) as natural savannas, grasslands, or steppes, has declined globally from an estimated 3200 million ha in 1700 to

1800–2700 million ha in 1990 (Lambin et al., 2003). Recent global estimates of grazing lands, however, indicate that the ecosystems have experienced less dramatic changes. The overall estimates of global land cover from FAO's regional data indicate relatively stable grazing lands, defined as "land used permanently for herbaceous forage crops, either cultivated or naturally growing" (FAOSTAT Database). The grazing lands are estimated to have slightly declined by 0.89% globally between the periods 1961 and 2011 (FAOSTAT Database). The estimates by FAO, however, do not differentiate between modified/improved pastures and extensive native grazing lands. This lack of differentiation could explain the relative stability of the grazing areas. Even so, the estimates do indicate varying grazing lands from one region to another.

Africa

In Africa, grazing lands have declined considerably from 84.02% to 77.92% of agricultural area/land area between 1961 and 2011 (FAOSTAT Database). The decline is relatively large in Eastern Africa and Western Africa, with declines of 8.88% and 8.59%, respectively (FAO 2013). The grazing ecosystems in the continent are dominated by natural pastures mainly composed of grasslands interrupted by woody vegetation (Kiage, 2013). Therefore, the trend described above can be taken to represent the dynamics of the native grazing ecosystems found on the continent.

Similar observations of declining grazing lands are made by several other studies on land use/cover changes in the region. Brink & Eva (2009) estimated the land cover changes for Sub-Saharan Africa between 1975 and 2000. The authors estimated that land cover classified as natural non-forest vegetation, comprising of natural vegetation such as grassland, bush land, shrub lands, and wooded grassland, diminished by 4.72%. Based on White's (1983) vegetation categories of Africa, the Sudanian, Sahel, Somalia-Masai, and Guineo-Congolian regions had the largest significant declines of 35.9%, 29.2%, 18.9%, and 8.1%, respectively (Eva et al., 2006). In Eastern Africa, land use and land cover changes in Kagera Basin, spanning across Burundi, Rwanda, Uganda, and Tanzania between 1901 and 2010, indicate a decline in savannas by 15.4% between 1901 and 2010 (Wasige et al., 2013). A similar study in the area between 1984–2011 indicated a decrease in Woodland savanna by 12.4% (Berakhi et al., 2014).

Comparable trends of declining grazing lands are observed in country case studies over the vast West African region. In Burkina Faso, between the years 1975 and 2000, savannas declined from 59.8% to 51.6% of the land area, while in Niger, steppes and savannas mainly used as extensive grazing lands decreased by 3.4% and 16.2%, respectively (Tappan and Cushing, 2013). In Togo, the country's savannas and woodlands declined by 10%, in Mauritania by 30%, in Benin by 10.4%, and in Guinea by 1.9% (Tappan and Cushing, 2013). In Senegal, the country's diverse savannas declined by 4.1% between 1965 and 2000 (Tappan et al., 2004). In South Africa, changes in land use/land cover between 1961 and 2006 indicated relatively stable conditions throughout the period (Niedertscheider et al., 2012). Within the period of 1961 to 1988, grasslands declined by 20,000 sq. km., but from 1988 to 2006, the ecosystems increased back to 1961 values of about 270,000 sq. km. These observations are similar to the findings by Brink and Eva (2009) and Eva et al. (2006), who found no significant land cover changes in the Karoo-Namib and Kalahari-Highveld regions between the years 1975 and 2000.

Asia

FAO's regional data on land cover indicates that grazing lands in Asia increased by 7.31% between 1961 and 2011 (FAOSTAT Database). Much more pronounced was the increase in Western Asia (7.32%), followed by Eastern Asia (2.32%) with an increase of 6.33% in China (FAOSTAT Database). Values of grazing areas, however, declined in Southern Asia and South-Eastern Asia by 5.82% and 5.73%, respectively, and in Central Asia by 0.65% (FAOSTAT Database). In Central Asia, land use/land cover changes from 1990–2009 indicate that natural vegetation comprising woody savanna or shrub canopy cover, herbaceous cover, and other natural vegetation types, increased by 10.67% of the land area (Chen et al., 2013). The change represented a 16.69% increase in natural vegetation cover from 1990 to 2000 following the conversion of abandoned farmland to natural vegetation such as grassland and shrubland (Chen et al., 2013). However, from 2000 to 2009, the area of natural vegetation declined by 5.16% following the reclamation of abandoned farmland (Chen et al., 2013).

Extensive research on land-use changes in montane mainland Southeast Asia in Thailand, Yunnan (China), Vietnam, Cambodia, and Laos is available for the period of 1950-2000. The results indicate that the increase in grazing lands, defined as grass, bamboo, and bushes, was greatest in Tan Minh, northern Vietnam, from 27% to 67% (1952-1995). Grazing areas were also observed to be on the increase in Mengsong, Southern Yunnan; in Ban Khun, Northern Thailand; and in Ang Nhai, Laos (Fox and Vogler, 2005). On the other hand, significant declines in grazing areas were observed in Baka, Southern Yunnan (25%) and Menglong, Southern Yunnan (12%) in the period of 1965-1992. Additional areas with declining grazing areas included Mae Tho, Northern Thailand and Ban Lung, Northeastern Cambodia (Fox and Vogler, 2005).

In Eastern Asia, land use/land cover changes in China indicate significant increases in grassland from 1988-1995 (Yang and Li, 2000). Over this period, gains of 18.5% in grasslands in the entire nation emerged from losses of cultivated land across provinces in the country. However, some areas in the country observed losses in grazing lands as in the case of Xishuangbanna, Southwest China (Hu et al., 2008; Fox and Vogler, 2005). In Xishuangbanna, Southwest China, swidden fields, defined as lands that have the ecological functions of grassland/rangeland, declined from 13.14% to 0.46% between 1988 and 2006 (Hu et al., 2008). On the other hand, shrubland declined from 17.29% in 1988 to 16.05% in 2006 (Hu et al., 2008). In addition, land-use changes in China between the years 1995-2000 feature a 134,4861 square hectometer (hm^2) decline in grasslands (Liu et al., 2003).

America

FAO's regional data on land cover in America indicates slight decreases in the area of grazing land of about 1.46% for the period 1961-2011 (FAOSTAT Database). The changes, however, vary across regions; for example, there were significant declines in grazing areas in South America (8.22%) and among the Caribbean countries (7.31%; FAOSTAT Database). Grazing areas also declined in Central America (3.41%), but in Northern America, there were notable exceptions to the declining trend, with a slight increase (1.03%) in the grazing areas (FAOSTAT Database).

During the earlier periods, changes in the landscape in Latin America indicate that approximately 83.21% of the grassland was lost between 1850 and 1985 from $310*10^6$ ha to

$52*10^6$ (Houghton et al., 1991). In the South American Temperate grasslands, changes in land use and land cover in the periods of 1985–1989 and 2002–2004 indicate that grasslands, comprising prairie and grass steppes, decreased from 67.4% (151,320 km²) to 61.4% (137,817 km²), a relative change of -8.9% (Baldi and Paruelo, 2008). Whereas in the Patagonian landscapes in South America, the landscape structure between 1940 and 1970 indicates a dominant decrease in shrublands by 40.9% and 20.4% in the coastal (LTC) and inland (LTI) areas, respectively (Kitzberger and Veblen 1999). Grasslands were observed to have a relatively smaller transition; they declined by 2.3% and 18.5% in coastal and inland areas, respectively (Kitzberger and Veblen 1999). On the other hand, extensive research on land-use changes in non-Amazonian South America estimating the difference between the present (2009-2012) and potential vegetation extent indicated a decline in savannas and grasslands by 52% and 70%, respectively (Salazar et al., 2015).

In North America, land cover changes by the North American Land Change Monitoring System (NALCMS) from 2005-2010 indicate that grasslands in Mexico gained a net of 172km² (Land cover monitoring | Biodiversidad Mexicana, n.d.). A similar study in the Yucatan Peninsula, Mexico, indicated similar trends in increasing grazing areas with an increase in tropical grasslands by 8% between the years of 2000 and 2005 (Mascorro et al., 2014). In the U.S., land-use change indicates a decline in total grazing lands by about 26% (274 million acres) from 1945 to 2007. In the same period, grassland pasture and range declined by almost 7% (45 million acres). However, recently (2002-07), grassland pasture and range increased by almost 5% (27 million acres), offsetting the 26 million acre decline in cropland pasture. On the other hand, grazed forestland was observed to be on a continuous decline, with estimates of about 218 million acres lost (63%) during 1945- 2007, and 7 million acres lost during 2002-07 (Nickerson et al., 2011).

Europe

According to FAO's regional dataset, grazing areas in Europe declined by about 12.17% between 1961 and 2011 (FAOSTAT Database). However, from 1961-1991, grasslands increased by 2.59% from 50.01% to 52.6% (FAOSTAT Database). A significant decline from 52.6% in 1991 to 37.63% in 2001 is then observed, and thereafter, the grazing areas are maintained at relatively the same level (FAOSTAT Database). The significant decline is mainly driven by a drastic decline in Eastern Europe over the same period and can be associated with the drop of the Union of Soviet Socialist Republics (USSR) data from the dataset.

An extensive study on land cover/land changes for the EU27 plus Switzerland using Historic Land Dynamics Assessment (HILDA) version 2.0 is used to assess historic net changes in grasslands in Europe. Grasslands in the study are defined to include natural grasslands, wetlands, pastures, and mediterranean shrub vegetation. Between 1900 and 2010, the HILDA net change indicated that grasslands had decreased by 16.11%, while between 1950 and 2010, grasslands are observed to have declined by 7.02% (Fuchs et al., 2013; Fuchs et al., 2015a; Fuchs et al., 2015b). However, in the most recent periods, 1990-2010 and 2000-2010, grasslands increased by 4.49% and 3.04%, respectively (Fuchs et al., 2013; Fuchs et al., 2015a; Fuchs et al., 2015b).

Local studies on land cover change over similar recent periods in the area indicate similar trends. In the Netherlands, land cover changes in the years 1986–2000 indicate that shrubs and/or herbaceous vegetation increased from 19.1 km^2 to 92.3 km^2 (Feranec et al., 2007). On the other hand, in the Slovak Republic, land cover changes for the period 1970–1990 indicates that shrubs and/or herbaceous vegetation increased from 96.6 km^2 to 922.4 km^2 **(**Feranec et al., 2007**).**

Australia

FAO estimates of grazing land in Australia & New Zealand indicate decreases of about 4.56% in the period of 1961-2011 (FAOSTAT Database). Similar observations are made by a study conducted to track the land use change in Australia from 1992–93 and 2005–06 (Lesslie et al., 2011). Observations indicate a steady decline in the total grazing areas from 4,551,100 sq. km. from 1992-93 to 4,287,600 sq. km from 2005-06 (6%; Lesslie et al., 2011; Mewett et al., 2013). The decline includes a decrease of 149,600 sq. km. (3.37%) in the most recent period (2000-01 to 2005-06; Lesslie et al., 2011). In the period of 2005-2006, grazing natural vegetation occurred on 46.30% of the land area (3,558,785 sq.km) and grazing modified pastures occurred on 9.37% of the land area (720,182 sq.km), while irrigated pastures occupied 0.13% (10,011 sq.km) of the land area (Lesslie et al., 2011). This indicates that native grazing lands are likely to have had a higher share of decline.

Recent studies provide more evidence on the declining grazing lands. Between the period 1992–93 to 2009–10, agricultural land uses, comprising grazing and cropped areas declined by 11% (Mewett et al., 2013). Other studies estimate the decline to have been by 8% over the same period (Lesslie et al., 2011). During the same period, crop areas (excluding grazing areas and pasture crops) increased by 50%, up by 40% between the period of 1992–93 and 2005–06 (Lesslie et al., 2011). The above implies that the decline in the agricultural area between the period of 1992–93 and 2009–10 was mainly from grazing areas.

Table 2.1: Summary of Land Use/Land Cover changes in global grasslands

Region	Ecosystem	Trend over time	Net Gains From	Net Losses To	References
WORLD	Permanent meadows and pastures-% of agricultural area /land area	***1961*** ***2011*** 69.27% 68.38%			FAOSTAT Database
	Natural savannas, grasslands or steppes (million ha)	***1700*** ***1990*** 3200 1800–2700			Lambin et al. (2001)
AFRICA	Permanent meadows and pastures	***1961*** ***2011*** 84.02 77.92			FAOSTAT Database
Sub-Saharan Africa	Natural non-forest vegetation (ha)	***1975*** ***2000*** 1,247,980 1,189,085		- Agriculture - Barren	Brink & Eva (2009) ; Eva et al. (2006)
Kagera basin	Savannas (% of land use/cover in the basin)	***1901*** ***2010*** 35% 19.6%		- Farmland	Wasige et al. (2013)
	Woodland savanna (% of land use/cover in the basin)	***1984*** ***2011*** 43.7% 31.3%	- Wetlands	- Agricultural land - Forests - Urban land and Water bodies	Berakhi et al. (2014)
Ethiopia	Grasslands			- Invasive bushes	Admasu (2008)
South Africa	Grasslands (sq. km of national land use/ land cover)	***1961*** ***1988*** ***2006*** 270,000 250,000 270,000			Niedertscheider et al. (2012)
Namibia	Grasslands			- Invasive bushes	Mlunga & Gschwender (2015)
Senegal	Savanna -% National land use and land cover trends	***1965*** ***2000*** 73.7% 69.6%		- Agricultural land - Steppes - Bare ground cover	Tappan et al. (2004) Tappan & Cushing (2013)
	Savannas and woodlands (% National land use and land cover trends)	***1975*** ***2000***		- Cropping lands - Wild lands - Protected areas - Bare surfaces - Sandy surfaces - Steppe vegetation	Tappan & Cushing (2013)
Burkina Faso		59.8% 51.6%			
Togo		78.1% 68.1%			
Guinea		75.9% 74%			
Benin		80% 69.6%			
Niger		Savannas decreased by 16.2%			
Mauritania		Savannas decreased by 30%			
ASIA	Permanent meadows and pastures	***1961*** ***2011*** 58.8 66.11			FAOSTAT Database
Central Asia	Natural vegetation area (100,000 sq.km)	**1990** **2000** **2009** 28.30 33.03 31.32	Abandoned farmland		Chen et al. (2013)
Southwest China	Swidden field (% of total land area)	***1988*** ***2006*** 13.14% 0.46%		- Crop lands (rubber plantations)	Hu et al. (2008)

Region	Ecosystem	Trend over time		Gains From	Losses To	References
		Period 1950- 2000				Fox and Vogler (2005)
Tan Minh	Grass, bamboo, bushes (% of land use/land cover)	27%	67%	- closed and open canopy forests		
Ban Lung		9%	3%		- agriculture	
Mae Tho		6%	4%		- agriculture	
Baka		32	7%		- closed and open canopy forests	
Mengsong		35	43%	- closed canopy cover		
Menglong		26	14%		- agriculture	
Ban Khun		10%	18%	- closed-canopy cover		
China	Grasslands(% gains from total converted cultivated land)	***1988*** 18.5% gains	***1995***	- Cropland (e.g. conservation efforts) - abandonment of poor quality cultivated land		Yang and Li (2000).
China	Grassland (square hectometer)	***1995 to 2000*** Decline in area by 1,344,861			arable land	Liu et al. (2003).
AMERICA	Permanent meadows and pastures	***1961*** 68.65	***2011*** 67.19			FAOSTAT Database
Latin America	Grassland (exclusive of pastures, in 10^6 ha)	***1850*** 310	***1985*** 52		- crops - pasture areas	Houghton et al. (1991)
South American Temperate Grasslands	Grasslands- prairie and grass steppe (% of land area)	***1985-1989*** 67.4%	***2002–2004*** 61.4%		- agricultural expansion - afforestation	Baldi and Paruelo (2008)
Patagonian landscapes in South America	Grasslands (Class area (%))	**1940** 7.3% (LTC) 28.3% (LTI)	**1970** 5% (LTC) 9.8% (LTI)		- forests - shrublands	Kitzberger and Veblen (1999)
Non-Amazonian South America	Grasslands area (km^2)	***Potential historic area*** 777,571	***Present area (2009-2012)*** 236,240		- crop and pastures - forests	Salazar et al. (2015)
Mexico	Grasslands	***2005*** 359	***2010*** 531	- shrublands - cropland - forest covers	- wetlands - barren land - urban and built-up - water	Land cover monitoring | Biodiversidad Mexicana, (n.d.)
Yucatan Peninsula, Mexico	Tropical Grassland	***2000*** Tropical grasslands increased by 8%	***2005***	- harvesting - hurricanes		Mascorro et al. (2014)

Region	Ecosystem	Trend over time		Gains From	Losses To	References
USA	Total grazing land Million acres (cropland pasture, grassland pasture, and range and forestland grazed).	***1945*** 1,051	***2007*** 777	- methodological changes in estimating cropland pastures	- recreational, wildlife, and environmental uses - urban uses - better forest management	Nickerson et al. (2011)
EUROPE	Permanent meadows and pastures	***1961*** 50.01	***2011*** 37.84			FAOSTAT Database
Netherlands	Shrubs and/or herbaceous vegetation (in sq. km)	***1986*** 19.1	***2000*** 92.3	- arable land - pastures - construction sites - heterogeneous agricultural areas - open spaces - wetlands	- industrial, commercial and transport units - forests - urban fabric - inland waters	Feranec et al. (2007)
Slovak Republic	Shrubs and/or herbaceous vegetation (in sq. km)	***1970*** 96.6	***1990*** 922.4	- forests (deforestation) - pastures - construction sites - inland wetlands and waters	- industrial, commercial transport units and artificial areas - arable land and heterogeneous agricultural areas - open spaces	Feranec et al. (2007)
EU27 plus Switzerland	Fuchs et al., 2013 estimates of grasslands (in sq. km)	***1900*** 1484992	***2010*** 1245803		- croplands - forests - settlements	Fuchs et al. (2013)
AUSTRALIA & NEW ZEALAND	Permanent meadows and pastures	***1961*** 93.01	***2011*** 88.45			FAOSTAT Database
Australia	Total grazing areas (in sq. km)	***1992–93*** 4,551,100	***2005–06*** 4,287,600		- modified pastures - area under intensive uses - conservation and natural environments - cropping/ horticulture	Lesslie et al. (2011)
	Agricultural area (grazing and cropped areas)	***1992–93 to 2009–10*** Decline in area by 8-11%			- formal nature conservation - cropping	Lesslie et al. (2011) Mewett et al. (2013)
					improved pastures by fertiliser application	Australian National Greenhouse Accounts (2013)

Source: Compiled by author

2.3 Where to? Conversions and/or Modifications of Grassland Cover

The expansion of agricultural area has been the greatest driving force behind land use/land cover changes globally (Maitima et al., 2009; Lambin et al., 2003; Foley et al., 2005). Globally, natural vegetation, including natural grazing lands, have declined at the expense of croplands and pastures (Maitima et al., 2009; Lambin et al., 2003; Foley et al., 2005). However, transformations of the dynamics of other vegetation types, such as forests, grazing areas, or cropland/grassland, have led to increases in grazing lands in some parts of the world (Fuchs et al., 2015a; Foley et al., 2005). As demonstrated in Table 2.1, these dynamics vary from one region to another region, and the transformations could result in either productive gains or losses.

Africa

In the case of Sub-Saharan Africa, land-use/cover dynamics from 1975-2000 indicate agricultural areas increased dramatically over the period (123,413 ha) at the expense of forests (71,325 ha) and non-forest natural vegetation (58,894 ha), comprised of woodlands and grasslands (Brink & Eva, 2009; Eva et al., 2006). Over the same period, barren areas are also shown to have increased (6565 ha), but the increase has only been associated with non-arid zones; hence, it does not indicate desertification processes (Eva et al., 2006).

A similar trend of expansion of cropping areas is also observed in country case studies. In East Africa, a land use matrix between 1984-2911 in the Kagera river basin indicates significant losses of woodland savanna to agriculture (54.24%; Berakhi et al., 2014). However, over the same period 23.45% of agricultural land was converted to woodland savanna (Berakhi et al., 2014). Additional losses of woodland savanna to forests (1.28%), urban land (0.17%), and water bodies (0.08%) are observed (Berakhi et al., 2014). Woodland savannah gained marginally from water bodies (0.05%), and wetlands (1.92%; Berakhi et al., 2014). A similar study in the same region indicates that an expansion of farmlands between 1901 and 2010 was made at the expense of savannas (1.12 Mha) and woodlands (0.61 Mha). In South Africa, cropland/grassland dynamics were observed, with losses and gains made between the two land covers. In the country, grasslands declined during the period of 1961 to 1988 due to expansion of croplands. However, from 1988 to 2006, the cultivated areas declined, resulting in gains in grasslands to the initial level seen in 1961 (Niedertscheider et al., 2012).

Losses of prime grazing areas are, however, not limited to crop farming. In Ethiopia, as well as other parts of Eastern Africa, a decline in prime grasslands is observed to occur with the invasion of species such as *prosopis* in the Afar Region. Admasu (2008) indicates that over 700,000 hectares of prime grazing land and cultivable land in the country is currently either invaded or at risk of invasion from bush encroachment. Similar observations are made in Southern Africa. In Namibia, massive bush encroachment has been a challenge that affects more than 26 million hectares of the country`s rangelands today (Mlunga and Gschwender, 2015). As indicated by Mlunga and Gschwender (2015), bush encroachment constitutes more than 30% of the country’s land area (829 000 sq. km) and affects eight of its 13 regions, with the central northern part being the worst hit.

Transformations of the native grazing lands in Western Africa portray a similar trend to the rest of the continent. In West Africa, expansion of agricultural land and climatic factors are cited to be the main driving force towards declining grazing areas over the period 1975 to 2000 (Tappan and Matthew Cushing, 2013). Despite savannas and woodlands being the dominant land use/land cover in most parts of the region, expansion of agricultural land overrides these ecosystems (Tappan and Matthew Cushing, 2013). In Benin, the increase in agricultural areas is observed to have been at the expense of savannas and woodlands and other wild lands and protected areas. Similar observations are made in Burkina Faso, where expansion of cropland has led to the shrinking of the natural savannas with the increasing population pressures (Tappan and Matthew Cushing, 2013). Comparable to other regions, expansion of cropping lands in Guinea is most commonly explained by declining savannas and woodland areas, with modest losses in forest areas (Tappan and Matthew Cushing, 2013). In Ghana, Senegal, and Togo, expansion of agricultural land was observed to fragment savannas and woodlands. In Senegal, harsh climatic conditions have led to the loss of savanna to steppes (4.9%) and increased bare cover (20.1%), mainly in the pastoral regions (Tappan and Matthew Cushing, 2013). However, in some parts of the country, abandoned agricultural land (11.2%) due to crisis periods in the agricultural economy gave rise to long-term fallows classified as shrub and tree savanna vegetation types (Tappan and Matthew Cushing, 2013). A similar study in Senegal, from 1965-2000, indicates encroachment of agricultural land on the country’s diverse savannas (Tappan et al., 2004). In addition, the diverse savannas declined by 0.4% and 1% with the expansion of steppes cover and bare ground cover (degraded areas), respectively. Similarly, in Niger, steppe and savanna vegetation are indicated to have declined mainly due to the expansion of agricultural land but also partly due to drought. Sandy surfaces are observed to have expanded (37%) in the steppes of the Mauritania's Sahelian and Saharo-Sahelian regions due to drought and encroachment of steppe vegetation (Tappan and Matthew Cushing, 2013). Although the agricultural area in Mauritania increased – rain fed cropping by about 700 sq. km and irrigated by about 300 sq. km – its effect on the herbaceous vegetation was modest.

Asia

In Central Asia, the increase in natural vegetation by $4.73*10^5$sq. km between the years 1990 and 2000 approximated the decrease in farmland by $4.89 *10^5$sq. km over the same period (Chen et al., 2013). As indicated by Chen et al. (2013), the dynamics reflect the conversion of abandoned farmland to natural vegetation such as grassland and shrubland. However, between the period of 2000 and 2009, farmland increased by $1.62 *10^5$ sq. km., whereas natural vegetation declined by a similar amount ($1.71 *10^5$sq. km), reflecting reclamation of some of the abandoned farmland (Chen et al., 2013). In Southwest China, losses in swidden fields, which have a biome equivalent to that of grass/rangelands, are attributed to shifts to large-scale rubber plantations, resulting in significant losses in ecosystem services (Hu et al., 2008).

In Montane Mainland Southeast Asia, with the growing population pressures, the presence of government interventions to slow down transformations of tree cover or encouraging agriculture played a big role in land use/land cover changes. In areas such as Baka, Southern Yunnan, the establishment of a nature reserve by the national government resulted in gains in closed and open-canopy forest cover, with losses in other vegetation covers such as grass, bamboo, and bushes (Fox and Vogler, 2005). However, in the absence of such interventions, as was the case in Mengsong, Southern Yunnan, tree covers were cleared between the years 1949 and 1992, in efforts towards self-sufficiency in food. Where more land was cleared than needed, gains in grass, bamboo, and bush categories were observed (Fox and Vogler, 2005).

Similarly, in China, gains in grasslands within the period of 1988-1995 were mainly from losses in cultivated areas. The increase in demand for fruits and aquatic products in response to high incomes led to the loss of cultivated land to horticulture and fish ponds. Where the destination of such conversions was not land to horticulture and fish ponds, the land was converted to other uses such as grasslands (Yang and Li, 2000). In addition, cropland-grassland conversions have been as a result of abandonment of poor quality land especially in the arid and semi-arid areas. However, reclamation of such crop lands has been on the increase with the increasing population pressures and demand for food (Yang and Li, 2000). Cropland-grassland conversions in the country have also been as a result of some land-conservation projects efforts conducted in the arid and semi-arid areas of the country, such as the Three-north Forest Protection Belt Program (Yang and Li, 2000). The reclamation of arable land from grasslands is further demonstrated by land-use/cover dynamics from 1995-2000 (Liu et al., 2003). Over this period, the net losses of grassland were mainly to arable land.

Europe

Land cover/land use changes in grasslands in Europe are demonstrated to be significantly determined by settlements (urbanization), afforestation/reforestation (and, in some instances, deforestation), and cropland/grassland dynamics (Fuchs et al., 2015a). Land use/land cover changes in Europe (EU27 plus Switzerland) between 1900 and 2010 demonstrate that, of all gains in grasslands (30.4% of the entire area covered), 20.4% were from cropland, 7.1% are a result of deforestation, and 1.6% are from settlements (Fuchs et al., 2015a). On the other hand, of all the grassland losses (37% of the entire area covered), 5.5% were to settlements, 20.8% were to croplands, and 9.4% were to forests (Fuchs et al., 2015a). Similar trends are observed in local case studies in the region.

In the Netherlands, the effort to fulfill the country's biodiversity goals has resulted in the conversion of agricultural land to shrub and/or herbaceous vegetation and other natural and/or semi-natural land such as forests and inland wetlands. In the period of 1986–2000, net gains of 37.3 sq. km of arable land and 13.9 sq. km of pastures to shrub and/or herbaceous vegetation were observed. Additional sources of net gains of shrub and/or herbaceous vegetation included construction sites (5.8 sq.km), heterogeneous agricultural areas (5 sq.km), open spaces with little or no vegetation (3.8 sq.km), and maritime wetlands (14.5 sq.km; Feranec et al., 2007). On the other hand, net losses of shrub and/or herbaceous vegetation to industrial, commercial and transport units (2.2 sq. km), inland wetlands (0.8 sq. km), forests (2.3 sq. km), urban fabric (0.1 sq. km), and inland waters (0.5 sq. km) were observed (Feranec et al., 2007).

In the Slovak Republic, significant gains in shrub and/or herbaceous vegetation in the period of 1970–1990 mainly resulted from net losses of forests (816.8sq. km) as a result of timber extraction and a number of calamities in the forests (Feranec et al., 2007). Additional net gains of shrub and/or herbaceous vegetation included conversions from construction sites (0.1 sq km), pastures (22.3 sq. km), inland wetlands (3.2 sq km), and inland waters (0.30sq km). Losses, on the other hand, were faced to industrial, commercial, and transport units (0.5 sq km); artificial, non-agricultural vegetated areas (0.5sq km); arable land (1.9sq km); heterogeneous agricultural areas (10.8 sq km); open spaces with little or no vegetation (3.3 sq km); and arable land (1.6 sq km).

America

In North America, losses of grazing land in the U.S. within the period of 1949 to 2007 are attributed to a combination of various activities. For instance, some losses are attributed to shifts of grazing land to recreational, wildlife, and environmental uses (Nickerson et al. 2011). In some instances, under favorable conditions, some grazing lands are indicated to have reverted back to forests (Nickerson et al., 2011). Other causes of grazing land losses include land converted for urban uses to meet the demands of the increasing population (Nickerson et al. 2011). In addition, the grazed forest area in the country has declined due to improvements in both forest management and livestock feeding practices and restricted grazing possibilities from increased forest densities, among other factors (Nickerson et al., 2011). In the period of 2002 and 2007, the increase in grazing area resulted mainly from methodological changes in estimating cropland pastures (Nickerson et al., 2011).

In Mexico, between 2005 and 2010, grasslands made gains from forest covers (10 sq. km), shrublands (123 sq. km), wetlands (7 sq. km), cropland (304 sq. km), barren land (27 sq. km), and water (59 sq. km; Land cover monitoring | Biodiversidad Mexicana, n.d.). On the other hand, losses to forest covers (3 sq. km), shrublands (38 sq. km), wetlands (54sq. km), cropland (123sq. km), barren land (54 sq. km), urban and built-up (11 sq. km), and water (77 sq. km) were observed. These transformations resulted in net gains of 172 sq. km. Similar gains in grasslands in Mexico are observed by Mascorro et al. (2014). In their study, the changes in grasslands and shrublands are attributed mainly to harvesting and hurricanes (Mascorro et al., 2014).

A cross-classification matrix of land use/land cover changes in the northern Patagonian landscapes for the period of 1940-1970 indicates that, in the coastal areas, grasslands had a net loss of 3.5% to forests but a gain of 0.7% of shrublands. However, in the inland areas, grasslands had a net loss of 4.2% and 13.4% of the total area to forests and shrublands, respectively. Over the same period, in the coastal areas, shrublands are indicated to have had a net loss of 40.6% to forests, whereas in the inland areas, the loss to forests was 36.2% (Kitzberger and Veblen 1999).

In Argentina and Uruguay, native grasslands have been converted to crops and pastures with increasing improvements in technology and in response to increasing global food, timber, and energy demands (Salazar et al., 2015). However, as indicated by Salazar et al. (2015), more recent trends indicate that forested areas are also encroaching upon native grasslands. Between the years of 1992 and 2001, Pinus and Eucalyptus plantations increased by 102,000ha in the areas, while from 2000-2012 there was a 13,859 km^2 increase in the forested area on the native grasslands (Salazar et al., 2015). Similar observations are made by Baldi and Paruelo (2008), where agricultural expansion in grasslands was observed in Argentina, Uruguay, and Brazil, and transitions from grassland to forest (afforestation) were observed in Argentina and Uruguay. An earlier cross-classification land matrix in Latin America, for the period of 1850-1985, indicates that losses in grasslands (258*10^6 ha) were mainly made to crops (75*10^6 ha) and pasture areas (183*10^{6}ha; Houghton et al., 1991).

Australia

Grazing areas and associated management intensities in Australia vary from highly modified/improved (sometimes irrigated) to extensive grazing lands (Australian National Greenhouse Accounts, 2013). Since the mid-1990s, there has been a significant increase in the area under modified pastures subsequent to declining native grazing vegetation (Australian National Greenhouse Accounts, 2013; Lesslie et al., 2011). For instance, according to Australian National Greenhouse Accounts, (2013), the area under improved pastures (by fertilizer application) increased from 27 to 44 million hectares in the period of 1990-2010 (Australian National Greenhouse Accounts, 2013). Similar observations are made in the period of 1992–1993 and 2005–2006. During this period, grazing areas declined by 6% while significant increases were observed in the area under intensive use (35%), which includes urban areas, transportation and waste, and intensive plant and animal production (Lesslie et al., 2011). In addition, significant increases were observed in the area under conservation and natural environments (8%), cropping (39%), and horticulture (26%; Lesslie et al., 2011; Mewett et al., 2013).

2.4 Drivers of land use/land cover changes

Grazing ecosystems have been demonstrated to be resilient and fluctuate in response to changes in climate. It is still unclear to what extent grazing intensities contribute to land use/land cover changes of these ecosystems (Kiage, 2013; Ramankutty et al., 2006; Miller, 1993; Meyer and Turner, 1992). Thus, grazing lands are seldom perceived as equilibrium ecosystems. Existing studies, however, show evidence of land use/land cover changes on grazing lands as a result of external factors other than climate (Le et al., 2014; Bai et al., 2008). This supports the theory that grazing ecosystems are viewed as non-equilibrium ecosystems being affected by climate and other external factors (Ramankutty et al., 2006). Dynamics in grazing ecosystems may, however, be explained by the presence and interaction of both equilibrium and non-equilibrium factors (Vetter, 2005; Domptail, 2011), as demonstrated in the discussion below.

Among the key external issues surrounding land use/land cover changes in grazing areas globally are the relatively unrestricted access to land, increased pressures on land resources, changing opportunities brought about by markets, policy interventions, technological change, and changes in social organizations and attitudes (Lambin et al., 2003; Fox and Vogler, 2005; Lesslie et al., 2011; Feranec et al., 2007; Baldi and Paruelo, 2008).

High population growth rates coupled with relatively unrestricted access to land in drylands have led to significant land use/land cover changes on native vegetation covers such as grasslands given the increasing demands for food, fibre, and energy (Lesslie et al., 2011; Hazell and Wood, 2008; Dong et al., 2011; Hamza, and Iyela, 2012; Pender et al., 2009; Feranec et al., 2007; Foley et al., 2005; Maitima et al., 2009; Brink and Eva, 2009). Increasing population pressures, intrinsic but mainly through migration, are associated with an increase in human-dominated cover types, resulting in decreases in the extent of native grazing lands in some parts of the world (Olson et al., 2008; Brink and Eva, 2009; Fox and Vogler, 2005; Lesslie et al., 2011; Hazell and Wood, 2008; Parton et al., 2005). As population increases, pressure on resource availability increases, including the availability of productive land (Lesslie et al., 2011). This leads to a shift of agricultural production to higher value production; for instance, from native grazing to intensive crop production or modified pastures (Fox and Vogler, 2005; Lesslie et al., 2011; Olson et al., 2008; Dong et al., 2011; Swallow and Mccarthy, 2000; Hamza and Iyela, 2012; Brink and Eva, 2009). However, the impact of increasing population pressures has in some instances led to the increase of both natural and managed herbaceous pasture crops (Mascorro et al., 2014; Feranec et al., 2007; Lambin et al., 2003; Maitima et al., 2009; Houghton et al., 1991). For instance, logging of trees for timber extraction has been observed to have led in gains in natural savannas and pastures as a result of deforestation in some parts of the world (Feranec et al., 2007; Lambin et al., 2003). Other pressures associated with population changes include loss of grazing land to built-up areas with the expansion of urban and rural residential areas (Bassett et al., n.d.; Lesslie et al., 2011; Fox and Vogler, 2005; Olson et al., 2008; Hobbs et al., 2008; Fuchs et al., 2015a).

Government policies such as interventions by national states to conserve native vegetation to sustain environmental flows are also among the drivers of the land use/land cover changes (Lesslie et al., 2011; Fox and Vogler, 2005; Reid et al., 2004; Feranec et al., 2007; Fuchs et al., 2015a). Such policies have resulted in increased natural vegetation, including native grasslands. Inappropriate policies, on the other hand, have been illustrated to lead to loss of grazing areas (Fox and Vogler, 2005; Hazell and Wood, 2008; Dong et al., 2011; Homewood et al., 2012; Harris, 2010; Sneath, 2003; Fernandez-Gimenez and Batbuyan, 2004; Swallow and Mccarthy, 2000; Kirk, 2000; Robinson et al., 2010; Meinzen-Dick and Mwangi, 2009; Kimani and Pickard, 1998). For instance, land policies promoting the fragmentation of grazing areas and transformations of pastoral systems into agricultural (cropping) systems have been demonstrated to result in the loss and subsequent degradation of grazing lands (Fox and Vogler, 2005; Reid et al., 2004; Hobbs et al., 2008; Niamir-Fuller, 2000; Dong et al., 2011).

Market pressures also play a significant role in land use/land cover changes worldwide (Lesslie et al., 2011; Fox and Vogler, 2005; Hazell and Wood, 2008; Sternberg, 2008; Hu et al., 2008; Baldi and Paruelo, 2008). Semi-arid grazing lands, as indicated by Lambin et al. (2001), are more prone to being developed as a consequence of conversion and intensification processes in response to triggers such as opportunities created by markets. For instance, changing opportunities with the development of both national and international markets for crop commodities provide a pull factor towards crop production leading to land use/land cover changes (Fox and Vogler, 2005; Reid et al., 2004; Olson et al., 2008; Baldi and Paruelo, 2008). As highlighted by Reid et al. (2004), people residing in grazing areas, as elsewhere, respond to opportunities with the development of external markets such as those with crop farming leading to grazing habitat conversion, modification, and fragmentation. New economic pressures with the development of market economies have also been observed to drive changes in land tenures and subsequently land uses in pastoral systems (Sternberg, 2008). Evolving pastoral land tenure systems towards private possession of land have resulted in increased conversion, modification, and fragmentation of grazing lands with significant environmental implications.

The vulnerability of rangelands to modifications and conversions is further exacerbated by market inefficiencies manifested in the form of distorted market prices for land and livestock outputs, among others (Hatfield and Davies, 2006; Makokha et al., 2013). Incorrect price signals of the actual value of rangelands leads to their undervaluation and thus practices such as conversion to alternative “best” uses (Hatfield and Davies, 2006). For instance, with the increasing demand for energy, high energy prices are shown to lead to increased profitability of energy crops (Johansson and Azar, 2007). This has resulted in an expansion of energy crops not only on cropland but also on grazing land despite non-land costs for cultivation in grazing lands being higher than those on croplands (Johansson and Azar, 2007). Cultivation is shown to expand on grazing areas due to the relatively unrestricted access to these lands and the lower opportunity costs associated with grazing lands when compared to other land covers such as forests. Therefore, the failures of markets to capture the true value of land and reflect externalities arising from their loss/conversion are key challenges to combating land use/land cover changes (von Braun et al., 2013). Furthermore, low benefits from livestock production are observed to encourage livestock producers to adopt alternative means of sustaining livelihood leading to land use/land cover changes (Dong et al., 2011; Steinfeld et al., 2006b; Swallow and Mccarthy, 2000; Pender et al., 2009; Makokha et al., 2013; Markelova et al., 2009; Ahuya et al., 2005; Aklilu, 2002; Hurrissa and Eshetu, 2002).

Harsh climatic conditions in combination with other factors, such as overgrazing, conflicts, topography, diseases, and pests restricting access to fragments are additional drivers of land use/land cover changes in grazing lands (Tappan and Matthew Cushing, 2013; Tappan et al., 2004; Reid et al., 2004; Asner et al., 2004; Olson et al., 2008; Niamir-Fuller, 2000; Dong et al., 2011; Steinfeld et al., 2006b; Harris, 2010; Säumel et al. 2011; Swallow and Mccarthy, 2000; Hamza and Iyela, 2012; Pender et al., 2009; Sternberg, 2008; Brink and Eva, 2009; Lambin et al., 2003). The above factors are observed to lead to increased bare ground and declines in productivity in grazing ecosystems.

Introduction of new and improved technologies, together with infrastructure development, have also brought about changes in land use/land cover in grazing areas (Baldi and Paruelo, 2008; Reid et al., 2004; Lesslie et al., 2011; Olson et al., 2008; Hazell and Wood, 2008). For instance, irrigation systems, non-tillage techniques, genetically modified crops, and advancements in transport infrastructures have increased access to grazing areas and presented various opportunities/land use options in these once “spatially isolated” ecosystems (Baldi and Paruelo, 2008; Reid et al., 2004). This has contributed to the conversion of grazing lands to other uses given the increased profitability associated with the ecosystems (Reid et al., 2004; Lesslie et al., 2011; Olson et al., 2008; Hazell and Wood, 2008).

Social changes including urban–rural interactions and the desire to access social amenities such as education and health care have affected how people use land in grazing areas (Lesslie et al., 2011; Reid et al., 2004; Sternberg, 2008; Lambin et al., 2003). Many communities that were mainly nomadic have adapted permanent settlements, either totally replacing nomadic herding systems or as a complement to it (Reid et al., 2004; Sternberg, 2008). Increased settlement patterns of the pastoral communities have pushed households into seeking ways to buffer against the risks they face, such as variable climatic conditions. This has led to different means of sustaining livelihoods and also to changes in land uses (Reid et al., 2004). Increased settlements are, however, observed to intensify grazing pressure in settled areas and have damaging effects on the grazing ecosystems (Sternberg, 2008).

It is generally accepted that poverty is among the drivers of land use/land cover changes and that its eradication is crucial for the sustainable management of land (Nkonya, 2008; Lambin et al., 2001; Barbier, 1997; Duraiappah, 1998). Though not a major factor, poverty is also shown to influence grazing land management practices (Kerven et al., 2012; Hazell and Wood, 2008). As with other poor households, poor pastoralists tend to be mainly concerned with subsistence demands (Duraiappah, 1998). The poor pastoralists mainly base their production decisions within short-term horizons with a bias against long-term land management strategies (Barbier, 1997). Coupled with inadequate input resources, little consideration for long-term rangeland management leads to practices such as irrational overstocking and overuse of accessible pastures (Kerven et al., 2012; Harris, 2010). This leads to a reduction in the vegetation cover, abundance, and richness of the species and productivity of the pasture resources in some fragments of land.

Disintegration of customary resource institutions and lack of recognition of traditional knowledge in the management of rangelands are among the key factors contributing to land use/land cover changes in grazing areas (Asner et al., 2004; Lambin et al., 2001). Weakened customary resource institutions, such as common property arrangements, have been on the increase with the tenure reforms governing grazing (Meinzen-Dick and Mwangi, 2009; Flintan, 2011; Kimani and Pickard, 1998). Among the resulting effects of weakened indigenous resource institutions are loss, conversion and fragmentation of grazing lands, and overuse and degradation of the accessible areas (Lambin et al., 2001; Flintan, 2011). On the other hand, lack of incorporating traditional knowledge may lead to changes in species diversity, changes in vegetation cover and plant production, changes in wood plants density, and changes in nutritional quality and accessibility of pastures (Westoby et al., 1989; Solomon et al., 2007; Angassa and Oba, 2008).

From the above discussion, it is evident that human-related factors play a considerable role in the transformations of grazing areas. The land use/land cover changes in grazing areas, as with other land covers, are observed to be predominantly in response to socioeconomic and policy-related factors mediated by institutional factors (Nkonya et al., 2011; Lesslie et al., 2011; Heshmati and Squires, 2013; von Braun et al., 2013; Olson et.al. 2008; Niamir-Fuller, 2000; Reid et al., 2004; Hazell and Wood, 2008; Dong et al., 2011; Sternberg, 2008). It is only in a few instances where environmental factors are observed to play a key role.

2.5 Effects and costs of land use land cover changes

The land use/land cover changes on grazing areas have important ecological, social, cultural and economic consequences. As demonstrated in the earlier sections, land use/land cover changes either result into conversion, modification or fragmentation of grazing lands. When grazing lands are converted, the individuals found on the habitat are lost leading to a direct decline in populations (Reid et al., 2004). On the other hand, when grazing lands are modified or fragmented, the processes result in a reduction in the persistence of the populations found in the habitat (Reid et al., 2004).

Among the ecological consequences of land use/land cover changes include: progressive loss of biodiversity; soil degradation; changes in nutrient and water cycling; changes in greenhouse gas emissions and carbon sequestration; changes in species connectivity and means for recovery, among other changes (Reid et al., 2004; Lesslie et al., 2011; Lambin et al., 2001; Lambin et al., 2003; Maitima et al., 2009; Parton et al., 2005; Foley et al., 2005; Davies et al., 2015; Kreutzmann et al. 2011; Mannetje, 2002; Ramankutty et al., 2006; Hu et al., 2008; Feddema et al., 2005; Meyer and Turner, 1992; Houghton, 1994; Houghton et al., 1991). The social and cultural long-term effects of land use/land cover changes include changes in landscape aesthetics (Lesslie et al., 2011) and conflicts over land, predominantly among cultivators, pastoralists, individual land users, wildlife conservationists, and governments (Campbell et. al., 2003; Maitima et al., 2009).

The main economic consequences of land use/land cover changes relate to changes in human economic welfare and productivity of grazing lands with impacts on food security (Reid et al., 2004; Lesslie et al., 2011; Foley et al., 2005; Maitima et al., 2009). As highlighted earlier, global grazing by biome supports the largest extent of pastoral systems (Asner et al., 2004). Land use/land cover changes affect the productivity of livestock populations and other herbivores in pastoral systems. The transformations affect the capacity of livestock and other herbivores to track pastures that vary over time and space (Hobbs et al., 2008; Niamir-Fuller). In addition, the transformations affect the ability of the herbivores to access resources, such as water, which are not substitutable for one another and found at different locations of the grazing ecosystem (Hobbs et al., 2008; Niamir-Fuller, 2000). Access to these resources has profound effects on the ability of the livestock and other herbivores to survive and reproduce, especially when confronted by variability in climate (Hobbs et al., 2008; Maitima et al., 2009). On the other hand, grazing lands remain central to pathways out of poverty for the majority of the world's poorest populations (Ashley et al., 1999; Neely et al., 2009; Robinson et al., 2014), and thus it is crucial to maintain the agricultural productivity of these resources to avoid aggravating poverty. In the following section, the study further focuses on the primary productivity consequences of land use/land cover changes on the remaining (static) grazing/rangelands areas.

2.5.1 Productivity influences of the land use/land cover changes

2.5.1.1 Degrading Areas

Le et al. (2014) make use of the long-term trend of inter-annual mean Normalized Difference Vegetation Index (NDVI) over the period of 1982–2006 to indicate areas with persistent reduction or loss of primary production service (degradation hotspots is). Table 2.2 presents the areas of long-term decline in NDVI in the shrub and grassland areas.

Based on Le et al. (2014), long-term vegetation productivity decline (with the correction of effects of rainfall and atmospheric fertilization and masking saturated NDVI zone), grasslands worldwide had the highest percentage decline in productivity. Within the regions, Africa is indicated to have the largest share of productivity decline in both grasslands and shrublands. Having corrected for rainfall and atmospheric fertilization effects, the decline in productivity can be attributed to "human-induced" degradation given the low occurrence of other natural drivers of productivity decline besides the climatic factors and atmospheric fertilization. External anthropogenic factors such as fragmentation of rangelands with encroachment of crop farming are therefore likely to explain such a decline in productivity. On the other hand, the least decline in both grasslands and shrublands is observed in Europe. These observations can be associated with efforts of the region to fulfill biodiversity goals. As highlighted earlier, efforts within the region have resulted to the conversion of agricultural land to natural vegetation such as herbaceous and/or shrub vegetation and other natural and/or semi-natural land (Fuchs et al., 2015a; Feranec et al., 2007).

Table 2.2: The share of degrading area by continental regions and world (% of total area of the land cover type across each region).

Region	*Grass land*	*Shrub land*	*Crop land*	*Mosaic vegetation-crop*	*Forested land*	*Mosaic forest-shrub/grass*	*Sparse vegetation*
Asia	**24%**	**33%**	30%	31%	30%	36%	43%
Europe	**17%**	**6%**	19%	21%	21%	20%	17%
North Africa and Near East	**52%**	**39%**	45%	42%	30%	36%	18%
Sub-Saharan Africa	**40%**	**28%**	12%	26%	26%	26%	29%
Latin America and Caribbean	**24%**	**29%**	25%	16%	10%	29%	34%
North America and Australasia	**40%**	**27%**	17%	16%	32%	36%	22%
World	**33%**	**25%**	25%	25%	23%	29%	23%

Source: Le et al. (2014)

In a comparable study, an assessment of global land degradation and improvement using spatial patterns and temporal trends of NDVI and rain-use efficiency was conducted for the period of 1981-2003 (Bai et al., 2008). From the analyses, the findings indicated that degradation was clearly a management issue (Bai et al., 2008). Among the areas which are indicated as severely affected by degradation include Africa south of the Equator, south eastern Asia and South China, N-Central Australia, the Pampas, and N America (Bai et al., 2008). Some of the areas identified correspond to areas with significant losses in grazing lands (Eva et al., 2006; Brink & Eva 2009; Lesslie et al., 2011; Salazar et al., 2015; Baldi and Paruelo, 2008 ; Houghton et al., 1991; Nickerson et al., 2011). As indicated by Bai et al., 2008, conversion of natural cover such as grassland to other vegetation types such as pastures normally results in an immediate reduction in NPP (and NDVI). However, this does not directly indicate degradation processes as the conversions might be profitable and sustainable, depending on the management taken.

A comparison of land degradation with associated land cover/land uses (Table 2.3) reveals that 25% of the land degradation was on grasslands (herbaceous vegetation; Bai et al., 2008). Of the land area occupied by grassland, 15.8% is indicated to be degrading, a much lower value to the 33% given by Le et al. (2014). From Table 2.4, we observe that grasslands that are natural and protected appear to be less degraded than grazed areas. In addition, grazing lands under extensive pastoralism are indicated to be less degraded than those under moderate/intensive pastoralism and intensive pastoralism, an indication of the presence of both equilibrium and non-equilibrium factors affecting land management.

2.5.1.2 Costs of Degradation

There is very little work on the economic costs of conversion, modification, or fragmentation of ecosystems, especially for grazing lands due to data limitations. Based on the availability of data, Kwon et al. (2016) estimated the on-farm cost of declining productivity of grasslands globally to be about 2007 US$6.8 billion over the period of 2001 to 2011. The study only considered on-farm losses of milk production and off-take rate for meat (Kwon et al., 2016). The losses in ecosystem services, such as the loss of carbon sequestration and the effects on livestock health which occur with land use/land cover changes, were not computed. This indicates that the estimated costs were quite modest. In addition, the associated benefits of land use/land cover changes on the grazing lands were not considered. This highlights the need for further research in evaluating the benefits versus costs of land use/land cover changes on grazing lands for policy advice.

2.5.1.3 Improving Areas

As illustrated by Le et al. (2014), the areas of land improvement (with corrections made for rainfall and atmospheric fertilization effect) are mainly located in the Sahelian belt in Africa, central parts of India, western and eastern coasts of Australia, central Turkey, areas of North-Eastern Siberia in Russia, and northwestern parts of Alaska in the U.S. (Fig. 2.2). Unlike with the land degradation trend, the areas of improvement in the study were not classified under various land use types, which limits the interpretation of the results. Furthermore, in grazing areas, increases of biomass production may be of lesser biological productivity. For instance, an increase in biomass production could be related to bush encroachment, which may not be considered as land improvement (Bai et al., 2008).

Table 2.3: Global degrading/improving lands (aggregated by land use systems)

Land use system	***Total pixels (TP) (5'x5')***	***Degrading pixels (DP)***	***DP/TP (%)***	***DP/TDP1 (%)***	***Improving pixels (IP)(5'x 5')***	***IP/TP (%)***	***IP/TIP2 (%)***
Forestry	661932	194321	29.3	46.7	65207	9.9	23.5
Grassland	**666668**	**105380**	**15.8**	**25.3**	**111458**	**16.7**	**40.1**
Agricultural land	329862	73104	22.2	17.6	65909	20.0	23.7
Urban	52640	9114	17.3	2.2	6152	11.7	2.2
Wetlands	42572	10637	25.0	2.6	4759	11.2	1.7
Bare areas	400220	11800	2.95	2.8	19617	4.9	7.1
Water	62893	11904	18.9	2.9	4571	7.3	1.6
Undefined	499	14	2.8	0.0034	11	2.2	0.004

Source: Bai et al., 2008

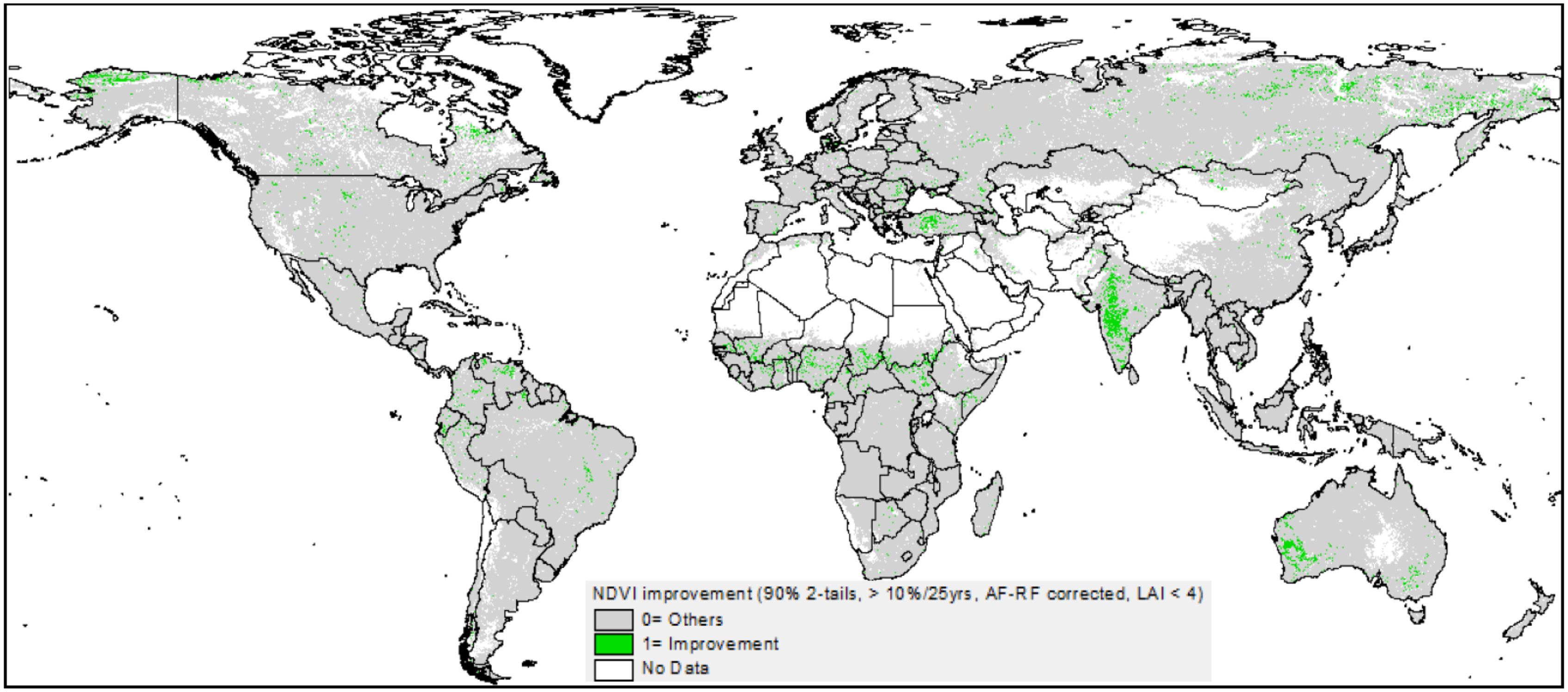
Bai et al. (2008), however, identify land improvement under various land use/land cover classes (Tables 2.3and 2.4). Grasslands are demonstrated to account for the largest improved areas globally; 40.1% of the improved areas were found in grasslands. The improvement represented 16.7% of the grassland areas. Contrary to degradation, grazed areas indicated much improvement compared to the natural and protected grasslands and the indication that anthropogenic factors do not always lead to degradation effects.

Table 2.4: Global degrading and improving areas by land use systems

Land use systems	*Total pixels(TP)*	*Degrading pixels (DP)*	*DP/TP(%)*	*Improving pixels (IP)*	*IP/TP (%)*
Herbaceous - not managed/natural	212858	19012	8.9	17870	8.4
Herbaceous - protected areas	76707	10435	13.6	8560	11.2
Herbaceous with extensive pastoralism	154528	33253	21.5	31181	20.2
Herbaceous with moderate/intensive pastoralism	129382	23199	17.9	33376	25.8
Herbaceous with intensive pastoralism	93193	19481	20.9	20471	22

Source: Bai et al., 2008.

Figure 2.2: The areas of NDVI improvement



Source: Le et al. (2014)

2.6 Are all grazing land losses productive losses?

The short answer is no. The analysis in the previous sections indicates that degradation is mainly a management issue. Better management of grasslands is associated with less degradation (Table 2.4). Degradation of grasslands is likely to occur where conversions of some part of the ecosystems occur and no additional management action is taken on the remaining grazing areas. This is illustrated in developing countries such as Africa under extensive grazing systems. With increasing human and livestock populations, diminishing grazing resources play a big role in determining the intensities at which grazing resources are exploited in the developing world (Kiage, 2013). This is in support of Mannetje (2002), who indicates that among the key causes of degradation in (semi-)arid rangelands in developing countries is the loss of the ecosystems to other uses such as cultivation. With hardly any adoption of intensive production systems, loss of grazing areas may present various problems: (1) less forage becomes available with declining grazing areas; (2) the ecosystems are used more intensively creating room for degradation with less vegetation cover and less palatable grasses; and (3) with less forage available, conflicts are likely to arise between different groups, such as conflicts between cultivators, pastoralists, and wildlife (Kiage, 2013; Eva et al., 2006; Tappan et al., 2004). Loss of grazing land leads to a decline in forage availability and restricted mobility, and this results in the overuse and degradation of the remaining grasslands (Eva et al., 2006; Mannetje, 2002; Homewood et al., 2012; Flintan, 2011; Campbell et al., 2003; Campbell et al., 2005; Butt, 2010).

Loss of grasslands is also associated with degradation when losses occur to shrublands/steppes and bare vegetation cover (Kitzberger and Veblen, 1999; Admasu, 2008; Tappan and Matthew Cushing, 2013; Mlunga and Gschwender, 2015; Tappan et al., 2004). Invasive shrubland vegetation are in most cases of lesser biological productivity and lead to a reduction of prime grazing lands and thus are not considered as land improvement (Bai et al., 2008; Admasu, 2008; Mlunga and Gschwender, 2015). In addition, as observed in West Africa, harsh climatic conditions in combination with other factors, such as overgrazing and topography, are observed to lead to increased bare ground in pastoral areas (Tappan and Matthew Cushing, 2013; Tappan et al., 2004).

However, not all conversions are associated with degradation. Conversion of native grasslands to highly modified/improved grazing lands (pastures) as observed in Australia is not only associated with increased productivity but may also lead to better management of the ecosystems (Lesslie et al., 2011). In addition, as observed in Argentina and Uruguay, adoption of better technologies may lead to conversion of native grasslands to pastures and croplands with little adverse effects on the remaining native vegetation (Salazar et al., 2015; Baldi and Paruelo, 2008). In fact, native grasslands in these two countries were observed to transit to forests (afforestation), which are of high natural value. Even so, it should be noted that conversion of native pastures to more intensive land uses such as modified/improved pastures may be trading short-term increases in productivity for long-term losses in the capacity of the resources to sustain productivity as well as other ecosystem services (Foley et al., 2005). Intensive land uses such as farming on grasslands is associated with increased invasive species at the expense of the number and abundance of native species, a decline in diversity and abundance of biodiversity such as wildlife, and soil productivity losses, among others (Maitima et

al., 2009, Foley et al., 2005; Greiner et al., 2013). Many of the above are important for agricultural production and thus imply that productivity is likely to be affected in the long term.
From the gains perspective, better management of land, as demonstrated in Europe and in Montane Mainland Southeast Asia, may lead to increases in grasslands as well as other natural vegetation at the expense of agricultural land (Fuchs et al., 2015a; Fox and Vogler, 2005). As highlighted earlier, conversion of agricultural land to shrub and/or herbaceous vegetation and other natural and/or semi natural land has occurred as a result of the countries' effort to fulfil their biodiversity goals and preserve nature (Feranec et al., 2007; Fox and Vogler, 2005). Contrariwise, increased grasslands are also not always associated with better management of the ecosystems. This is well demonstrated in Central Asia, where increases in natural vegetation, such as grassland and shrubland, resulted from abandoned farmland (Chen et al., 2013). The abandoned lands in most instances are of poor quality and degraded from salt accumulation among other factors and thus do not necessarily translate to better management of land (Kitamura et al., 2006).

2.7 Conclusion

In spite of providing essential ecosystem goods and services, rangelands continue to be degraded. Understanding rangeland dynamics and the paths of degradation is critical in the design of sustainable rangeland use. The analysis on LULCC in global livestock grazing systems indeed indicates that, despite native grazing lands being globally vast, the ecosystems are on a decline. Globally, rangelands are undergoing various transformations which, in most instances, involve losses to other land uses/covers. Expansions of agricultural land, invasive vegetation, urban areas, and in some instances bare land cover are overriding these ecosystems. Although some conversions are related biophysical factors such as climatic factors, the key driving forces behind native grazing lands conversions are related to human activities.
This study presents a balanced picture by demonstrating that not all losses of native rangelands are pessimistic and not all gains are associated with better managed systems. Despite some transformations being linked to degradation of the ecosystems, such as invasive bush vegetation, increased bare cover, and reduced productivity of the ecosystems, some transformations involve productive gains.

Increasing population pressures coupled with improved technology, changing opportunities brought about by markets, and changes in social organizations and attitudes have, in many cases, resulted in the loss of grazing areas to cropping and pastures, with observable negative effects on the remaining rangelands. While such conversions may involve increased productivity of the introduced land use/land covers, caution should be taken to ensure sustainability of the landscapes. The transformations should not sacrifice the long-term ecosystem services, the resilience of the remaining grazing areas, or the modified landscapes. On a more positive note, the study observed that, in some parts of the world, conservation efforts coupled with better management of land have resulted in gains in grazing areas from other land covers other than forests, which are of high natural value.

Effective and better management of native grazing lands would be beneficial not only from an economic point of view but would also safeguard the capacity of the ecosystems to provide the larger biosphere's goods and services such as protection of the soil and serving as carbon sinks. As such, this paper supports the need of policy measures to ensure better management of native grazing systems, including minimizing undesirable conversions. Where transformations of the ecosystems are inevitable, the study supports the placement of strategic measures to ensure sustainability of both the remaining native ecosystems and the modified landscapes. This may include adoption of technologies such as conservation agriculture and production of good quality forages adapted to grazing and drought stress.

Chapter Three

3 Determinants of Land Degradation and Improvement in Kenyan Rangelands

3.1 Introduction

Kenyan rangelands are found in arid and semi-arid lands (ASALs) and comprise over 80% of the country's total area (Harding and Devisscher, 2009; Kameri-Mbote, 2005; GOK, 2012a). The ecosystems provide critical livelihood resources to over 20% of the total human population residing in these areas (GOK, 2012a; Kameri-Mbote, 2005). Extensive pastoral systems of land use prevail in the ASALs. Pastoralism not only feeds the millions in the system but also makes significant contributions to the environment (Flintan, 2011).

Rangelands also play a key role in the economic development of the country. The ecosystems support livestock and wildlife predominantly through their role as a natural resource management system (GoK 2012a; Harding and Devisscher, 2009). Over 90% of the wild game that supports wildlife tourism is found in rangelands (GoK, 2012a). In addition, in total, approximately 70% of the national livestock are found in ASALs, with more than 80% of the locally produced beef coming from the pastoral communities (Behnke and Muthami, 2011; GoK 2012a; Kameri-Mbote, 2005; Mwagore, 2003). Recent research estimates indicate that the contribution of livestock to agricultural GDP was about Kshs. 320 billion (4.54 billion US dollars) in the year 2009 (Behnke and Muthami, 2011). The amount was slightly less than that from crops and horticulture with a contribution of $5.25 billion US dollars (Behnke and Muthami, 2011). This underscores the importance of maintaining the productivity of the resource base for purposes of national development. Rangelands also serve as an important biodiversity conservation area crucial for tourism, research, and national heritage (Maitima et al., 2009; Mireri et al., 2008; Flintan, 2011; Harding and Devisscher, 2009).

The majority of the people living in ASALs are poor, the contributing factors being vulnerability to drought, marginalization, poor infrastructure, and long distances to markets (GOK, 2012a; Campbell et al. 2003). In addition, various processes over the years have impaired the dryland ecosystems, through degradation, setting the rangeland communities further into poverty and destitution. Estimates from research indicate that over the period 1982–2006, 18% of grasslands and 42% shrub-lands in the country have experienced persistent decline in biomass productivity (Le et al., 2014). This has been at the expense of livestock production, livelihood strategies, and biodiversity (Maitima et al., 2009; Campbell et al., 2003).

Figures 3.1 and 3.2 present the areas experiencing significant biomass productivity changes across rangelands in the country between the period 1982 and 2006.

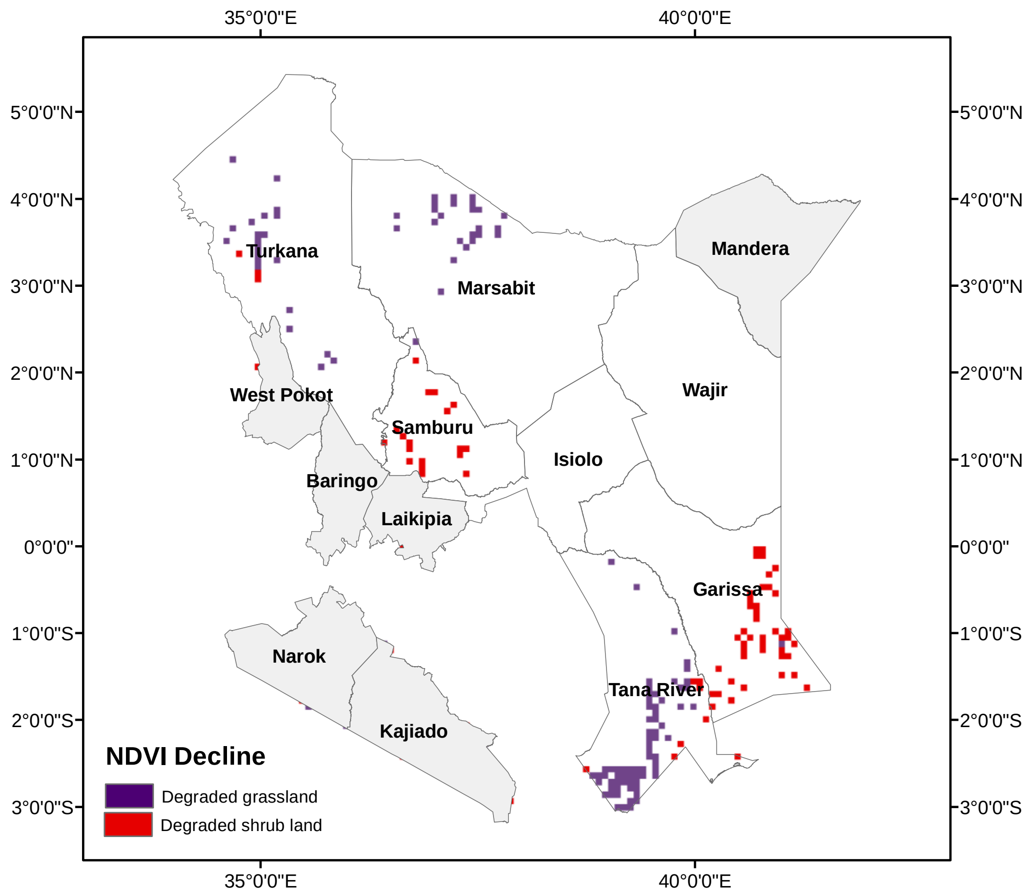


Figure 3.1: Distribution of degraded grassland and bushland pixels in rangelands
Data Source: (Le et al., 2014)[1]*.*

Figure 3.1 shows the rangeland areas experiencing persistent significant biomass productivity declines across grazing vegetation: grassland and shrubland land cover/use types. The areas with significant NDVI declines range from 0% to 12.82% of the administrative area (sub-location). Figure 3.2 presents the areas showing significant positive biomass productivity changes within the study areas.

[1]Rangelands defined as per FEWS livelihoods zones data for Kenya and are available at: http://www.fews.net/east-africa/kenya/livelihood-zone-map/march-2011. See appendix A for the livelihoods zones map

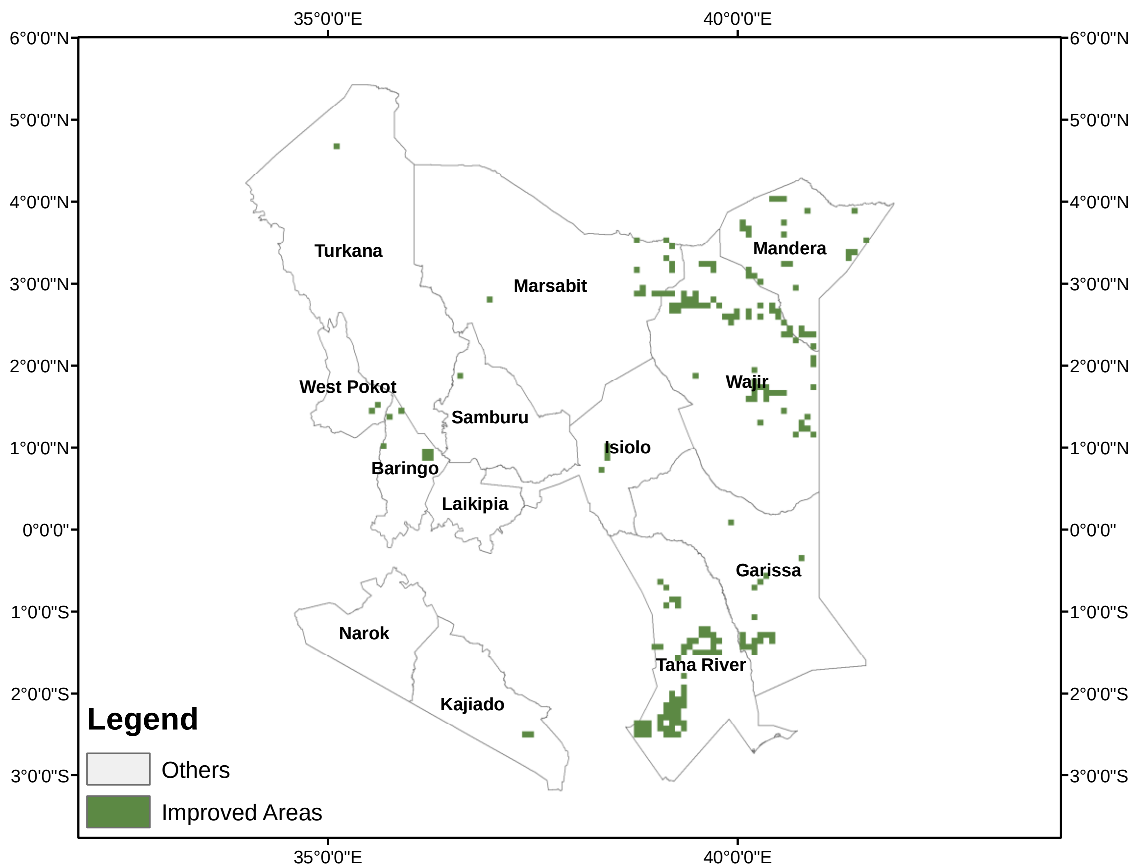


Figure 3.2: Distribution of areas with significant positive biomass productivity changes
Data Source: (Le et al., 2014).

Unlike the degraded areas, the data on areas with improved biomass productivity is not classified under various land use/land cover types. This presents a challenge in identifying whether the areas present grazing vegetation covers. In addition, invasive species such as *P. juliflora* are indicated to have colonized large parts of the ASALS areas where improved productivity is shown (Fig 3.2; Sirmah et al. 2008). With no grounding-truthing exercises of the dataset to verify the vegetation cover, the above challenges complicate possible analyses on improved vegetation cover.

Adequate policy action is needed to mitigate the adverse effects of rangeland degradation on the capacity of the ecosystems to provide essential ecosystem goods and services. Effective policy can be enhanced through an understanding of the factors driving land degradation as well as those enhancing sustainable rangeland management (SLM) (Campbell et al., 2003; Liniger et al., 2011; Akhtar-Schuster et al., 2011; Nkonya et al. 2013). This information is crucial for the planning, management, and conservation of the rangeland natural resources. Although general drivers of land degradation and SLM practices have been identified (Lambin et al., 2003; Vlek et al., 2008; Nkonya et al. 2011; Liniger et al., 2011; Akhtar-Schuster et al., 2011; von Braun et al., 2013; Nkonya et al. 2013), comprehensive analyses of the factors and their causality in different contexts is hardly sufficient to provide credible and policy-relevant scientific information (von Braun et al., 2013; Nkonya et al., 2013).

At the global and regional levels, the identified causes of land degradation are mainly based on expert opinions with less empirical analyses assessing the relationship between land degradation and the selected variables (Oldeman et al., 1990; Barbier, 1997; Bregas, 1998; Lambin et al., 2001; Lambin et al., 2003; Ravi et al., 2010; von Braun et al., 2013; Vlek et al., 2008). Similar observations are made with regard to factors enabling SLM practices in which analyses are mainly qualitative (Akhtar-Schuster et al., 2011; Liniger et al., 2011; Reed et al., 2011; Nkonya et al., 2013). Among the identified factors likely to promote SLM practices in rangelands and vice versa are the need to integrate pastoralists and other relevant stakeholders in efforts towards effective management of rangelands (Reed et al., 2007; Poulton and Lyne, 2009; Homewood et al., 2012; Hobbs et al., 2008; Upton, 2010; Liniger et al., 2011); recognition of traditional institutions in the management of rangeland resources (Reed et al., 2007; Nkonya et al., 2011; Westoby et al., 1989; Solomon et al., 2007; Angassa and Oba, 2008); knowledge constraints (Liniger et al., 2011; Akhtar-Schuster et al., 2011; Reed et al., 2011; von Braun et al., 2013); the need for policy to move away from protection/conservation to sustainable use of the natural resources with direct benefits to households (Shaoliang and Muhammad, 2011; Mekuria and Yami, 2013; Dorj et al., 2013); inadequate and poor-quality services ranging from lack of extension support to all weather roads (Neely et al., 2009; Liniger et al., 2011) ; market failures (Markelova et al., 2009; Ahuya et al., 2005; Aklilu, 2002; Hurrissa and Eshetu, 2002; Duraiappah, 1998; Hatfield and Davies, 2006; von Braun et al., 2013); institutional failures and institutional capacity constraints (Liniger et al., 2011; Akhtar-Schuster et al., 2011; Reed et al., 2011; Kirsten et al., 2009a; Meinzen-Dick and Mwangi, 2009; Kerven et al., 2012; Chavunduka and Bromley, 2011; Bruce et al., 1994; Amman and Duraiappah, 2004; von Braun et al., 2013); conflicts (Bromwich, 1980; Osman-Elasha and El Sanjak, 1980); poverty and financial constraints (Nkonya, 2008; Barbier, 1997; Duraiappah, 1998; Liniger et al., 2011; Akhtar-Schuster et al., 2011; Reed et al., 2011; Kerven et al., 2012; von Braun et al., 2013); the need to diversify the means of sustaining livelihoods to lessen pressure on rangelands (Coppock et al., 2011; Jian, 2011); power, wealth, and greed (Duraiappah, 1998; Nunow, 2011); and low economic benefits associated with traditional pastoralism (Kamara et.al, 2004; Alston et al., 1995; Campbell et al., 2005; Behnke, 1985; Hatfield and Davies, 2006). Where empirical analyses on drivers of land degradation have been made, only correlation relationships between land degradation proxies and selected biophysical and socioeconomic variables have been analyzed, with no strong causal relationships identified (Nkonya et al 2011).

Similar observations are made in the majority of the local case studies in which analyses are mainly qualitative (Turner, 1999; Ayoub, 1998; Douglas, 2006). In Kenya, there is ample qualitative research on land degradation in drylands (Flintan, 2011; Pickmeier, 2011; Temper, 2012; Homewood 2012; Hobbs et al., 2008; Meinzen-Dick and Mwangi, 2009; Mwangi, 2009; Mireri et al., 2008; Harding and Devisscher, 2009). Only a few empirical studies on drivers of rangeland degradation have been performed, with hardly any on the determinants of SLM practices (Kiage et al., 2007; Serneels and Lambin et al., 2001; Maitima et al., 2009; Greiner et al., 2013). In addition, the main focus of these studies is on land cover/use change, with no causal association to land degradation or SLM practices. Thus, there is a need for analyses on the determinants of land degradation and SLM practices to move from simplistic explanations and single-cause relationships to quantitative analyses that integrate multiple causes while identifying the causal relationship (Lambin et al., 2003; Nkonya et al 2011). In addition, the causal relationships should be carried out within social–ecological strata, such as land use zones (in this case rangelands), for more insightful analyses (Vlek et al., 2008; Sommer et al., 2011; Vu et al., 2014). Based on the above and data availability issues, this paper aims at identifying the causal relationship of the biophysical and socio-economic factors affecting SLM practices in rangelands at the national level in Kenya.

To lay ground for the analysis, the study first presents a brief review of key rangeland degradation components, the main drivers and the corresponding consequences of rangeland degradation in Kenya in Section 3.2. Thereafter, the study presents the conceptual and empirical frameworks in Section 3.3. Section 3.4 outlines the study area, data, and analysis methods. Presentation of the analyses results follows in Section 3.5, followed by a discussion of the results in Section 3.6. Finally, the conclusion and policy implications are presented in Section 3.7 of the study.

3.2 Key Rangeland Degradation Components, Drivers, and Corresponding Consequences in Kenya

3.2.1 Rangeland degradation components

As highlighted earlier, rangeland environments in Kenya are mainly found in ASALs and represent over 80% of the country's total area (Harding and Devisscher, 2009; Kameri-Mbote, 2005; GOK, 2012a). ASALs on average have rainfall ranging from 300-800 mm annually and are found in agro climatic zones IV, V, and VI (Orodho, 2006; Sombroek et al., 1982). The dominant soils in ASALs of Kenya include *Yermosols, Xerosols, Lithosols, Regosols, Solonetz, Solonchaks, Luvisols, Lixisols, Acrisols, Alisols, Ferralsols, Planosols, Vertisols,* and *Fluvisols* (Biamah, 2005). These soils are characterized by structural instability, high levels of salinity and sodicity, poor drainage, soil crusting and compaction, very low inherent fertility, and complete lack of moisture and vegetation all year round (Biamah, 2005). The range areas are further characterized by high temperatures and frequent wind storms, making the soils very vulnerable to degradation (Orodho, 2006). Degradation of the national range areas manifests itself mainly in the form of soil erosion, vegetation cover conversions, soil salinity, and physical degradation by trampling, especially around watering points (Odhengo et al., 2012; Gomes, 2006; Duraiappah et al., 2000; Mwagore, 2003; Mugai, 2004; Maitima et al., 2009; Greiner et al., 2013).

Poor protective cover of the soils brought about by vegetation clearing, overgrazing, and trampling along livestock tracks increases the vulnerability of the soils to soil erosion. These processes leave the land bare and soil exposed during periods of heavy wind or rain, thus encouraging runoff (Mwagore, 2003). With reduced cover, bare soils erode easily, leading to losses of fertile top soils (Maitima et al., 2009). Soil erosion may appear either in the form of splash erosion, sheet erosion, rill erosion, gully erosion, or wind erosion (Mwagore, 2003). In addition to soils eroding easily, removal of plant cover leads to low replenishment of soil nitrogen, phosphorous, potassium, soil organic matter, and high evaporation water losses (Maitima et al., 2009; Biamah, 2005).

Other than soil erosion, vegetation degradation is a key problem facing rangelands in the country. Over the years, succulent bushes and thorny shrubs have been on the increase in range areas at the expense of palatable grasses. Palatable perennial grass species such as *T. triandra* are on the decrease with the replacement of bare ground cover and unpalatable grass species such as *H. schimperi*, *A. adoensis* and, *Microchloa kunthii* (Orodho, 2006; Olang, 1988). Vegetation cover is also changing from grassland to bush with the encroachment of woody plants such as *Dodonaea angustifolia var. viscosa, Tarchonanthus camphoratus, Prosopis juliflora,* and *Acacia drepolobium* (Olang, 1988; Flintan, 2011; Greiner et al., 2013). Removal of natural woody savannah grassland vegetation is associated with invasive shrub vegetation (Greiner et al., 2013).

Salinity is another problem facing ASALs, and it occurs due to either natural or anthropogenic causes (Mugai, 2004; Maitima et al., 2009). Natural processes forming saline salts are accelerated by the removal of natural vegetation (Mugai, 2004). Clearance of deep-rooted native vegetation with the replacement of shallow-rooted vegetation causes a rise in the water table of the soils, thus mobilizing salts in the soil (Mugai, 2004). Accumulation of salts at the surface affects the productivity of the land, killing the protective plant cover. This leaves the land bare and vulnerable to soil erosion.

Physical degradation of rangelands by trampling, especially around watering points, is also common in the country's rangelands (de Leeuw et al., 2001). Attraction to scarce and declining rangeland water resources contracts rangeland activities into isolated pockets, especially during prolonged drought periods, resulting in trampling. The influx of pastoralists along watering points increases pressure on river banks, leading to degradation by trampling and overuse of pasture resources (Pickmeier, 2011; Gomes, 2006).

3.2.2 Drivers of Rangeland Degradation

Globally, there is high variability in biophysical factors and human-related activities associated with land degradation (Lambin et al., 2003). Efforts geared towards mitigating or halting land degradation therefore require an understanding of the various causes in specific contexts. Human-related factors, also known as anthropogenic factors, affect the biophysical state attributes, such as soils, biomass, and vegetation community structure through land use, defined as the manner in which the biophysical attributes of land are manipulated and the intent of that manipulation (Lambin et al., 2003; Lambin et al., 2006). Insights into the anthropogenic drivers of rangeland degradation are hence crucial in counteracting rangeland degradation. Understanding the biophysical drivers of rangeland degradation is also essential as they define the natural capacity for land use changes (Lambin et al., 2003). Based on a review of the literature of the various determinants of land degradation in range areas in Kenya, we categorize the key drivers into three main groups: institutional, socio-economic, environmental, and physical variables.

3.2.2.1 Institutional Variables

The pressure points which have had the greatest impact on pastoral land management have been the land reforms codifying individual rights to resources that were formerly used collectively under common property arrangements (Mwangi, 2009; Meinzen-Dick and Mwangi, 2009; Duraiappah et al., 2000; Campbell et al., 2003; Kameri-Mbote, 2005; Mwagore, 2003).

Recognition of economic opportunities with altered land holding systems coupled with the belief that mobile pastoralism was irrational and environmentally destructive has contributed to the motivation for subdivision of rangelands into individual holdings (Campbell et al., 2003; GOK, 2012a).

The transformations in land tenure have resulted in fragmented rangelands, a key cause of rangeland degradation (Flintan, 2011; Rutten 1992; Galaty and Ole Munei, 1999; Amman and Duraiappah, 2004). Fragmented rangelands result in the loss of flexibility, thus disrupting seasonal movements of livestock (Flintan, 2011). Restricted mobility leads to loss of the opportunistic spread of grazing pressure, leading to overuse of resources in the confined areas (Boone and Hobbs, 2004; Hobbs et al., 2008; Meinzen-Dick and Mwangi, 2009). This undermines the capacity of pastoral communities to sustainably use the ecosystems as well as deal with risks such as droughts. On the contrary, Lesorogol (2005) found that individual rights to pastoral resources have resulted in gains for pastoral communities. The benefits emanate from the role privatization plays in diversifying means of livelihoods in which crop farming is a supplement to livestock production.

Land alienations for private interests is another factor affecting the resource base of livestock with negative consequences on the land within confined areas. With land ownership in most rangelands falling either as trust or government land, elite segments of the Kenyan society and private developers have been allocated large tracts of land illegally near bodies of water as it is with the Tana Delta (Pickmeier, 2011). In other areas, pastoralists have been limited in the drier parts of range areas, with the remaining areas restricted for use by private undertakings. For instance, in Laikipia County, most pastoralists are limited in the drier northern parts covering 7.45% of the county, with 48 individuals privately controlling 40.3% of the rest of the land as commercial ranches or conservancies and 23 large-scale farms covering 1.48%. The individual properties are fenced off and rarely provide migration routes for pastoralists, thus limiting their mobility (Flintan, 2011). Development projects such as dam constructions and large-scale irrigation schemes have also alienated large tracts of land from common ownership, thus limiting grazing areas (Pickmeier, 2011; Nunow, 2011; Temper, 2012).

Inappropriate development policies such as those encouraging increased permanent watering points in pastoral drylands have been observed to result in degradation (Gomes, 2006). For instance, increased borehole development in ASALs attracts permanent settlement of pastoralists. Sedentarization of pastoral communities negatively affects vegetation productivity in range areas reducing ground cover and thus increases the vulnerability of the soils to soil erosion (Butt, 2010). In addition, conservation protectionism policies in some cases have been observed to lead to marginalization of pastoralists despite their ability to live successfully with wildlife. For instance, some policies such as those invariably encouraging wildlife activities to replace pastoralism instead of the two co-existing may emerge as a threat competing for pastoral land, restricting livestock mobility and access to pastoral resources which are necessary for sustainable rangeland use (Homewood, 2012; Flintan, 2011; Campbell et al., 2003; Campbell et al., 2005).

3.2.2.2 Socio-Economic Variables

Important changes in ASALs have been observed with the expansion of crop farming, especially in wetter rangeland areas (Pickmeier, 2011; Temper, 2012). In addition to changes in land tenure, the expansion of agriculture has been supported by the expansion of market opportunities for crop production, both for local consumption and for export (Campbell et al., 2005; Duraiappah et al., 2000). With the encroachment of crop farming, four forces cause degradation in these resource bases. The first is the inevitable overgrazing by pastoralists driven into small, drier grazing areas, but still maintaining large herds of livestock (Duraiappah et al., 2000; Kameri-Mbote, 2005). Better-watered locations provide important ecological functions during dry seasons. These dry-season grazing areas form part of the sustainable grazing cycle, as they relieve grazing pressures on the wet season grazing areas (Temper, 2012; Mireri et al., 2008). Loss of the well-watered areas to crop farming means lack of relief of the wet season grazing areas in dry seasons, subjecting the areas to serious environmental degradation through depletion of biomass, loss of biodiversity, and soil erosion (Mireri et al., 2008; Mwagore, 2003). Second, commercial farmers leasing land in rangelands have little incentive to make conservational investment measures on leased parcels. Once the leased parcel becomes unproductive, the commercial farmers shift and lease other parcels, creating 'dustbowl' conditions (Duraiappah et al., 2000). In addition, continued cultivation of rangelands results in much drier soils subject to soil erosion (Gachimbi, 2002). Third is the degradation by salinization caused by the irrigation of unsuitable soils and the replacement of deep-rooted natural vegetation by shallow crops (Gachimbi, 2002; Mugai, 2004). The fourth factor is nutrient mining caused by continued cultivation of the ecologically unsuitable land (Mwagore, 2003; Gachimbi, 2002).

Poverty is also observed to be a likely force driving rangeland degradation. Rangelands have the lowest development indicators and the high levels of poverty in the country (GOK, 2012a). The high incidence of poverty limits the pastoral communities' capability of mitigating their vulnerability to drought. To reduce livestock mortality during critical periods, pastoralists are observed to keep large numbers of livestock. Their goal is to maintain sufficient livestock in the face of an unpredictable physical environment. This is, however, a self-defeating mechanism, as the large number of livestock increases grazing pressure on marginal lands exacerbating livestock mortality. This sets the pastoral communities in a downward spiral of poverty (Duraiappah et al., 2000; Campbell et al., 2005). Poverty is also associated with the continued dependence on the natural resources with little adoption of appropriate technologies to increase productivity of the ecosystems in a sustainable way.

The increasing number of people searching for economic security with the growing population in the country is among the factors causing intense pressure on the pastoral natural resources (Mwagore, 2003). With the increasing population growth, rangelands serve as sinks for migrating farmers from the high-potential areas, leading to increased competition for pastoral resources (Kameri-Mbote, 2005; Campbell et al., 2005; Mwagore, 2003). On the other hand, Tiffen and Mortimore (1994) showed that population increase may compel the society to adapt mechanisms in response to challenges presented by increased pressure on land. Increased population may stimulate investments in intensification technologies to restore and improve the land resource base with the increasing population (Tiffen and Mortimore, 1994).

Increasing livestock densities is also an important factor driving rangeland degradation in the country. The population of livestock has also been on the increase with the increasing pastoralist population. An additional contributing factor to increased livestock densities are sales/leases of pastoral land in the exchange of livestock at a time when access to pastoral resources is on the decline (Duraiappah et al., 2000; Rutten, 1992). The adverse effect of increasing livestock densities accompanied by the loss of rangelands is further exacerbated by inadequate participation in markets by pastoralists (Rutto, 2014). As competing land use increases, the ability of livestock keepers to respond to potential increases in demand for livestock in livestock markets would relieve pressure on rangeland resources.

Disregard for indigenous knowledge and rangeland management strategies of pastoralists is also another factor leading to the degradation of rangelands. De-emphasizing the links and relationships between people, their culture, and resources has contributed to unsustainable practices in the management of environmental and natural resources (Mwagore, 2003). For instance, traditionally pastoralists developed an efficient system for managing resources to deal with the erratic rainfall characterizing the drylands. Herds were moved between dryland wet-season pastures, making use of the scattered rangeland resources on a large scale (Duraiappah et al., 2000; Campbell et al., 2005; Meinzen-Dick and Mwangi, 2009). As previously mentioned, restricted herd mobility has negative effects on the ecological sustainability of the pastoral resources. These observations are supported by empirical studies showing a pronounced positive relationship between cattle mobility and resource availability during dry periods, indicating the importance of mobility to resource access (Butt, 2010). In addition, the study revealed that livestock used different parts of the ecosystem at different times.

3.2.2.3 Environmental and Physical Variables

Climate is an important factor affecting productivity of rangelands in ASALs. Drought is a recurrent phenomenon that affects large areas and numbers of people living in ASALs in the country (Harding and Devisscher, 2009). During drought years, the natural production capacity of the range areas reduces, leading to pastoral communities exploiting vulnerable environmental resources, such as along water points, in order to meet livelihood needs. The intensive influx of livestock and wildlife concentrated around a few water points leads to severe vegetation and soil degradation processes (Mwagore, 2003; Pickmeier, 2011).

Additional biophysical factors affecting rangelands are land characteristics such as soil characteristics and terrain. The high temperatures and frequent wind storms in these areas further exacerbates the vulnerability of the ecosystem to degradation (Orodho, 2006). These factors combined make the areas inherently susceptible to degradation compared to other geographical areas in the country.

Drawing from the above discussions, the drivers of rangeland degradation emerge to be highly interrelated with externalities running from one factor to another. The study therefore recognizes the challenge of generalizing drivers into simple categories: under the simple generalizations, interactions of factors do come to play.

3.2.3 Consequences of Rangeland Degradation

There are various consequences of rangeland degradation in relation to humans, animals, water, soils, and the national development of the country.

Loss of ecological functions of degraded range areas has resulted in catastrophic social and economic losses in the past (Kay, 2012). With degradation of rangelands, the pastoral resources become less and less productive, resulting in the loss of livestock to hunger or quality decline, especially during drought seasons (Duraiappah et al., 2000; Mireri et al., 2008; Maitima et al., 2009). Cattle mortality is estimated to rise as high as 3 million cattle countrywide, leading to losses of about $1 billion (Western, 2009; Flintan, 2011) during a drought year. The losses incurred could be significantly higher as the estimates exclude mortality of other livestock such as sheep and goats. Loss of livestock coupled with a drop in value of degraded land results in the decrease of the income levels of pastoralists, pushing the communities further into poverty (Duraiappah et al., 2000). In addition, declining productivity of rangelands increases the vulnerability of the rural households to shocks from variable climates (Galaty and Ole Munei, 1999; Amman and Duraiappah, 2004; Mwagore, 2003). Loss of coping mechanisms during droughts also results in high loss of human life and huge expenditures of humanitarian relief, reaching heights of over of $4.0 million (Kay, 2012; Flintan, 2011).

Competition over limited and declining rangeland resources has compounded conflicts among cultivators, pastoralists, and wildlife in the range areas of the country (Kay, 2012; Orindi et al., 2007; Mogaka, 2006; Pickmeier, 2011; Maitima et al., 2009). Due to insecurity, pastoralists concentrate in some areas thought to be secure, leaving other pastures unused. The limited mobility further exacerbates the unsustainable use of the range areas, with livestock becoming more subject to diseases (Orindi et al., 2007; Notenbaert, 2007; Gomes, 2006). Prolonged and regular conflicts result in loss of wildlife, livestock, and human life. Incomes are also lost with closure of markets and with grazing areas becoming no-go zones (Flintan, 2011).

Rangeland degradation also has negative effects on biodiversity. Trends in economically useful plants over time have been on the decline with intensification of land use and the subsequent negative consequences on the ecological function of rangelands (Maitima et al., 2009). In addition, empirical studies show a strong negative correlation between soil erosion severity and plant species numbers (Maitima et al., 2009). Additionally, wildlife in some ASALs in the country is on a strong decline, with losses in some regions reaching as high as over 50 percent between the years 1970 and 1990 (Maitima et al., 2009). Among the key causes of wildlife decline is pasture scarcity, emanating from a loss of habitat through land fragmentation and conversion to cultivation and the resulting ecological instability of rangelands (Maitima et al., 2009; Harding and Devisscher, 2009; Homewood, 2012). In addition, loss of wildlife is observed as a consequence of human wildlife conflict, exacerbated by movement of wildlife into people's settlements as they look for water and pasture.

The off-site effects of rangeland degradation include effects on the tourism sectors, sedimentation of water systems, and expenditure on meat imports. Loss of wildlife emanating from degraded rangeland ecosystems has a negative impact on wildlife tourism, which is a major national development sector in the country. The tourism sector is the country's highest foreign exchange earner, and it contributes about 12% to Kenya's GDP (GOK, 2012a). In addition, the tourism sector contributes over half of the earnings from the restaurant and hotels sectors of the country, and thus the decline of wildlife would have greater implication to the country as a whole (Mogaka, 2006). With loss of flood plains and river banks to crop farmers, influx of pastoralists on limited watering points causes sedimentation of water. Other than affecting negatively aesthetic activities and exclusive settlements around water bodies, sedimentation reduces the capacity and lifespans of water bodies and leads to ecosystem damage such as risk to marine life (Mwagore, 2003).

Low productivity of rangelands is a contributory factor to Kenya's state of being a meat-deficit country. The country imports about 25-30% of its beef through illegal movement of livestock from neighboring countries (Muthee, 2006). Research suggests that if 50% of the domestic deficit meat were to be met by increased livestock production from an ASAL region, for instance, the North Eastern province alone, more than 400,000 jobs would be created, thus reducing unemployment in the region by about 2.4% each year, and producers' incomes would increase by more than Kshs 2 billion each year (Rakotoarisoa et al., 2008).

Livestock production plays a significant role in the economic development of the country (Behnke and Muthami, 2011; GOK, 2012a). As highlighted earlier, value added by livestock to agricultural GDP is significant and only slightly less than that of arable agriculture (Behnke and Muthami, 2011). Degraded rangelands are therefore likely to have a negative impact not only on livelihoods but also on the economy of the country. The total cost of milk and meat losses associated with land degradation in the country were estimated to be about 2007 US$ 49.5 million and 2007 US$ 8.7 million, respectively, for the year 2007, with the highest costs occurring in rangelands (ASALs) (Mulinge et al., 2016). When the costs associated with the weight loss of animals not slaughtered or sold is included, the estimated costs related to land degradation were estimated to be about 2007 US$ 77.9 million (Mulinge et al., 2016).

The above discussion underscores the urgent need to adopt SLM management practices in rangelands.

3.3 Conceptual and Empirical Frameworks

3.3.1 Conceptual Framework

The conceptual framework for this study is based on the ELD conceptual framework (Nkonya et al., 2011; von Braun et al., 2013; Nkonya et al., 2013; Figure 3.3). Drivers of land degradation are classified into two groups: proximate and underlying drivers. Proximate drivers of land degradation are those that directly affect land and involve physical action on land (Nkonya et al., 2011; Lambin et al., 2003). Proximate drivers as shown in Figure 3.3 are further divided into biophysical drivers and unsustainable land management practices. The underlying drivers of land degradation refer to the indirect causes of land degradation. They are also known as root causes, as they influence land use/cover through the proximate causes of degradation (Nkonya et al., 2011; von Braun et al., 2013; Lambin et al., 2003). The drivers of land degradation determine its level, which ultimately determines its outcomes/effects. Action can be taken, however, to halt or mitigate rangeland degradation (Figure 3.3). The action taken can be to control either the causes of land degradation, the levels of degradation, or its effects (Nkonya et al., 2011).

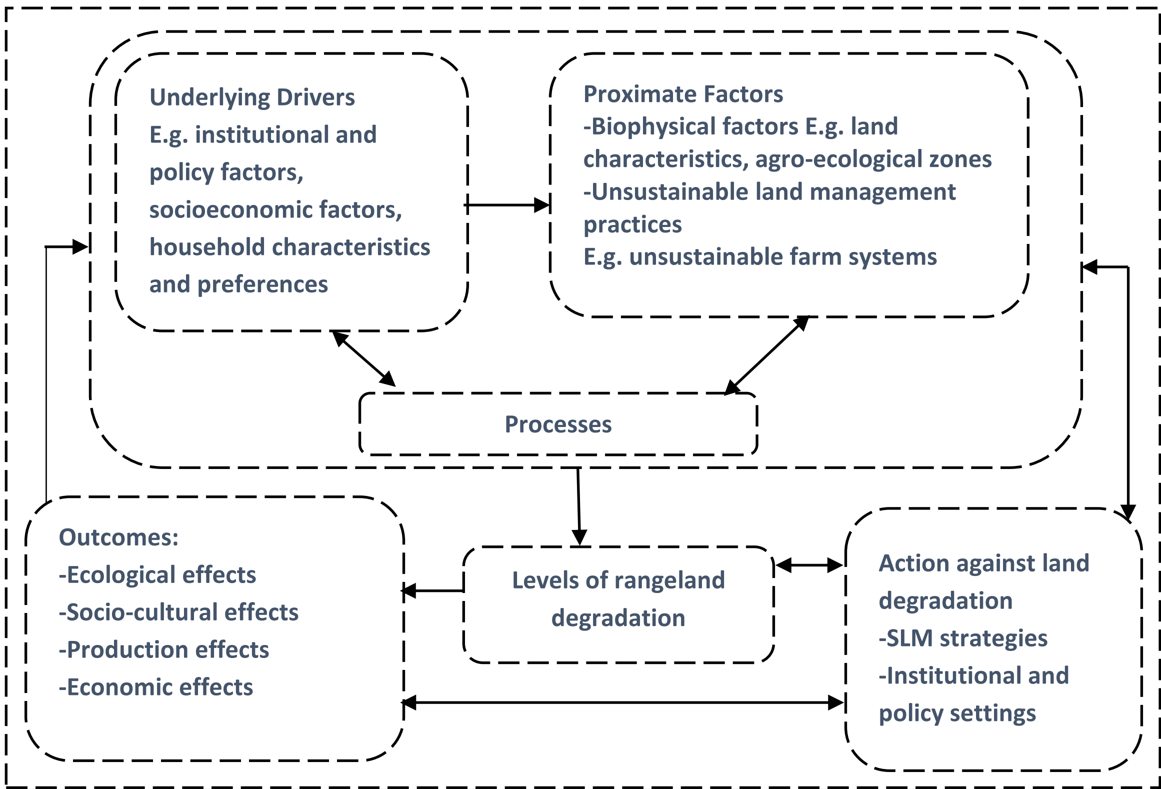


Figure 3.3: Conceptual Framework: Determinants of land degradation and SLM adoption
Source: Adapted from Nkonya et al. (2011) with modifications by the author

There exists ample empirical evidence that the factors driving land degradation are similar to those inhibiting the adoption of SLM practices (Nkonya et al., 2016a; Shiferaw et al., 2009; Prokopy et al., 2008). For instance, empirical studies show that decisions on the adoption of SLM practices depend on biophysical environments such as the slope of land and agro ecological zones (Pagiola, 1996; Pender et al., 2006; Gillespie et al., 2007; Kim et al., 2004).

Additional factors influencing adoption of best practices on natural resource management include incentives such as input and output prices (Shiferaw and Holden, 1999; Shiferaw and Holden, 2000; Pagiola, 1996); access to markets, production diversification and off-farm income opportunities (Tiffen et al., 1994; Pender et al., 2006; Pender and Kerr, 1998; Gillespie et al., 2007; Kim et al., 2004; Shiferaw and Holden, 1998); poverty, capital constraints, farm resource assets, income, and wealth (Grepperud, 1997; Shiferaw and Holden 1999; Prokopy et al., 2008; Kim et al., 2004; Gillespie, et al., 2007; Pender et al., 2006); human capital resource and other household characteristics (Shiferaw and Holden, 1998; Pender and Kerr, 1998; Park and Lohr, 2005; Gillespie et al., 2007; Kim et al., 2004; Prokopy et al., 2008); land tenure (Shiferaw and

Holden 1999; Ahuja, 1998); access to extension services, information asymmetry, and farmer participation (Park and Lohr, 2005; Pender et al., 2006; Tiffen et al., 1994a; Gillespie et al., 2007; Prokopy et al., 2008); and technology characteristics such as labor demand (Shiferaw and Holden, 1998; Shiferaw et al., 2009).

Based on the synthesis of the SLM adoption literature and data availability issues, adoption of SLM practices on Kenyan rangelands is conditioned on the identified factors.

3.3.2 Empirical Framework

To assess the determinants of SLM adoption on Kenyan rangelands, a binary probit model was chosen due to the nature of the dependent variable which is measured on a binary scale: $Y_i = 1$ if a household adopted SLM practices in rangeland management, and otherwise $Y_i = 0$.

The observed decision (Y_i) is however assumed to represent a latent variable Y_i^* which represents households' utility acquired from adopting SLM practices. Y_i is observed if the underlying latent variable Y_i^* exceeds a certain threshold following the decision rule:

$$Y_i = \begin{cases} 1 \text{ if } & Y_i^* > 0 \\ 0 \text{ if } & Y_i^* \leq 0 \end{cases} \tag{3.1}$$

Adoption of SLM practices is specified as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 z_i + u_i \;\; ; u_i \sim NID(0, \sigma^2) \tag{3.2}$$

where

Y	is adoption of SLM technologies
x_1	is a vector of biophysical factors (e.g. soil type, slope, agro-ecological zones)
x_2	is a vector of household characteristics (e.g. age, gender, education, household size)
x_3	is a vector of socio-economic factors and asset endowment (e.g. cultivable land, livestock wealth, poverty, off-farm income)
x_4	is a vector of institutional and policy factors (e.g. extension services, credit facilities, land tenure, market opportunities)
z_i	is a vector of vector district-fixed effects and
u_i	captures stochastic disturbances, assumed to be normally distributed.

Other than relying on the literature to correctly specify the model, the study carries out robust checks to check for model misspecifications (Dimara and Skuras, 2003). The study also employs instrumental variable (IV) estimation to address possible endogeneity issues likely to arise. The robustness of the regression results is made by comparing the results of the probit model and the instrumental variable (IV) estimations.

3.4 Study area, data, and analysis methods

3.4.1 Description of the Study Area

The study is conducted in thirteen counties in Kenya located in the dry lands (arid and semi-arid lands [ASALs]) of the country. The counties include Turkana, Marsabit, Mandera, West Pokot, Samburu, Isiolo, Wajir, Garissa, Baringo, Laikipia, Narok, Kajiado, and Tana River. The production system in these counties is either largely pastoralism or agro-pastoralism (Fig. 1.7). These counties are endowed with a variable climate and have the highest incidence of poverty in the country (GOK, 2012a; Campbell et al., 2003; Orodho, 2006; Sombroek et al., 1982). Livestock production remains the key component of agricultural production in these areas, with pastures forming the main feed for livestock.

3.4.2 Data

The data set used in the analysis comes from the Kenya Integrated Household Budget Survey (KIHBS) 2005/06, a national survey conducted in 2005/06 over a period of 12 months (KNBS, 2005/06a; KNBS, 2005/06b). The last national survey of this nature was conducted in the early 1980s (KNBS, 2005/06a). No current national surveys exist. The extensive dataset covers all possible seasons and was drawn from each of the country's districts, including all ASALs (KNBS, 2005/06a; KNBS, 2005/06b). A multistage sampling procedure was followed in the data collection process. In the first stage, urban and rural clusters were drawn from each of Kenya's 70 districts. In total, the survey covered a total of 1,343 clusters (KNBS, 2005/06a; KNBS, 2005/06b). In the second stage, 10 households were selected, with equal probability from each of the clusters, giving a total sample of 13,430 households. Of the total 13,430 households sampled, 2190 households are within the focus area of the study. The geographical location of all the households surveyed was captured using the Geographical Positioning System (GPS) enabling their precise location. The KIHBS dataset provides detailed data on agriculture holdings, agriculture input and output, livestock information, household consumption, and purchase information, among others (KNBS, 2005/06a; KNBS, 2005/06b).

Data on geographical areas with persistent decline in biomass productivity was obtained from the dataset from Le et al. (2014). The data estimates persistent decline in biomass productivity using the long-term trend of inter-annual mean Normalized Difference Vegetation Index (NDVI) over the period of 1982–2006 (Le et al., 2014). The long-term NDVI data is derived from Advanced Very High Resolution Radiometer (AVHRR) 8km NDVI and has been calibrated and corrected for rainfall and atmospheric fertilization effects (Le et al., 2014). In addition, the data has been masked for ineligible pixels and saturated NDVI zones (Le et al., 2014). Grounding-truthing exercises of the dataset have been conducted in various countries, including Senegal, Niger, Ethiopia, and Tanzania. The exercise involved selection of both land degradation hotspots and improvement bright spots for the major land use/land cover in each country. Though grounding-truthing was not conducted in Kenya, the exercises conducted in the other countries verified the land productivity estimates obtained and thus determined the reliability of the remotely sensed data used in the analysis. In addition, field visits in southwestern Kenya coupled with experts' inquiries in southeastern Kenya verified the land conditions as portrayed in the satellite data. Furthermore, comparative analyses on productivity trends in the country using Moderate Resolution Imaging Spectroradiometer Normalized Difference Vegetation Index (MODIS/NDVI) of higher resolution (250m) have been conducted in existing studies (Waswa, 2012). In the study by Waswa (2012), the accuracy of the productivity estimates using remote sensing data analysis was verified using the Land Degradation Sampling Framework (LDSF). Accuracy of the data used is further verified by similar results of other studies analyzing productivity trends (degradation) in Kenya (Bai and Dent, 2006; Pricope et al., 2013).

3.4.3 Description of Variables

The dependent variable in the analysis is adoption of SLM practices in rangelands. SLM practices in rangelands involve investment in improved grassland management such as pasture establishment, control of bush encroachment, rotational grazing, tree planting, and investments in soil conservation measures (soil erosion measures), among other measures (Nkonya et al., 2016b; UNDP-Kenya, 2013; Liniger et al., 2011). Investments in improved grassland management practices have various production, economic, socio-cultural, and ecological benefits (Nkonya et al., 2016b; Liniger et al., 2011). Among the ecological benefits are biodiversity conservation, vegetation regeneration, improved soil cover, reduced loss of top soil through erosion (by water/wind), increased soil fertility, increased biomass/above-ground carbon (Liniger et al., 2011; Nkonya, E et al., 2016). For example, pasture establishment and rotational grazing are likely to lead to improved soil cover (Nkonya et al., 2016b; UNDP–Kenya, 2013; Liniger et al., 2011). Improved soil cover in semi-arid areas of the country is indicated to reduce runoff to almost zero (Liniger et al., 2011). Tree covers such as acacia trees are also indicated to preserve high-value perennial grasses, even in overgrazed areas (Liniger et al., 2011). Some tree species are also indicated to be suitable for rehabilitation and prevention of land degradation in rangelands, such as around water sources (UNDP–Kenya, 2013) of degraded areas. Production, economic, and socio-cultural benefits include increased fodder production, increased animal productivity, and food security (Nkonya et al., 2016b; Liniger et al., 2011)

The grazing systems in Kenyan rangelands are based on a transhumance grazing system, defined as the regular movement of livestock in defined areas so as to exploit the seasonal availability of pasture resources (Liniger et al., 2011). This traditional system involves grazing rotation strategies and the establishment of pasture reserves for the dry season (Reid et al., 2005). The study therefore evaluates the adoption of additional SLM practices in rangelands other than rotational grazing.

Table 3.1 provides the descriptive statistics of the variables used in the estimation. About 14.2% of the households in the sample adopted improved grassland management practices beyond the transhumance grazing systems explained above.

Table 3.1: Description of dependent and explanatory variables

Variable	***Description/measurement***	***Mean***	***Std.Dev***
Dependent variable			
SLM	Investment in improved grassland management, such as pasture establishment (paddock grass) (1=Yes, 0=No).	0.142	0.349
Explanatory Variables			
Household characteristics			
Hhsize	Household size	4.458	2.822
Gender	Female headed household (1=Female, 0=Male)	0.375	0.484
Education	Level of household education (years)	3.649	4.834
Education squared	Level of household education (years) squared	34.534	55.713
Age	Age of household (years)	43.949	17.585
Age squared	Age of household, squared	2241	1822
Fertility	Maternal age at first birth (years)	14.252	6.376
Socio-economic factors and asset endowment			
Cropped area	Land operated by a household for crop farming activities (Acres)	2.200	6.837
TLU	Herd Size (TLU)	28.491	60.920
Otherinc	Nonfarm income (1=Yes, 0=No)	0.162	0.368
Poverty level	Household real per capita consumption is below the poverty line (1=Yes, 0=No)	0.517	0.500
Biophysical factors			
Slope	Slope of parcel (Base Flat)		
	Slight Slope	0.363	0.481
	Moderate Slope	0.153	0.360
	Steep/Hilly	0.043	0.203
Soiltexture	Soil Texture (Base Sandy)		
	Loamy	0.501	0.500
	Between Sand and Clay	0.397	0.489
	Clay	0.044	0.205
Agrozone	Agro-ecological zones (Arid =0, Semi-Arid=1)	0.390	0.488
Land Degradation	Persistent decline in biomass productivity (1=Yes, 0=No)	0.080	0.271
Institutional and policy factors			
Extension	Access to extension services (1=Yes, 0=No)	0.082	0.275
Credit	Access to Credit (1=Yes, 0=No)	0.220	1.693
Market access	Distance to the market (km)	2.412	2.998
Land tenure	Household has title to land (1=Yes, 0=No)	0.053	0.224
Observations	***1,381***		

Source: KIHBS 2005/06 survey data

The distribution of the number of households adopting SLM practices varies across districts as shown in Fig 3.4 and 3.5. Among the SLM practices highly adopted are the establishment of pastures and capital investment in land improvements such as bush control. Based on the SLM adoption literature, the main determinants of SLM adoption in rangelands are as shown in Table 3.1.

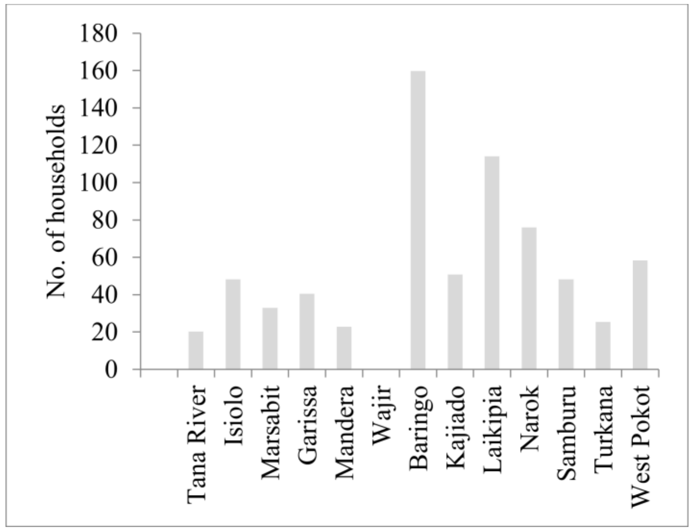


Fig. 3.4: Number of households adopting SLM practices in Kenyan Rangelands

3.5 Results

3.5.1 Model Performance

Regression estimates from the probit model on the determinants of SLM adoption in Kenyan rangelands are presented in Table 3.2. To evaluate the analysis results, the study carried out the linktest specification and the “collin” tests. The Pregibon (1980) linktest was employed to test whether the models were specified correctly. If a model is specified correctly, then the prediction squared in the linktest would have no explanatory power. The linktest for model specification failed to reject the null hypothesis that the model was correctly specified.

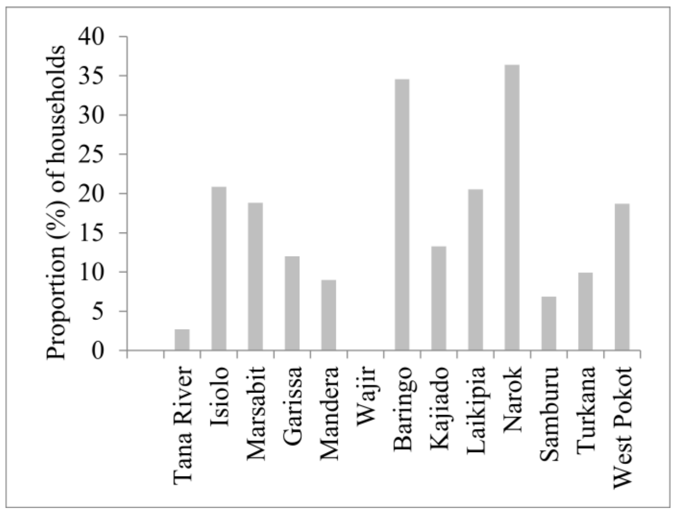


Fig. 3.5: Proportion of households adopting SLM practices in Kenyan Rangelands

Source: KIHBS 2005/06 survey data

Though the problem of multicollinearity cannot be clearly defined, since it violates none of the classical assumptions (Wooldridge, 2012), it is better to have less correlation between independent variables.

High correlation between two independent variables makes it difficult to uncover the partial effect of each variable. Using the “collin” test, a smaller condition number indicates less collinearity between the independent variables compared to larger values. As a rule of thumb, a condition number of greater than 10 indicates the presence of multicollinearity problems. The “collin” test indicates no multicollinearity problems, with the condition number being below 10, and even this is mostly driven by the presence of both level and squared terms. The likelihood ratio test measuring the goodness of fit of the model indicates that the model is highly significant (Table 3.2). Robust standards errors are employed.

3.5.2 Determinants of SLM adoption: Probit model

The regression results indicate several biophysical, institutional and policy, socio-economic, and household characteristics as key factors influencing SLM adoption in the country (Table 3.2).

Among the key biophysical factors influencing SLM adoption is the persistent decline in biomass productivity, a proxy for land degradation. Households in areas experiencing land degradation are more likely to adopt SLM practices by 17.4 percentage points. Additional biophysical factors influencing SLM adoption include land erodibility characteristics. Two land erodibility measures were assessed: soil texture and slope of land. With regard to soil texture, taking sandy soils as the base soil texture, results show that SLM practices are more likely to occur on loamy soils by 15.8 percentage points. In terms of the slope of the land, while taking flat areas as the base slope of land, the probability of SLM adoption increases by 14.2 and 19.7 percentage points on parcels with moderate slopes and steep/hilly slopes, respectively. Agro-ecological zones also significantly influence SLM adoption, where households in the high-potential rangelands (semi-arid areas) are more likely to adopt SLM practices by 51.8 percentage points.

The institutional and policy variables having a significant effect on SLM adoption include access to extension services, distance to the market, and land tenure (Table 3.2). The results indicate that SLM adoption increases with access to extension services by 14.0 percentage points. Households with limited market access are less likely to adopt SLM practices by 8.7 percentage points, while private land ownership increases the probability of adoption by 6.8 percentage points.

Adoption of SLM practices is also significantly influenced by socioeconomic variables. Households below the poverty line, measured as Kshs 1,562 and Kshs 2,913 for rural and urban areas, respectively (KNBS, 2007), are less likely to adopt SLM practices by 9.8 percentage points. The results also indicate that improved grassland management practices are likely to be lower for households with larger cropped areas.

Table 3.2: Determinants of SLM adoption: Probit regression

	SLM Practices in Rangelands			
	Probit regression		**Marginal Effects**	
Variable	**Coeff.**	**Std. Errors**	**Coeff.**	**Std.Errors**
	(1)	(2)	(3)	(4)
Household characteristics				
Household size	-0.038**	0.017	-0.010**	0.004
Female headed household (1=Female, 0=Male)	-0.088	0.100	-0.023	0.026
Level of household education (years)	0.074**	0.032	0.019**	0.008
Level of household education (years) squared	-0.004	0.003	-0.001	0.001
Age of household (years)	-0.009	0.011	-0.002	0.003
Age of household, squared	0.000	0.000	0.000	0.000
Socio-economic factors and asset endowment				
Cropped Area (Acres)	-0.020*	0.011	-0.005*	0.003
Herd Size (TLU)	0.001	0.001	0.0003	0.0003
Nonfarm income (1=Yes, 0=No)	-0.498	0.379	-0.130	0.099
Poverty level (1= Household is below the poverty line, 0=Otherwise)	-0.377***	0.105	-0.098***	0.027
Institutional and policy factors				
Access to Credit (1=Yes, 0=No)	-0.149	0.183	-0.039	0.048
Distance to the market (km)	-0.335***	0.100	-0.087***	0.026
Access to extension services (1=Yes, 0=No)	0.535***	0.128	0.140***	0.033
Household has title to land (1=Yes, 0=No)	0.259**	0.119	0.068**	0.031
Biophysical factors				
Soil Texture (Base=Sandy)				
Loamy	0.606***	0.224	0.158***	0.058
Between Sand and Clay	0.307	0.305	0.077	0.060
Clay	0.295	0.232	0.080	0.079
Slope of parcel (Base=Flat)				
Slight Slope	0.117	0.103	0.031	0.027
Moderate Slope	0.543***	0.164	0.142***	0.042
Steep/Hilly	0.756***	0.237	0.197***	0.061
Agro-ecological zones (Arid =0, Semi-Arid=1)	1.985***	0.299	0.518***	0.075
Degraded Land (1=Yes, 0=No)	0.668***	0.146	0.174***	0.037
District Dummies (13)	**Yes**	**Yes**	**Yes**	**Yes**
Constant	-1.852***	0.468		

Observations = 1,381 **Pseudo R-squared** = 0.335
LR chi2(32) = 641.23 **Prob > chi2** =0.000
Log likelihood = -636.561

The results also indicate that household characteristics are key factors influencing the adoption of SLM practices in rangelands. The education level of a household head increases the probability of SLM adoption by 1.9 percentage points, while the number of family members providing unpaid labor, proxied by household sizes, reduces the adoption of SLM practices in rangelands by 1.0 percentage points.

3.5.3 Simultaneity issues

The judgment on potential endogenous variables in this study, as a standard practice, was guided by economic theory. The study acknowledges the debate surrounding the poverty-environmental degradation nexus (Bremner et al., 2010; Duraiappah, 1998). The vicious circle model (VCM) concept of poverty and the environment illustrates not just how poverty growth impacts the environment, but also how the environment affects poverty (Bremner et al., 2010; Kerven et al., 2012; Barbier, 1997; Duraiappah, 1998). This indicates the likelihood of an endogeneity problem between poverty and SLM adoption. To correct for this, this study employs IV estimation.

There exists ample empirical evidence on the strong correlation between female education and development, including the economic performance of households not only in developing countries but also worldwide (Browne and Barrett, 1991; LeVine et al., 2001 and Drèze and Murthi, 2001). On the other hand, fertility rates, measured by early childbearing age, are indicated to have a negative effect on female education and consequently on poverty (Heck et al., 1997; Klepinger et al., 1995; Moore and Waite 1977; Waite and Moore 1978; Cardoso and Verner, 2006). Fertility rates are also shown to have a direct impact on the poverty level of households (Gupta and Dubey, 2003).

An assumption might be made that age at first birth is highly correlated with household sizes (as influenced by children ever born and living). This assumption might be been true where most births occur within a monogamous union (Ngalinda, 1998). The assumption, however, does not hold where a considerable share of births occur out of wedlock, with use of contraceptive methods, in polygamous unions and where extended family members make up a particular household, as is true of rural households in Kenya (Ngalinda, 1998; KNBS, 2005/2006a; KNBS & ICF Macro, 2010). This shows household sizes are not just confined to age at first birth. The “collin” test further indicates no multicollinearity problems, showing no high correlations among explanatory variables. Age at first birth, on the other hand, has a great influence on women's education in Kenya, which affects the economic development of a household (KNBS & ICF Macro, 2010). The study therefore uses fertility, measured as maternal age at first birth (Heck et al., 1997; Moore and Waite 1977; Waite and Moore 1978), as an instrument for household poverty in the IV estimation.

Table 3.3 presents the regression results of the IV estimation. For the instrument to be valid, fertility should be highly correlated with poverty level and uncorrelated with the error term of the IV model (Fisher, 2005; Klepinger et al., 1995).

Table 3.3 Determinants of SLM adoption: IVProbit regression

Variable	1st stage reg		2nd stage reg.		Marginal effects[1]	
	Coeff.	**Std. Errors**	**Coeff.**	**Std. Errors**	**Coeff.**	**Std. Errors**
	(1)	(2)	(3)	(4)	(5)	(6)
Household characteristics						
Household size	0.023***	0.004	-0.029	0.018	-0.008	0.006
Female headed household (1=Female, 0=Male)	-0.081***	0.021	-0.094	0.094	-0.028	0.030
Level of household head education (years)	-0.019**	0.007	0.068*	0.035	0.020*	0.011
Level of household head education, squared	0.002***	0.001	-0.004	0.003	-0.001	0.001
Age of household head (years)	-0.005**	0.002	-0.010	0.010	-0.003	0.003
Age of household head, squared	0.000***	0.000	0.000	0.000	0.000	0.000
Socio-economic factors and asset endowment						
Cropped Area (Acres)	0.001	0.001	-0.020**	0.009	-0.006*	0.003
Herd Size (TLU)	-0.0002	0.0002	0.001	0.001	0.0003	0.0003
Nonfarm income (1=Yes, 0=No)	-0.029	0.067	-0.484	0.381	-0.165	0.149
Poverty level ((1= Household is below the poverty line, 0=Otherwise)			-0.545***	0.172	-0.165***	0.056
Institutional and policy factors						
Access to Credit (1=Yes, 0=No)	-0.115***	0.041	-0.189	0.211	-0.059	0.071
Distance to the market (km)	0.018	0.022	-0.329***	0.095	-0.102***	0.038
Access to extension services (1=Yes, 0=No)	0.051**	0.025	0.558***	0.120	0.143***	0.050
Household has title to land (1=Yes, 0=No)	-0.080***	0.028	0.239**	0.119	0.066*	0.039
Biophysical factors						
Soil Texture(Base=Sandy)						
Loamy	-0.120**	0.060	0.592***	0.199	0.174**	0.072
Between Sand and Clay	-0.127**	0.062	0.280	0.208	0.081	0.058
Clay	-0.148**	0.073	0.300	0.285	0.079	0.065
Slope of parcel (Base=Flat)						
Slight Slope	0.006	0.022	0.120	0.106	0.035	0.029
Moderate Slope	-0.057*	0.032	0.521***	0.172	0.130***	0.037
Steep/Hilly	0.473***	0.060	0.840***	0.232	0.172***	0.061
Agro-ecological zones (Arid =0, Semi-Arid=1)	-0.093*	0.049	1.993***	0.366	0.634***	0.058
Degraded Land (1=Yes, 0=No)	0.000	0.035	0.668***	0.171	0.161**	0.067
District Dummies(13)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Instrument						
Fertility- maternal age at first birth	-0.052***	0.002				
Constant	0.899***	0.097	-1.807***	0.479		

Observations= 1381 **Wald chi2(32)** =409.67 **Prob > chi2** = 0.000 **Log likelihood =** -940.149
Wald test of exogeneity= (/athrho = 0): chi2(1) = 1.59 Prob > chi2 = 0.208, *** p<0.01, ** p<0.05, * p<0.1

1 Probability of positive outcome. By default, mfx compute after ivprobit calculates the linear prediction, and thus would simply return the estimated coefficients. The study therefore estimates the marginal effects on the probability of a positive outcome.

The first stage regression shows that poverty is negatively associated with maternal age at first birth, consistent with the empirical literature (Heck et al., 1997; Moore and Waite 1977; Waite and Moore 1978; Table 3.3). The test on whether the instruments employed are independent of the error can only be carried out on the condition that the equation is over identified (more than one instrument), which is not the case here due to the instrument-choice challenge (Fisher, 2005; Klepinger et al., 1995). However, a regression of the dependent variable on the instrument can be used as an indication of the appropriateness of the instrument used (Fisher, 2005). A regression of SLM adoption on fertility (maternal age at first birth) indicated that fertility had no direct effect on SLM adoption, giving some assurance regarding the instrument choice (Fisher, 2005). Having identified an instrument, the study carries out an exogeneity test to examine whether poverty is exogenous to SLM adoption. The Wald test of exogeneity fails to reject the null hypothesis of exogeneity, thus there is no endogeneity bias in the probit estimates, and the estimators are consistent. The IV estimation gives similar results to those of the probit model, indicating the robustness of the regression results.

3.6 Discussions

SLM practices have the potential of maintaining the capacity of land to provide essential goods and services in the present and in the long term (Liniger et al., 2011; Pender et al., 2006). Most importantly, SLM practices have the capacity to maintain the agricultural productivity of land with important ecological, economic, and socio-cultural effects (Pender et al., 2006; Shiferaw et al., 2009; Liniger et al., 2011). SLM practices may, however, require additional inputs, leading to such alarmingly low adoption rates, especially among poor rural households in developing countries (Pender et al., 2006; Shiferaw and Holden, 1998; Shiferaw et al., 2009; Liniger et al., 2011). This is in agreement with the findings of this study, in which only about 14.2% of the households surveyed had adopted SLM practices in rangeland management.

Despite this, there are several factors that condition the adoption of SLM practices. Among the key biophysical factors influencing adoption of SLM practices are agro-ecological and land characteristics. Similar to the findings of Pender et al. (2006), SLM adoption is likely to be higher in high-potential areas, in this case the semi-arid areas. As indicated by Shiferaw et al. (2009), the returns on investments in SLM practices are influenced by several factors, such as climate. This implies that the benefits of SLM adoption are likely to be higher in the semi-arid areas characterized by higher potentials compared to the drought-prone the arid areas. Land characteristics such as soil texture and slope of land also influence the adoption of SLM practices. Households on land with higher physical erosion potential/greater erodibility are likely to adopt SLM practices (Shiferaw and Holden, 1998; Pender and Kerr, 1998; Gillespie et al., 2007; Kim et al., 2004). Adoption of SLM practices is also found to be highly in response to land degradation. This is in agreement with the observations in many developing countries where SLM practices are mainly adopted as intervention measures to reverse and restore degrading lands rather than as preventive measures (Shiferaw and Holden, 1998; Pender et al., 2006). The findings highlight the importance of information and perception issues. Households are likely to adopt SLM practices when they perceive degradation as a key factor affecting the productivity of their land and also their livelihood (Shiferaw et al., 2009). Along with other complementary factors, stimulating awareness and action among rural households in developing countries on the benefits and risks associated with land degradation versus SLM adoption is likely to lead to adoption of SLM practices as preventive measures rather than as intervention measures.

Institutional and policy factors are among the key variables in influencing SLM practices in rangelands. For instance, access to output markets increases the value of production (Pender et al., 2006). This translates to higher returns for adoption of SLM practices (Tiffen et al., 1994; Pender et al., 2006). Constrained market access on the hand leads to higher transactional costs and negatively affects SLM adoption (Pender and Kerr 1998). In addition, limited access to markets is also associated with low probabilities of rangeland conversions to other land use (Serneels and Lambin, 2001). With low transformation of the grazing cover, the traditions systems of grazing based on transhumance are likely to be adequate for sustainable rangeland management, thus negating the need to adopt additional SLM techniques.

Lack of information on the potential benefits, costs, and risks associated with land degradation or SLM adoption is a key factor limiting the adoption of SLM practices (Gillespie et al., 2007; Park and Lohr, 2005; Shiferaw et al., 2009). Extension services associated with diffusion of information, creation of awareness, training, and promotion of SLM practices increase adoption rates among households (Liniger et al., 2011; Tiffen et al., 1994). The presence of extension services is, however, not always associated with the adoption of SLM practices, especially in cases in which extension officers are inadequately trained and lack appropriate extension packages (Liniger et al., 2011). Land tenure is also observed to have significant effects on the adoption of SLM practices. Secure land tenure increases the planning horizon of a household, thus increasing the probability of SLM adoption (Liniger et al., 2011; Kabubo-Mariara, 2007; Shiferaw and Holden, 1998; Ahuja, 1998).

Adoption of SLM practices is also influenced by the capacity of a household to invest in sustainable practices (Grepperud, 1997; Shiferaw and Holden, 1999; Shiferaw and Holden, 1998; Gillespie et al., 2007). This is illustrated by the effect of poverty on SLM adoption. High poverty levels raise the time preference of households, leading to lower adoption levels of SLM, which are mostly associated with longer planning horizons (Shiferaw and Holden, 1999; Shiferaw and Holden, 1998). Increased cropped areas are associated with less adoption of SLM practices on rangelands. This effect may be driven by competing labor and constraints between SLM adoption on cropped areas and grassland management (Pender and Kerr, 1998). This finding is consistent with observations of the negative effect of farm size on SLM adoption (Pender et al., 2006).

Human capital endowments are also found to be important in determining SLM adoption (Gillespie et al., 2007; Park and Lohr, 2005; Pender and Kerr, 1998; Kim et al., 2004). Households with higher educational levels are more likely to adopt SLM practices. As indicated by Shiferaw et al. (2009), education is likely to enhance the perception of degradation being a problem as well as to increase information on available SLM practices/technologies. On the other hand, household sizes are observed to reduce the probability of SLM practices on grazing land management. In rangelands in which extensive systems of livestock production are practiced, household sizes indicate the availability of unpaid labor to adopt labor-intensive practices such as transhumance or rotational grazing (Gillespie et al., 2007). It is therefore expected that households with more unpaid labor in ASALs are less likely to adopt intensive improved pasture management practices such as pasture establishment.

3.7 Conclusions and Policy Implications

Land degradation is a major problem affecting the sustenance of rangelands in Kenya. Recent estimates indicate that land degradation affects about 18% of grasslands and 42% of shrub lands in the country. Rangeland degradation has significant negative effects on human welfare, animal productivity, water, soils, and national development. For instance, the total milk and meat losses associated with land degradation in the country were estimated be about 2007 US$ 49.5 million and 2007 US$ 8.7 million, respectively, for the year 2007, with the highest costs occurring in rangelands (ASALs).

Despite the increasing rangeland degradation problem, the adoption rates of SLM practices are alarmingly low among rural households in developing countries, including in the ASALs of Kenya. This necessitates the identification of factors that condition the adoption of SLM practices among rural households in rangelands. SLM adoption is found to be highly response to land degradation. SLM practices are adopted as intervention measures to reverse and restore degrading lands. When not affected by degradation, less adoption rates are likely to occur. This highlights the importance of information and perception issues, as households are likely to adopt SLM practices when they perceive degradation as a significant factor affecting production and their livelihood. Stimulation of awareness and action among rural households on the opportunity cost of inaction against land degradation is therefore identified as a key factor likely to facilitate the adoption of SLM practices. This is in agreement with the positive effect access to extension services has on SLM adoption where extension services are associated with increased awareness of the problems of land degradation. Additional factors influencing SLM adoption include agro-ecological and land characteristics, access to output markets, capacity of a household to invest in sustainable practices, and human capital endowments.

From these findings, key policy implications can be drawn. Policies promoting raising awareness of the effects of rangeland degradation and on various SLM options/technologies available are likely to facilitate SLM adoption among rural households. Information on possible SLM options is likely to increase adoption among rural households, as this will allow households to adopt techniques depending on their unique socio-economic characteristics. In addition, capacity building and training of households on various SLM techniques is also likely to increase adoption rates. A possible approach to achieve this is through the expansion of extension services and Farmer Field Schools (FFS) in rangelands. Policies facilitating institutional capacity building of extension services on innovative SLM practices are also likely to enhance SLM adoption. Furthermore, policy action empowering livestock producers to participate in high-value product markets, such as niche markets, is also likely to increase economic incentives in adopting SLM practices.

Chapter Four

4 Improving Access to Livestock Markets for Sustainable Rangeland Management

4.1 Introduction

Livestock production is a key component of Kenyan rangelands and indeed for rangelands in Sub Saharan Africa found in the ASALs. About 70% of the nation's livestock is found in the ASALs, valued at about Kshs. 70 billion (GOK, 2012a). Livestock production also plays a key role in the economic development and welfare of the county. Recent estimates indicate that the value added by livestock to the agricultural GDP is about US$4.54 billion, slightly less than that from arable agriculture with a contribution of US$5.25 billion (Behnke and Muthami, 2011; GOK, 2012a). Livestock production also provides a source of livelihood to about 14 million people residing in the ASALs and millions of others through backward and forward linkages (GOK, 2012a).

Extensive systems of livestock production prevail in the ASALs where pastures provide the main feed for livestock as well as other herbivores found in the rangelands. This highlights the need to maintain the productivity of the grazing systems with regard to the role they play in livestock production. However, rangelands in the country are being impaired by degradation manifested in the form of soil erosion, vegetation cover conversions, and salinity (Greiner et al., 2013; Odhengo et al., 2012; Flintan, 2011; Pickmeier, 2011; Maitima et al., 2009; Harding and Devisscher, 2009; Gomes, 2006; Mugai, 2004; Duraiappah et al., 2000; Olang, 1988). Among the resulting consequences of degradation are the declining productivity of the ecosystems with negative effects on livelihoods.

Numerous studies have been carried out identifying the driving forces of the observed biophysical changes in rangelands in the country (Pickmeier, 2011; Harding and Devisscher, 2009; Mwangi, 2009; Gomes, 2006; Campbell et al., 2005; Amman and Duraiappah, 2004; Mwagore, 2003; Lambin et al., 2001; Duraiappah et al., 2000; Rutten 1992). The majority of the above studies are mainly qualitative, and only a few studies discuss the drivers of rangeland degradation in light of how different socio-economic, political, and biophysical factors influence each other and the resulting effect on the productivity of the ecosystems (Campbell et al., 2003; Campbell et al., 2005). In addition, despite the scant empirical literature on the sustainability of rangelands in the country, there is little information available on how the factors interplay and their impact on the ecosystem.

Serneels and Lambin (2001), focusing on the proximate causes of land use change, show that mechanized and smallholder agriculture replace rangelands in higher potential areas.

Butt (2010) analyzed the relationship between vegetation variability, cattle mobility, and density in Kenya. The author identifies that cattle intensively utilize different parts of the landscape at different times, showing the implications that sedentarization and reduced cattle mobility are likely to have on vegetation. Maitima et al. (2009) similarly focused on the relationship between land use change, biodiversity, and land degradation. The study indicates that land use changes not only reduce the quality and abundance of species of conservation concern, but also lead to a significant decline in soil nutrients. Though they present important findings, these studies are hardly sufficient to inform policy makers about how drivers of rangeland degradation come to play, how they affect each other, and their effect on the sustainability of the ecosystems. The present study contributes in filling this important gap in this field of research.

From the literature review, a large share of the drivers of rangeland degradation relates to land use/land cover changes. Among the key factors influencing LULCC in global livestock grazing systems are the changing opportunities brought about by markets (Lesslie et al., 2011; Fox and Vogler, 2005; Hazell and Wood, 2008; Sternberg, 2008; Hu et al., 2008; Baldi and Paruelo, 2008; Lambin et al., 2003). This study seeks to offer evidence that inefficient livestock markets, in the face of developing national and international markets for crop commodities, may have externalities to a number of factors driving rangeland degradation. The study postulates that inefficient livestock markets may lead to conversion of grazing areas to competing land uses. Conversion of grazing vegetation to other land use/land covers limits access to wider grazing options that provide important ecological functions for rangelands in ASALs. In addition, loss of grazing areas limits the mobility of livestock and increases grazing pressure of livestock in confined areas. This is likely to have negative impacts on the sustenance of the ecosystems, leading to productivity losses. Less grazing areas and less productivity of the ecosystems is likely to have negative impacts on incomes as well as increase the vulnerability of rural households to the variable climate characterizing rangelands. This indicates that livestock market inefficiencies may have far-reaching side effects on other drivers of rangeland degradation and consequently on rural livelihoods.

In Kenya as well as in many other developing countries, semi-arid grazing lands are more prone to being developed as a consequence of conversion and intensification processes in response to market triggers (Lambin et al., 2001). The analysis of the study is therefore based on semi-arid rangeland environments within the country. The study is organized as follows: Section 2 provides a description of the case study area and data. Here we also discuss in some detail the factors driving rangeland degradation and the ways in which inefficient livestock markets contribute to degradation. Section 3 describes the rangeland model, while Section 4 presents the results. A discussion of the modeling results drawing policy implications is presented in Section 5, and Section 6 provides the conclusion.

4.2 Case Study Area, Rangeland Management, and Livestock Markets

4.2.1 Study Area

The study area, Narok County, is a semi-arid agro-pastoral region located in southwestern Kenya inhabited by the pastoral Maasai. Narok County primarily supports extensive livestock operations and wildlife. The principal livestock found in the region are cattle, sheep, and goats. Characterized by an average rainfall ranging from 500 to 1,800 mm annually, the region seems promising to agricultural neighbors, but most of the suitable areas only lie along the borders. The center of the region is either very dry with very unreliable rainfall, or the soils are infertile and shallow (Jaetzold *et al*., 2009).

Despite some differences in the challenges affecting rangeland areas, the semi-arid lands in Kenya face similar challenges regarding the loss of grazing lands to other land uses, mainly crop farming. Based on these similarities, the data availability, and the accessibility of the rangelands, the study used Narok County to achieve its objectives.

4.2.2 Rangeland Conversions and Modifications

Maps of land degradation patterns by Le et al. (2014) and Waswa (2012) identify Narok as one of the country's degradation hot spots; the findings were supported by field observations. Recent scientific research provides various narratives regarding the key drivers of rangeland degradation in Narok as well as other ASALs in Kenya (Duraiappah, 2000; Campbell et al., 2005; Kameri-Mbote, 2005; Mwagore, 2003; Rutten, 1992; Harding and Devisscher, 2009; Pickmeier, 2011; Gomes, 2006; Homewood, 2012; Flintan, 2011; Campbell et al., 2003). A key driver of rangeland degradation in semi-arid areas has been LULCC (Cheche et al., 2015; Maitima et al., 2009; Kiage et al., 2007; Serneels and Lambin, 2001). These land use/land cover changes are often associated with the loss of natural vegetation, biodiversity loss, and land degradation (Maitima et al., 2009; Kiage et al., 2007). The pressure points which have had the greatest impact on land use/land cover changes in Narok County as well as other semi-arid rangelands in the country have been the changing crop market conditions mediated by land reforms (Campbell et al., 2003; Campbell et al., 2005; Duraiappah et al., 2000; Serneels and Lambin, 2001; Temper, 2012; Pickmeier, 2011; Amman and Duraiappah, 2004). Increasing opportunities for commercial arable farming created by the development of both local and international markets act as pull factors leading to LULCC in better-watered grazing areas (Campbell et al., 2005; Duraiappah et al., 2000; Serneels and Lambin; 2001;Temper, 2012; Pickmeier, 2011). The facilitating land reforms constitute the redefinition of land use arrangements from communal ownership to exclusive property rights (Mwangi, 2009; Meinzen-Dick and Mwangi, 2009; Duraiappah et al., 2000; Campbell et al., 2003; Kameri-Mbote, 2005; Mwagore, 2003).

Selective conversion of grazing areas to other land uses such as cropping leads to fragmentation of land, a key driver of rangeland degradation (Flintan, 2011; Rutten, 1992; Galaty and Ole Munei, 1999; Amman and Duraiappah, 2004; Hobbs et al., 2008). Fragmentation of the grazing ecosystems leads to flexibility losses and the opportunistic spread of grazing pressure that occurs with the seasonal movement of livestock, subjecting rangelands to environmental degradation (Mireri et al., 2008; Mwagore, 2003; Flintan, 2011; Boone and Hobbs, 2004; Hobbs et al., 2008; Meinzen-Dick and Mwangi, 2009). This undermines the capacity of pastoral communities to sustainably use the ecosystems as well as deal with risks such as drought.

4.2.3 Livestock Markets

Feasible markets for livestock and livestock products serve as engines for drawing surplus herds from grazing areas to consumption points and the attraction of investments such as SLM technologies (Hurrissa and Eshetu, 2002). The ability of rural livestock producers to raise their incomes also depends on their ability to compete in the market effectively (Markelova et al., 2009). Despite livestock production being key in Narok County, markets for livestock in the region, as well as in other parts of the country, are faced with significant market price disincentives. The market price disincentives arise from issues related to market inefficiencies such as middlemen rent-seeking behavior, government taxes and fees imposed on cattle trekkers, high transport costs, lack of market infrastructure, financial and technical service constraints, and market information system constraints, among others (Makokha et al., 2013; Muthee, 2006; Ahuya et al., 2005; Aklilu, 2002). High exploitation by traders/middlemen and high transport costs represent the largest shares of these inefficiencies (Makokha et al., 2013; Muthee, 2006). The numerous challenges that hinder smooth trade in livestock markets may explain the apparent limited price responsiveness of pastoralists in the country to livestock markets (Ng'eno et al., 2010). Given the challenges facing livestock markets and in the face rural households' need to increase their incomes and improve their livelihoods, rural households are likely to explore more profitable rangeland uses such as conversion to crop farming, land leases, or sales to immigrant crop farmers.

Drawing from the above discussions, the drivers of rangeland degradation emerge to be highly interrelated, with externalities running from one factor to another. We postulate that, with low benefits from livestock production, the need to internalize potential economic benefits with alternative uses of rangelands has led to evolving property rights in the area. With property rights reforms, significant spatial expansion of cropping lands occurs with the increasing market opportunities for crop production both for local consumption and for export. However, these changes in land use/land cover occur at the expense of pastoralists and sustainable rangeland use.

Theoretical models support the above discussion. The demand-led model states that redefinition of property rights mainly follows the need to internalize externalities resulting from increasing market opportunities and population growth. This implies that property rights in pastoral areas evolve when the benefits of pursuing private rights exceed the costs (Kamara et al., 2004). Similarly, Anderson and Hill (1975) state that competitive forces lead to the erosion of institutions that no longer support economic growth. Changes in market conditions and the potential economic benefits that can be exploited motivate adjustments to existing property rights structures. According to the new institutional economic theory, competition, such as that between conflicting land uses, is stated to be the key to institutional change (North, 1995).

The study further employs Hertel's (2011) partial equilibrium model of a profit-maximizing farm to illustrate land supply in response to commodity prices. According to the model, change in agricultural land use can be determined as follows:

$$q_L^* = \left[\frac{\Delta_A^D + \Delta_L^S - \Delta_L^D}{1 + \dfrac{\eta_A^{S,I}}{\eta_A^{S,E}} + \dfrac{\eta_A^D}{\eta_A^{S,E}}} \right] - \Delta_L^S \qquad (4.1)$$

where q_L^* is the long run equilibrium change in agricultural land use. The key determinants of q_L^* are:

Δ_A^D = Change in demand for agricultural output due to exogenous factors

Δ_L^S = Change in supply of agricultural land due to exogenous factors

Δ_L^D = Exogenous yield growth

η_A^D = Price elasticity of demand

and the aggregate agricultural supply response to output price comprising of:-

$\eta_A^{S,I}$ = Intensive margin of land supply

$\eta_A^{S,E}$ = Extensive margin of land supply

The study focuses on the size of the intensive margin of land use relative to extensive margin of land use $\left(\frac{\eta_A^{S,I}}{\eta_A^{S,E}}\right)$. This ratio captures the incentives to expand at the intensive margin (Stevenson et al., 2011). It indicates that agricultural output can either expand with increase in yields (at the intensive margin) or with physical expansion of area (at the extensive margin) (Stevenson et al., 2011). When the ratio is high, the size of the denominator in equation (4.1) increases leading to fall in equilibrium agricultural land use. In regard to rangelands, an increase in the size of the ratio leads to less natural grazing lands being converted to agricultural land, mainly cropping land. This occurs when the opportunity cost of converting grazing areas is high and producers are encouraged to increase crops yields from existing cropping areas so as to increase output. However, when the opportunity cost of conversion is relatively low, a positive shock in crop commodity prices is likely to lead to increased crop production at the extensive margin (physical expansion of cropping areas). Agricultural encroachment would result in loss of natural grazing cover.

Loss of rangelands to other land uses can be minimized by increasing value/competitiveness of livestock production. A viable method is to enhance the productivity and profitability of the livestock production with well-established linkages to markets (improved market access). Incorporating livestock producers directly into the value-addition chain and linking them to existing terminal markets would loosen the grip of the livestock traders and improve pastoralists' and other livestock producers' margins. In addition, adoption of efficient methods of transporting livestock at the prevailing road infrastructure conditions is likely to generate higher margins for producers. Higher profitability of livestock production provides an avenue through which rangeland conversion processes can be minimized. In addition, efficient livestock markets are capable of facilitating the destocking of animals during periods of low rainfall, such as drought years, thus relieving grazing pressure on the rangelands. Some of the suggested initiatives have been rolled out, but on a small scale (CARE- Livestock marketing and enterprise project, Garissa, Kenya), and thus it is important to evaluate their effect for policy advice. With the underutilization of the existing meat processing facilities (Ng'eno et al., 2010) and the country serving as a net importer of red meat (Muthee, 2006), the study assumes a ready market for livestock in the country. We evaluate the effect of the identified options on land use/land cover changes on rangelands and their subsequent effect on the sustainable management of the ecosystems.

4.2.4 Data

Among the key reasons for selecting this case study area for rangeland modeling was the opportunity to verify the land conversions and degradation processes as shown on the maps by Le et al. (2014) and Waswa (2012). The area is also characterized by different pastoral systems (pastoral leasing, agro-pastoral, pastoral) forming a good representation of the pastoral systems found in the country. The Kenya integrated household budget survey (KIHBS) 2005/06 provided detailed data on agriculture holdings, agriculture input and output, and livestock information for a period of 12 months, covering all possible seasons (KNBS, 2005/06c). The rich dataset provided crucial data for our model. Data on livestock marketing costs is obtained from the detailed study on livestock market value chains by Muthee (2006). The GlobCover 2005 was employed to obtain land cover estimates in the area (Bicheron et al., 2006).

4.3 The Rangeland Model

4.3.1 Model Description

There is growing literature on the use of dynamic ecological-economic rangeland models to assess the impact of alternative policies on the management of the natural rangeland resources (Moxnes *et al*., 2001; Hein, 2006; Hein and Weikard, 2008; Kobayashi et al., 2007). Among the potential benefits of these models is their ability to integrate the feedback effects between natural resources and human activity. This is particularly important in rangeland studies, as human rangeland use decisions may have long-term effects on the productivity of the ecosystem.

I present here the basic structure of the dynamic ecological-economic rangeland model[1]. The model is adapted from Hein (2006) and Hein and Weikard (2008) and has been applied in several empirical studies (see Weikard and Hein, 2011; Hein, 2010; Kobayashi et al., 2007). The novelty of the model presented here lies in the introduction of stochastic rainfall realizations in the analysis. In addition, an extension of the model is made to enable calibration of the model to the actual land use activities in the study area using Howitt's (1995) positive mathematical programming (PMP) model. The model is implemented using GAMS software with nonlinear programming solver CONOPT3, with 20 repetitions characterized by different rainfall realizations. Fig.4.1 provides an illustration of the main elements and structure of the model.

1 The model is dynamic in the sense that it will be able to determine a dynamically optimal series of actions (controls) at every time in response to states prevailing then.

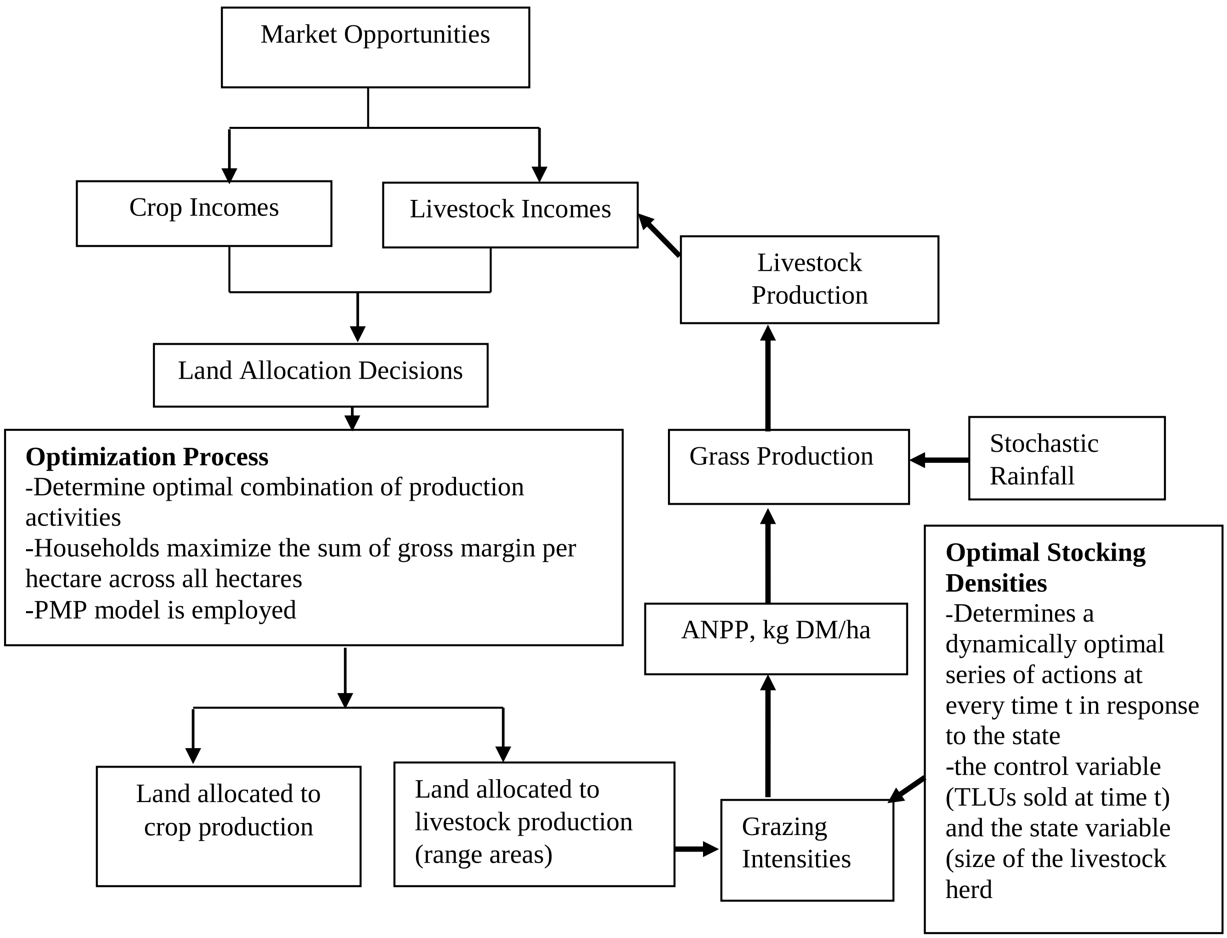


Figure 4.1: Main components of the ecological-economic rangeland model
Source: Adapted from Hein (2010) with modifications by the author

4.3.2 Optimization Problem

Households are assumed to maximize the sum of gross margin per hectare across all hectares subject to production constraints. In the study area context, there are five main possible production activities: four different crops (wheat, maize, beans, and potatoes) and grass, representing pasture areas. The optimal combination of production activities is solved using the PMP approach with a nonlinear land cost function [1](Mérel and Howitt, 2014; Howitt, 1995).

For $i =$ wheat, maize, beans, potatoes, and grass; the optimization problem is defined as:

$$Max \sum_{i} p_i y_i l_i - (\alpha_i + 0.5\gamma_i l_i) l_i - \sum_{j=2}^{n} w_j a_{ij} l_i$$

s.t . $Ax \leq b$ (4.2)

1 Heterogeneous land quality results in the marginal cost per unit of output increasing as more land is converted to croplands.

where a_{ij} is a matrix of technical coefficients of resource requirements, l_i is the land allocated to the crop which yields y_i, α_i and γ_i are respectively the intercept and slope of the cost function per unit land, w_j is the cost per unit of the j^{th} input, A is a matrix with elements a_{ij}, and b is a vector of resource constraints. Land is the binding constraint for calibration. Observed data is used to calibrate the model to replicate initial land allocation conditions.

4.3.3 Crop production

The study adopts a constant elasticity of substitution (CES) production function for each crop. The production function allows for substitution between production inputs[1]. Constant returns to scale (CRS) regarding CES production function is assumed for Narok County. The parameters of the CES are solved following Howitt (2005). Crop yields are assumed to be fixed[2] while the prices are exogenous. The output of crops is determined by the number of acres of land allocated to each crop.

4.3.4 Rangeland Productivity/Degradation Assessment

Prolonged grazing pressures, with loss of grazing areas, leads to poor protective cover of the soils. This increases the vulnerability of soils to degradation. Reduced vegetation cover coupled with intense animal tracks from trampling exposes the grazing areas to soil erosion, among other forms of degradation. Soil erosion leads to the loss of nutrient rich topsoil and exposure of vegetation roots, thus affecting the productivity of the soils. The above process informs the choice of the study's indicator of rangeland degradation/productivity as aboveground net primary production (ANPP).

ANPP, or its quotient to the corresponding precipitation, rainfall use efficiency (RUE), are two ecological parameters commonly used for assessing the rangeland ecosystem state (Le Houérou 1988; Hein, 2006; Hein and de Ridder, 2006; Hein and Weikard, 2008; Ruppert *et al*., 2012; Snyman and Fouché 1991). The principal ability of ANPP to assess an ecosystem's state (including degradation and desertification) has been widely confirmed (Bai and Dent, 2006; Sala *et al*., 1988; Snyman and Fouché, 1991; Prince *et al*., 1998; Diouf and Lambin, 2001; Holm *et al*., 2003; Buis *et al*., 2009; Ruppert *et al*., 2012).

Studies on the relationship between grazing biomass and rainfall in ASALs in East Africa demonstrate biomass production to be a linear function of rainfall (De Leeuw and Nyambaka, 1988; De Leeuw et al., 1991). Sites used to measure the relationships were either protected or located in low grazing areas (De Leeuw and Nyambaka, 1988). To model biomass productivity, the study adopts from the work of De Leeuw et al. (1991) the linear relationship between median rainfall and annual aboveground net primary productivity (ANPP, kg DM/ha). The relationship is measured in a neighboring region with similar characteristics as the study area.

1 With a lack of substitution elasticity available from existing studies and lack of data to estimate, the study fixes the CES value equal to 0.6 for all inputs. This allows for limited substitution between the production inputs as observed from farmer production practices.

2 The focus of the model is on health of grazing areas (represented by area covered by grass).

Following Hein (2010) and Hein and Weikard (2008), the model in this study is formulated to account for the feedback effects of grazing intensities on biomass production, where grazing limits biomass growth and the marginal reduction increases with high stocking rates (Hein and Weikard, 2008). The model also incorporates the effects of uncertain rainfall events on biomass production. In semi-arid areas, rainfall occurrence is primarily bimodal with two distinct rainy seasons: short rains (October to December) and the long rains (March to May) (Biamah, 2005). Four possible rainfall realizations for each season (very low, low, fair, and high) are considered. A time series of stochastic rainfall realizations is obtained from scenarios of possible combinations of short and long rains, together with the probability of their realization. Land users make decisions *ex ante* in view of the risks and encounter the 'realized' stochastic value of rainfall *ex post* (Domptail and Nuppenau, 2010).

4.3.5 Available Forage

Unlike the high-potential areas, pastures are the main source of livestock feed in ASALs. About 90% of the livestock diet in rangelands is composed of natural pastures[1]. Crop residues constitute negligible components of livestock feed, while fodder crops are hardly grown in the dry lands. Total available livestock forage in the model is formulated as being governed by biomass productivity by hectare (ANPP, kg DM/ha) and pasture/grazing area. A 'proper-use factor' forage allowance is made where the standard 50% (or "take half, leave half") rule of thumb in range management is employed. An adjustment factor for biomass share available for livestock use is also made as some of the biomass produced is consumed by other herbivorous animals among other uses.

4.3.6 Optimal Stocking Levels

Livestock producers' current decisions do have an effect on the long-term productivity of rangelands. Successful decisions should therefore constitute an optimal sequence of actions based on the level of state variables in each period. This is achieved by adopting the value iteration approach that solves the Bellman equation (Judd, 1999; Howitt 2005; Kobayashi et al., 2007). The livestock producer's problem is presented as follows:

$$\underset{c}{Max}\left[E_0\left\{\sum_{t=0}^{\infty}\beta f\left(c_t\right)\right\} \mid \mathrm{x}_{t+1}=\mathrm{x}_t-c_t+g(\mathrm{x}_t;\theta_t)\right] \tag{4.3}$$

where x_t is the state variable (the size of the livestock herd measured in Tropical Livestock Units) c_t is the control variable (TLUs sold at time t), $E_0\{.\}$ is the expectation operator, $f(.)$ is the current profit equation; β is the discount factor; $g(.)$ characterizes net livestock herd size

1 Statement made from field observations as well as calculations from the 2005/06 KNBS survey

expansion. It also constitutes the equation of motion[1;] and θ_t is the level of stochastic forage production[2].

Equation (4.3) presents an infinite-horizon problem where livestock producers aim at maximizing the current and future profits. As stated earlier, current decisions do have an impact on the long-term productivity of the ecosystems. Optimal livestock producers would therefore consider the state of forage production in each time period when making decisions. A closed-loop system is therefore defined where feedback occurs from information obtained on the level of state variables in each time period (Kobayashi et al., 2007).

The livestock producer's problem is then presented using the Bellman equation as follows:

$$V(x_t;\theta_t) = \underset{c_t}{Max}\{f(c_t) + \beta E_{\theta_{t+1}}[V(x_{t+1};\theta_{t+1})]\} \tag{4.4}$$

where $V(.)$ is the value function and $E_{\theta_{t+1}}[.]$ represents the expectations formed on forage production in period $t+1$. The Bellman equation expresses the value function as a combination of a current payoff and a discounted continuation payoff. The forward solution of the equation is such that the sum of the maximized current payoff and the discounted or carry-over value maximize the total value function (Howitt 2005).

The livestock sale control is represented as follows:

$$c_t = x_t + g\left\{x_t;\tilde{\theta}_t\right\} - x_{t+1} \tag{4.5}$$

where $\tilde{\theta}_t$ is the realized forage production.

Using equation (4.5), the control variable (c_t) can be expressed in terms of the optimal herd size in the next period (x_{t+1}) (Kobayashi et al., 2007). Equation (4.4) can then be rewritten as:

$$V\left(x_t;\tilde{\theta}_t\right) = \underset{x_{t+1}}{Max}\left\{f(x_t + g(x_t;\tilde{\theta}_t) - x_{t+1}) + \beta E_{\theta_{t+1}}[V(x_{t+1};\theta_{t+1})]\right\} \tag{4.6}$$

Rewriting equation (4.6) using $\Phi(.)$ and substituting the next period's value function gives:

$$V\left(x_t;\tilde{\theta}_t\right) = \underset{x_{t+1}}{Max}\left\{\Phi(x_t, x_{t+1};\tilde{\theta}_t) + \beta E_{\theta_{t+1}}\left[\underset{x_{t+2}}{Max}\{\Phi(x_{t+1}, x_{t+2};\theta_{t+1}) + \beta E_{\theta_{t+1}}(V(x_{t+2};\theta_{t+2}))\}\right]\right\} \tag{4.7}$$

The first order condition of equation (4.7) (w.r.t. x_{t+1} in time t) gives us the Euler condition:

1 We can logically assume that $g(.)$ is concave in x i.e. $g_x^{'} > 0, g_x^{''} < 0$

2 Because future rainfall events are unknown, the model incorporates uncertainty with the help of probability distribution.

$$-\frac{\partial\Phi(x_t, x_{t+1}; \tilde{\theta}_t)}{\partial x_{t+1}} = \beta\left[\frac{\partial\Phi(x_{t+1}, x_{t+2}; \theta_{t+1})}{\partial x_{t+1}}\right] \tag{4.8}$$

Equation (4.8) defines the condition for intertemporal optimality (Kobayashi et al., 2007). The left-hand side gives the marginal cost, where the marginal cost is measured by potential marginal payoffs foregone in period t, while the right-hand side gives the discounted marginal payoffs in period $t+1$.

Following Judd (1999), Howitt (2005) and Kobayashi, et al. (2007), the study employs a Chebychev Polynomial to obtain a continuous approximation to the value function. The approximation is given as:

$$V(x) \approx \hat{V}(x) = \sum_{j=1}^{n} \alpha_j \phi_j\left(\hat{x}\right) \tag{4.9}$$

Where α_j is the coefficient of the j^{th} polynomial term $\phi_j(.)$ and $\hat{x}$ is the state variable mapped onto [–1, 1] interval on which Chebychev polynomial functions are defined.

4.3.7 Herd Dynamics

Following Hein (2010), to model livestock dynamics, the livestock herd is assumed to follow a logistic growth process:

$$\Delta x_t = LAM * (1-(x_t / MTLU_t)) * x_t \tag{4.10}$$

where x_t are the tropical livestock units (TLU)[1] in the current period, Δx_t is the change in TLU, LAM captures the potential natural growth in livestock, and $MTLU_t$ is the maximum grazing capacity of the grazing areas.

Livestock in the next period (x_{t+1}) are determined by the livestock growth process defined in Eq. (4.10) above and the number of sales (c_t) as shown below:

$$x_{t+1} = x_t + (LAM * (1-(x_t / MTLU_t)) * x_t) - c_t \tag{4.11}$$

Livestock sales are considered to be the key source of livestock production revenue in the grazing areas. The prices/costs incorporated in the model are assumed to be deterministic. The detailed model is presented in the appendices (see Appendices B-D).

1 1 TLU = 1.43 cattle or 10 sheep or goats

4.4 Results

4.4.1 Base Specification

A brief summary of the survey data observations and results are presented in Table 4.1. The base land allocations in Narok County between the four major crops grown and range areas (grass) are illustrated in Table 4.1, column 1. Using the PMP model, we are able to replicate the land allocations as observed on ground as shown in Table 4.1, column 2. While the majority of the land appears to be grazing/pasture

Table 4.1: Survey data and model results

	Survey (data 2005–2006)	**Modeled results**			
	Initial observations (Average Sample)	**Model Validation**	**Base Scenario**	**Scenario 1**	**Scenario 2**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Land Allocations ‘000’Ha:					
Wheat	82.75	82.75	82.75	77.39	76.45
Maize	316.44	316.44	316.44	297.23	293.86
Beans	94.41	94.41	94.41	-	-
Potatoes	30.30	30.30	30.30	14.68	11.94
Grass(Range areas)	974.43	974.43	974.43	1,109.04	1,116.08
Average Margin (KSH. per TLU)	10,526.23		10,526.23	15,461.98	16,110.40
Average herd size (TLU, ‘000’)*	610.0		583.01	531.87	535.15
Stocking density (TLU/ha)*	0.63		0.60	0.480	0.479
Optimal stocking densities*			0.467	0.447	0.449
Optimal stocking levels*			455.5	495.8	502.0
Average sales volume (TLU‘000’)*	78.56		80.08	115.60	116.17
Average net returns over variable costs per ha:	KSH. per ha				
Wheat	27,175.98				
Maize	28,749.02				
Beans	4,906.84				
Potatoes	6,631.80				

**For modeled results: Results are an average of 20 repetitions per scenario characterized by different rainfall realizations*
For Survey data: Source: KIHBS 2005/06 survey data
Average exchange rate: 1 USD ≈75 KES[1]

1 Source: https://www.centralbank.go.ke/index.php/rate-and-statistics/exchange-rates-2?

In the base scenario, at the existing market conditions, the modeled stocking density, average herd size, and average sales volume are similar to the observations on the ground from the sample data (Table 4.1 column 3). The consistency of the results of the base model with sample observations suggests that the model accurately depicts the conditions on the ground.

A plot of net primary productivity against the median rainfall from our baseline information reveals an almost one to one relationship between ANPP and rainfall (Fig. 4.2).

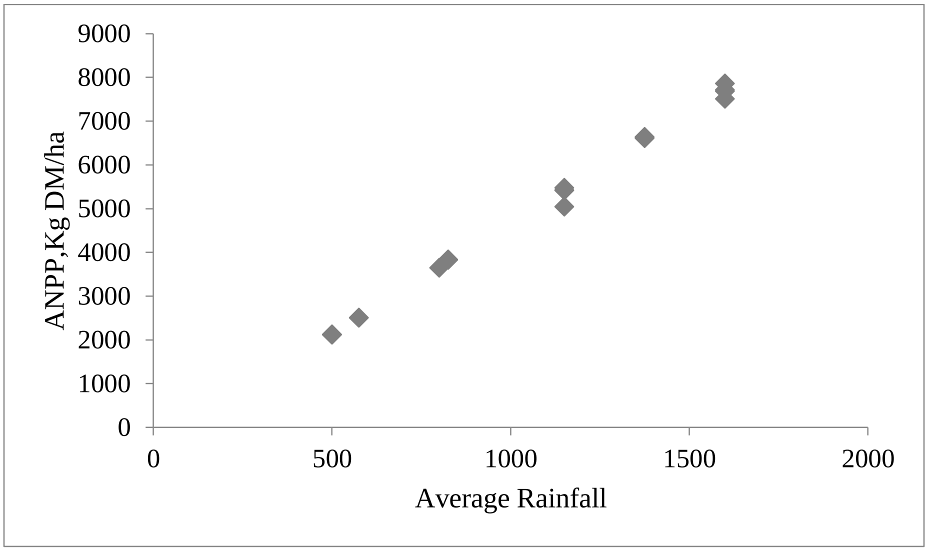


Figure 4.2: Relationship between ANPP, kg DM/ha and rainfall

However, ANPP, kg DM/ha is also affected by grazing intensity, as shown in Fig. 4.3.

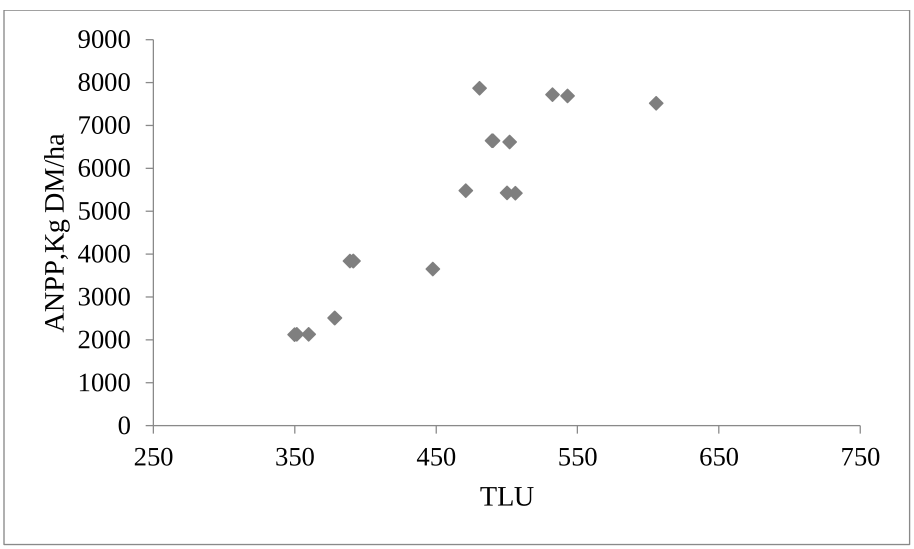


Figure 4.3: Relationship between ANPP, kg DM/ha, and TLU in the baseline scenario

Grazing pressures beyond the ecologically sustainable level leads to the declining productivity of land. This is shown by the decline in ANPP, kg DM/ha, with increasing flock sizes beyond a certain level. The turning point of the relationship between ANPP, kg DM/ha, and herd size gives us the optimal stocking density, beyond which increasing grazing intensities will have a negative effect on the ecosystems. At the base level, the optimal herd size of 455.5 TLU yields an optimal stocking rate of 0.47 TLU/ha, which is significantly below the observed current stocking rates of 0.63 TLU/ha and the modeled 0.60 TLU/ha (Table 4.1). The results indicate that the current grazing-livestock population exceeds the total grazing capacity in the area.

4.4.2 Re-apportioning value-added in the livestock marketing chain : Incorporating livestock producers directly into the value-addition chain and linking them to existing terminal livestock: Scenario 1

The detailed study on livestock market value chains in the country by Muthee (2006) is used to estimate changes in producers' benefits from incorporating livestock producers directly into the value-addition chain and linking them with the buyers at the terminal market. The above concept has been employed, on a small scale, by organizations such as CARE Kenya[1], thus ensuring its practicability. The approach involves establishing a market-based intervention whereby the pastoralists are organized into producer associations and enabled to participate in the value-addition chain (fattening of animals before sale) and linked to the livestock terminal markets (McKague et al., 2009; Muthee, 2006). Strengthening vertical linkages between fattening camps and livestock producers improves the live weight of livestock, enabling the producers to receive better margins, unlike in cases in which livestock is sold to middle men at the primary markets. On the other hand, linking livestock producers to existing terminal markets would minimize the exploitation by middlemen and further improve the livestock producers' margins.

The purpose of organizing producers into groups is to improve cooperation among pastoralists, reduce transport costs and consolidate supply, and improve the collective bargaining power of the livestock producers (McKague et al., 2009). As in the case of CARE Kenya, existing producer associations, such as water users associations commonly found in pastoral and agro-pastoral areas, can be used as a basis of these producer-marketing groups. The use of existing groups limits the transaction costs of forming new associations. From the above, this study is based on the assumption that there are existing producer associations which would act as the basis of the above market base intervention. Hence, no transaction costs associated with forming new associations are incurred.

This market-based intervention also requires the help of a value chain actor/market facilitator, whereby the role can be played by either the government, or, as in the case of CARE Kenya, by an NGO. The work of the value chain actor is just to provide support, meaning they are not involved in buying or selling but mainly assist in removing obstacles that limit livestock producers from participating in the terminal markets (McKague et al., 2009). The related costs of the intervention, such as the transport costs to the terminal markets and the costs of facilitating contracts at the terminal markets, fattening fees at fattening camps, among other costs, are provided in detail in the study by Muthee (2006) (Table 4.2). It is on the basis of the existing

1 A non_governmental organization involved in creating market linkages to livestock farmers by enabling them to become involved in the value chain itself charging a small fee for operational costs

work on livestock market value chains and market facilitation processes that the study evaluated the effects of re-apportioning value-added in the livestock marketing chain.

Table 4.2: Value chain facilitation

Margins in Marketing Immatures/Head	**KSH**
Buying Price (Price received by livestock producers from middlemen)	6,500
Marketing Costs	2,220
Terminal Market Facilitation Fee (5 percent of Selling price[1])	906.25
Total Costs	9,626.25
Selling Price	18,125
Margin (Excesses that are extorted by middlemen)	8498.75
Margin as a Percent of Selling Price	0.4689
Breakdown of Marketing Costs	
Broker Fees	100
Trader Costs	65
Loading	30
Branding	5
County Fee	40
Permits	100
Veterinary Costs	100
Transport	850
Loader	20
Fattening Fee	480
Herder Fee	60
Transport to Slaughter	120
Trader Costs	150
Boma Fee/others	100

Source: Values from Muthee (2006)
Average exchange rate: 1 USD $\approx$75 KES[2]

1 Additional costs that producers would incur if directly linked to terminal markets (logistical support and facilitation expenses)

2 Source: https://www.centralbank.go.ke/index.php/rate-and-statistics/exchange-rates-2?

Linking livestock producers to the end market and involving them in the livestock value addition is estimated to increase the producers' margin by 46.89% (Table 4.2). With the increased benefits associated with livestock production, land allocation moves in favor of livestock production (grass). Higher producer margins lead to land allocated for livestock production increasing from 974,431ha to 1,109,041ha, confirming that land allocations are driven by the benefits the land users expect to derive from the land (Table 4.1, column 4). The reallocated land is crucial as it represents the regaining part of former fertile rangelands. Higher allocation of land for grazing purposes is likely to facilitate livestock mobility and access to wider pasture areas. We further evaluate the effect of increased land allocation to land management and livelihoods (Fig 4.4).

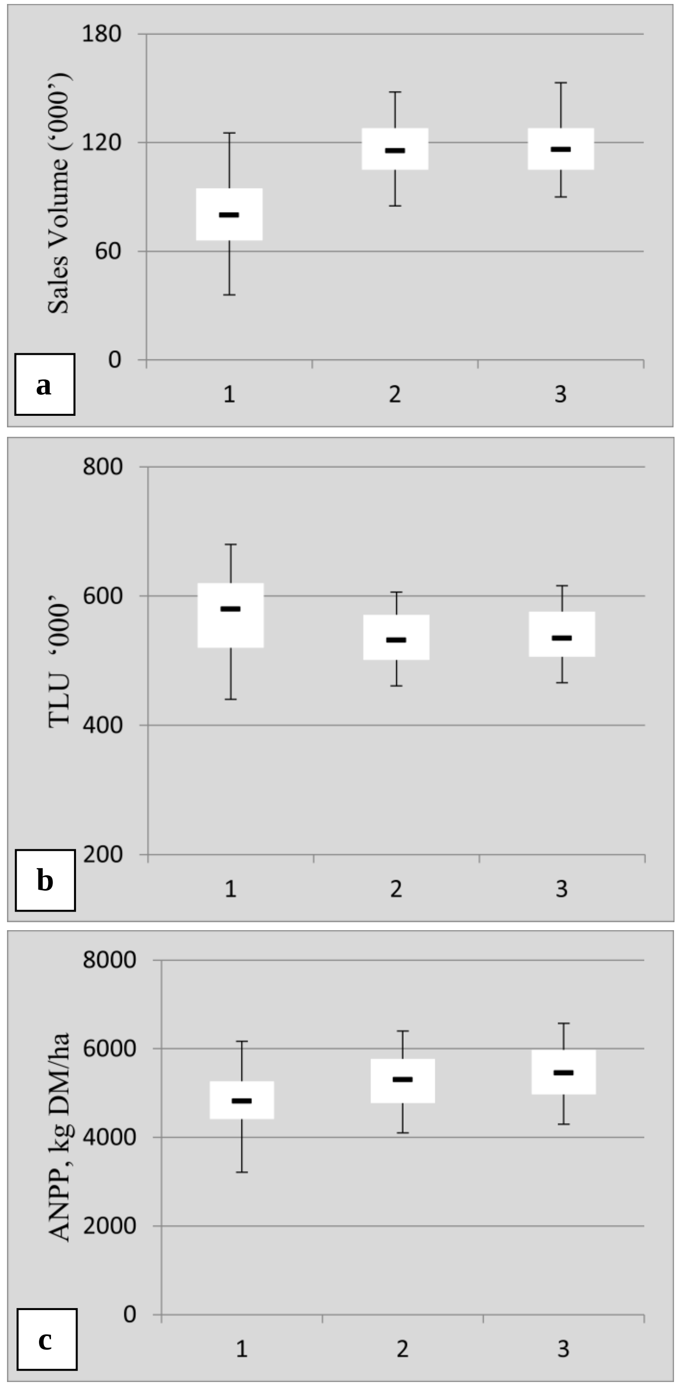


Figure 4.4: Plots of model output results. The results are an average of 20 repetitions per scenario characterized by different rainfall realizations. Legend: 1=Baseline Scenario; 2=Scenario1; 3=Scenario 2.

With the re-apportioning of value addition and links to terminal markets, we observe the increased livestock sales levels compared to the base average sales level (Table 4.1, column 4 and Fig. 4.4, a). With livestock sales as the control variable in the dynamic livestock model, increased livestock sales indicate that livestock producers are able to utilize markets more in taking action (livestock sales) in every time period in response to the state of the rangelands. This leads to better management of land as productivity increases and is less variable compared to the base scenario (Fig. 4.4, c). In addition, compared to the optimal stocking density of 0.45 TLU/ha[1] in Scenario 1, the stocking density of 0.48 TLU/ha indicates better management of land, given its close proximity to the optimal level and also compared to the Base Scenario stocking density of 0.60 TLU/ha (Table 4.1, column 4).

1 Obtained at the turning point of the relationship between ANPP, kg DM/ha and herd size as shown in Fig. 4.3

Given the higher off-take levels, as expected, the herd size in Scenario 1 is lower compared to that of the base scenario (Table 4.1, column 4 and Fig. 4.4, b). While this might not look appealing at first sight; Scenario 1 presents a better strategy, as it involves fewer variations in herd sizes. With livestock as important assets for pastoralists, Scenario 1 presents more stable wealth levels for the livestock producers (Fig. 4.4, b). In addition, fewer variations in livestock levels indicate that the producers are less likely to face drastic reductions in livestock compared to the base scenario. The live weight of livestock is also expected to be better in Scenario 1, given the higher productivity levels compared to the base scenario.

4.4.3 Efficient livestock transportation means : Efficient livestock transportation means in addition to re-apportioning value-added in the livestock marketing chain: Scenario 2

Similarly to the value addition and terminal market scenario, all the transports costs (trucking of livestock) were obtained from the detailed livestock market study by Muthee (2006). Transport costs constitute a large share of livestock marketing costs in the country, going as high as 65% of the total marketing costs in some parts of the country (Muthee, 2006). In Narok, trucking/trekking costs constitute about 40% of the total marketing cost (Muthee, 2006). Trucking vehicles are normally hired and the associated costs charged per livestock head (transport, loading, and off-loading). With the aim of mitigating the high transportation costs, the study evaluates the effects of adopting efficient transportation means at the prevailing road infrastructure conditions. The use of a double-decker trailer as a transport means is assessed as a possible means of reducing transportation costs. A standard double-decker transporter has the capacity to carry 26 cattle and 70 shoats (Muthee, 2006). We assess the benefits/savings made by transporting shoats alongside cattle in a double-decker cabin versus transporting the shoats separately (see table in Appendix C).

Use of a double-decker truck increases the producers' margin further by 6.16%, leading to land allocations as shown in Table 4.1. Higher producer margins have the potential of increasing land allocated to pastures to 1,116,076 ha (Table 4.1).

Similar to Scenario 1, the higher producer margins with the use of a double-decker truck are associated with higher livestock sales levels compared to the base average sales level (Table 4.1, column 5 and Fig. 4.4, a). This indicates the use of efficient transport not only facilitates movement of livestock to the terminal markets but also that producers are able to save on transportation costs. As highlighted earlier, increased sales levels indicate the ability of livestock producers to utilize livestock markets more in taking action (livestock sales) in response to the state of the rangelands. With higher ability to take action in response to the state of the land, productivity of the rangelands increases and is less variable compared to the base scenario and Scenario 1 (Fig. 4.4, c). Similar to Scenario 1, the optimal stocking density in Scenario 2 is given as 0.45 TLU/ha[1]. The stocking density of 0.475 TLU/ha indicates better management of land compared to the Base Scenario and Scenario 1 (Table 4.1, column 5)

1 Obtained at the turning point of the relationship between ANPP, kg DM/ha and herd size as shown in Fig. 4.3

Increased participation in livestock markets leads to lower livestock levels in Scenario 2 compared to the Base Scenario but higher compared to Scenario 1 due to more land allocations for grazing purposes (Table 4.1, column 5, and Fig. 4.4, b). Scenario 2 is also associated with higher and more stable wealth levels compared to Scenario 1 and the base level. This is from the higher herd sizes compared to Scenario 1 and stable livestock levels compared to the Base Scenario (Fig. 4, b).

4.5 Discussion and policy Implications

Competing land use options in rangelands are likely to lead to the conversion of grazing vegetation to other land uses/land covers with subsequent consequences on the health of the ecosystems. The increasing practice of crop cultivation on the rangelands is identified as a serious threat to future livestock production and rangeland management (Solomon *et al*., 2007). Expansion of crop farming curtails the traditional adaptive strategies of pastoralists and limits the mobility of livestock and access to key resources in particular during dry seasons (Butt, 2010). This leads to concentrated livestock densities above optimal levels on the rest of the rangeland, as shown in the initial observations (Table 4.1). The key consequence of rangeland losses is restricted access and mobility of livestock (Flintan, 2011), leading to high livestock densities and unsustainable production on the rest of the rangeland. This is demonstrated by the effect of large herd sizes on the productivity of rangeland (ANPP,Kg DM/ha) beyond the optimal level (Fig. 4.4, c).

Indeed, while crop farming may provide an alternative to pastoralism, especially in the wetter semi-arid areas, the associated costs, in the mid- to long term, appear too great to bear (Davies and Bennett, 2007). With lower productivity of the grazing areas (ANPP, kg DM/ha) and high livestock densities (0.6 TLU/ha), communal pastoralists become more vulnerable to the ecological climate variability of rangelands resulting in larger livelihood impacts (Fig. 4.4, b). This is in line with observations of Banks (2003), stating that the opportunity costs of disrupting the traditional operations of rangelands are overlooked, while the benefits may be overstated. Among the overlooked costs are the effects of rangeland use changes on biological diversity and the ability of biological systems to support human needs (Maitima *et al*., 2009). The effect of the loss of rangelands on the sustainability of the ecosystems is further exacerbated by low take-off rates of livestock. Well-established markets could greatly facilitate the movement of livestock from areas of forage scarcity, thereby regulating livestock densities and minimizing the ecological vulnerabilities of the dry lands (Turner and Williams 2002).

To understand the driving forces of the observed transformations in rangelands, emerging now is the acknowledgement of the presence and interaction of both equilibrium and non-equilibrium factors in the dynamics and the paths of rangeland degradation (Vetter, 2005; Domptail, 2011). Responses to emerging economic opportunities, facilitated by institutional factors, are driving the observed rangeland uses (Lambin et al., 2001). Rangeland users in the region, as with other developing countries, no longer live outside the cash economy (Davies and Bennett, 2007). Expected economic gains have been observed to influence their land use decisions. This is shown by the land allocation decisions in response to changes in returns realized from the current land uses. For instance, Table 4.1 shows how land allocations to various land uses differ from the base land allocations in response to the increased benefits associated with livestock production. The reverse, as has been the case, can also occur as shown by Tiffen et al. (1994), where expansion of the area under cultivation occurs in a semi-arid area with increased crops marketing opportunities and a decrease in livestock prices.

In their study, Tiffen et al. *(*1994) show that the progress of rural farmers can be facilitated by raising producers' prices through transport improvements and minimization of marketing costs. However, livestock markets function poorly with high marketing costs and high reliance on itinerant traders with whom they often have poor bargaining power to sell stock; this finding corroborates with that of McDermott et al. (2010), Makokha et al. (2013), and Muthee, (2006). The inefficiencies characterizing the livestock markets affect the benefits that livestock producers receive and drive rangeland use changes where opportunities prevail.

In addition to sustaining livelihoods, improved livestock marketing may have significant opportunities for improving environmental management (Frost et al., 2007). Ecological research shows that, with erratic rainfall characterizing rangelands in ASALs, the design of marketing systems should be such that they absorb fluctuations in marketed livestock. Among the components of such marketing systems identified is access to the largest markets and improved transport infrastructure (Behnke, and Kerven, 1994). Similar to Turner and Williams (2002), we found that livestock markets are capable of facilitating the destocking of animals leading to better productivity of land (Table 4.1; Fig. 4.4). Improving market access through the creation of opportunities for pastoralists to sell livestock more profitably and lower transportation costs increases the benefits associated with rangelands, leading to higher land allocations to grazing purposes (Table 4.1). Our analysis concurs with previous empirical work by Barrett and Luseno (2004), highlighting the main factors affecting livestock producers' earnings in the country as transportation costs and lack of competition within the marketing channel which create an unattractive marketing environment for pastoralists. Price fluctuations in the terminal market provide little empirical justification to worry about (Barrett and Luseno, 2004). Improved earnings associated with range areas are also observed to stabilize wealth of households (Fig. 4.4 c). This is expected to have direct positive effects on the livelihoods of rural rangeland users and less vulnerability to the variable ecological climate characterizing ASALs.

Currently, the existing national policy for the sustainable development on ASALs, titled, "Releasing our full potential," entails a key number of objectives aimed at achieving the sustainable use of rangelands while improving livelihoods. Among the elements include 1) the development of an enabling environment for accelerated investment in foundations to reduce poverty and build resilience and growth; 2) a responsive government to the uniqueness of arid lands which include ecology, mobility, population distribution, economy, and social systems; and 3) climatic resilience (GOK, 2012a). Our findings could prove useful if brought into play by Kenyan ASALs policy planners. The findings suggest that policy measures to attain the stated objectives should include efforts to minimize barriers limiting livestock producers' participation in value-added livestock production and access to high-value markets such as terminal markets. This can be achieved, as illustrated in the study, by minimizing/eliminating the price market disincentives currently characterizing rangelands. Second, community participatory approaches, such as producer groups, could be used as market-based interventions for livestock producers. Policy action promoting collective action at the grass-roots levels is therefore likely to have positive effects not only on improving livelihoods but also on the sustainable management of rangelands.

The study acknowledges that additional policies should go hand in hand with efforts to make livestock markets serve as mechanisms of destocking livestock, especially during periods of low biomass production as well as promote sustainable rangeland management. Although pastoralists have been shown to be generally open minded, capable of producing livestock optimally (Kimani and Pickard, 1998; Mwangi and Meinzen-Dick, 2009), and in great need for stronger links to the outside world, such as with improved livestock market access (Coppock, 1994), more incentives may be required for active participation in markets and sustainable rangeland management practices. An existing initiative that would complement the improved access to livestock markets would be the expansion of the index-based livestock insurance (IBLI). Insurance of livestock would be a critical concept encouraging livestock producers to participate in livestock markets. Insurance would enable the producers to stabilize their livestock accumulation, making them less likely to face drastic reductions in livestock, with increased offtake levels, in the event of a shock from the risky climatic conditions characterizing range areas. In addition, improved access to livestock markets coupled with IBLI is likely to lead to crowding in of finance to provide the much-needed credit for the economic development of the rangelands.

In addition, the livestock production associations can further be used to foster cooperation among pastoralists, for example, with regard to how much of the grazing areas should be unaltered and also on livestock production strategies, such as stocking levels. Such cooperation among pastoralists currently exists, as observed in the case of conservancies, where land use regulations have contributed to numerous ecosystem benefits (Osano et al., 2013). Producer associations therefore present a viable option to foster sustainable management practices in semi-arid grazing lands as a complement to market-based interventions. Further research work may address other possible synergies between improved livestock incomes and sustainable rangeland management.

4.6 Conclusions

Livestock production plays a key role in the economic development and welfare of the county. In spite of their significant role, rangelands in the country are being impaired by factors related to LULCC. Among the key factors driving conversion of rangelands to other land use/land covers are the changing opportunities brought about by markets. This study explores the linkages between improved livestock market access, rangeland use change, and livestock producers' livelihoods in the semi-arid Narok County of Kenya. In an effort to realize potential economic benefits with rising domestic and export markets for crops, fertile rangelands are observed to be increasingly converted to crop farming in the country. Among the resulting consequences of the declining range areas are degradation of rangeland ecosystems leading to negative effects on the social and economic security of the remaining livestock producers.

This study shows that improved livestock market access affects the economic returns of producers, which in turn affects rangeland management decisions. Improved market access in the study is sought through the creation of opportunities for pastoralists to sell livestock more profitably by re-apportioning value-added in the livestock marketing chain, linking them with terminal markets and through reduced livestock transportation marketing costs. Livestock producers' margins improve with re-apportioning value-added and reduced livestock marketing costs. Increased benefits associated with livestock production, on the other hand, lead to fewer conversions of former rangelands to crop farming, stabilizes herd levels, and increases market participation among livestock producers. The livelihood of livestock producers improves with better earnings and stabilized assets levels. In addition, livestock producers' vulnerability to ecological climate variability characterizing rangelands is reduced with better productivity of the ecosystems. From the study findings, national policy on improved livelihoods of pastoral communities should therefore entail efforts to include pastoralists in value-added livestock production and also access to high-value markets.

Chapter Five

5 Basic Capabilities Effect: Collective Management of Pastoral Resources in South Western Kenya

5.1 Introduction

Co-management of pasture resources under collective ownership systems has gained importance in managing and structuring the use of rangelands in arid and semi-arid areas (Banks, 2003; Hundie and Padmanabhan, 2008; Mwangi and Meinzen-Dick, 2009; Ostrom, 1990). Under these systems of joint provision and exploitation of range resources, pastoralists have access to diverse livelihood options to hedge against risks (Kimani and Pickard, 1998; Mwangi and Meinzen-Dick, 2009). The risks mainly emanate from low and erratic rainfall and variations in pasture productivity characterizing the arid and semi-arid lands (ASALs). With regard to diverse livelihood options, communal ownership of rangeland resources allows users to have access to a larger land area that provides water and pastures in both the dry and wet seasons. This serves as an insurance against individuals incurring losses, especially during dry periods (Mwangi and Meinzen-Dick, 2009). As further illustrated by the authors, collective rights to land and land resources in range areas provide a more equitable way of distributing variable resources and are associated with significant savings on transactions and production costs (Mwangi and Meinzen-Dick, 2009). In addition, collective systems present the necessary scale required to maintain the ecological function of the heterogeneous land surfaces associated with rangelands (Baland and Platteau, 1996; Meinzen-Dick and Mwangi, 2009; Ostrom, 1990). The system provides the scale necessary for mobility that supports more sustainable livestock production in marginal environments (Mwangi, 2009).

Redefinition of traditional land use arrangements from communal ownership to exclusive property rights has however been observed to result in fragmentation, a key cause of rangeland degradation (Amman and Duraiappah, 2004; Flintan, 2011; Galaty and Ole Munei, 1999; Rutten, 1992). Fragmentation of rangelands results in the loss of flexibility of livestock movements. This disrupts the seasonal movements of livestock necessary to access resources (water and pastures) that are heterogeneous in space and time (Flintan, 2011). Restricted mobility of livestock has been shown to lead to the loss of the opportunistic spread of grazing pressure and ultimately leads to the overuse of resources in the confined areas (Boone and Hobbs, 2004; Hobbs et al., 2008; Meinzen-Dick and Mwangi, 2009). Fragmentation also occurs with the loss of land, especially in well-watered areas, to alternative land uses such as crop farming.

Well-watered areas (i.e., dry season grazing areas) provide grazing relief in the marginal areas (wet season grazing areas), particularly during the dry seasons (Wade, 2013). Thus the loss of well-watered areas subjects the marginal areas to serious environmental degradation through depletion of biomass, loss of biodiversity, and soil erosion (Mireri et al., 2008; Mwagore, 2003). This undermines the capacity of pastoral communities to sustainably use the ecosystems as well as deal with risks such as droughts.

While the benefits of collective management of natural resources such as rangelands are clear, what remains unclear are the conducive factors to successful collective actions. Collective management of natural resources does not always emerge, and thus attention by a number of studies on factors either facilitating or hindering participation in collective action emerges (Agrawal, 2001; Dayton-Johnson, 2000; Gebremedhin et al., 2004; Meinzen-Dick et al., 2002; Ostrom, 2009; Willy and Holm-Müller, 2013). While there has been some general consensus on the role of certain factors, such as the number of users, importance of the resource system to users, and mobility of the resource system (Agrawal, 2001; Baland and Platteau, 1999; Ostrom, 2009), the role of some factors is debatable. For instance, on one hand, social networks and social participation, which are key elements of social capital, have been identified to enhance individuals' interactions in societies and facilitate participation in collective action (Gebremedhin et al., 2004; Willy and Holm-Müller, 2013). On the other hand, social capital may bring about subjective norms and may affect collective action negatively (Ajzen and Fishbein, 1980). For example, perceived social pressure to opt for subdivision of commonly managed pastures would hinder the collective management of pastoral resources. Market orientation has also been found to affect the capacity of communities to manage resources collectively. It has been found that, in some market-integrated societies, cooperative behavior prevails. In these environments, markets have been found to foster social interactions, leading to the evolution of norms that influence individual values and returns to relationship-specific investments (Bowles, 1998). However, markets may result in competitive environments undermining collective action (Agrawal, 2001; Carpenter and Seki, 2005). The composition of resource users within a group is also likely to affect collective actions in natural resource conservation. While some studies argue that inequalities in wealth within a community facilitate collective action in overcoming social dilemmas (Baland and Platteau, 1999, 2007; Naidu, 2009), others argue that inequalities may lead to low levels of collective action and cooperation (Dayton-Johnson, 2000; Gebremedhin et al., 2004; Janssen et al., 2011; Johnson and Smirnov, 2012).

The seemingly inconsistent results highlight the importance of the context in which collective action occurs (Baland and Platteau, 2007). This paper aims at contributing to the literature on factors affecting the collective management of natural resources. The study provides evidence on the role of basic capabilities as a determinant of collective action in communal grazing land management in a semi-arid setting. Capabilities, as defined by Krishnakumar and Ballon (2008), refer to the ability to achieve and relate not only to the opportunities that individuals access but to also the opportunities that one could potentially have access to (Ballet et al., 2015). Basic capabilities, as defined by the UNDP (1997), refer to the opportunity to achieve some minimally acceptable levels of functioning – the presence of some basic capabilities to function. Functionings, on the other hand, refer to the various valuable things that an individual manages to do or be, that is, the doings and beings of an individual (UNDP, 1997; Krishnakumar and Ballon, 2008).

As illustrated by Sen (2009), the important components of human capabilities relate to the well-being of individuals, the role of individuals in influencing economic production, and the role of individuals in influencing social change. Although these components are not directly observable, they do manifest themselves in observable functionalities (Krishnakumar and Ballon, 2008; Bérenger and Verdier-Chouchane, 2007). Capability constraints curtail the ability of individuals to utilize the opportunities available to them (Ballet et al., 2015; UNDP 1997). In the context of rangeland resource management, the geographical nature of the ecosystems (arid and semi-arid lands) narrows the range of opportunities that individuals have at their disposal to exploit the ecosystem. However, individuals' basic capabilities further determine individuals' capacity to exploit the pasture resources in more ways than one (grazing), and this leads them to make certain choices. The indigenous people residing in Kenyan rangelands primarily rely on common resource ownership systems of livestock production to sustain their livelihoods. The inhabitants, however, have been observed to react to increased opportunities to promote their economic well-being (Campbell et al., 2005, 2003). With increased opportunities that one can access with the exclusive appropriation of the resource pie and ability to exploit them, an individual cooperating in common resource ownership is likely to exit and opt to exploit the potential higher benefits.

In Kenya, there has been a growing body of research on collective action among smallholder farmers (Andersson and Gabrielsson, 2012; Fischer and Qaim, 2012; Kariuki and Place, 2005; Narrod et al., 2009; Willy and Holm-Müller, 2013). However, only a few studies focus on collective action in pastoral drylands (Mwangi, 2007, 2009), with even fewer empirical studies existing (Nduma et al., 2001) and none illustrating the contribution of basic capabilities, an important factor explaining cooperation (Ballet et al., 2015). The present study fills this important gap in this field of research, not only in terms of identifying the causal relationship between multiple factors and the collective management of pastoral resources but also in showing how basic capabilities impact collective action. The crossing between basic capabilities, among other factors, and participation in collective management of grazing lands is thus the subject of analysis in this paper. The objective is modeled in two separate questions: Which factors affect (1) participation in collective management of pastoral resources and (2) the extent of participation? To achieve the stated objective, the paper applies fractional variate estimation procedures to data collected in a household survey among randomly selected agro-pastoral households in six different divisions in Narok County, in Kenya.

The rest of the study is structured as follows: In Section 2, I present the institutional developments in natural resource management in the study area. Section 3 presents the conceptual and theoretical frameworks in addition to the empirical model. Section 4 describes the location of the study area and data collection methods. Section 5 presents regression results, while Section 6 discusses the results. Lastly, Section 6 draws policy implications and concludes the study.

5.2 Understanding Institutional Developments in Natural Resource Management in Narok County

5.2.1 Background

Narok County is located on the southwestern part of the Rift Valley Province of Kenya. The county, a semiarid region, lies between latitudes 34°45'E and 36°00'E and longitudes 0°45'S and 2°00'S, with annual precipitation ranging from 500 to 1,800 mm and local variations in topography playing a major role in the distribution patterns (Ojwang et al., 2010). The county has three districts covering an area of about 17,933.1 km^2, with an estimated population of 850,920 according to the 2009 census, and a population density of 47 people/km^2 (Republic of Kenya, 2010). Most of the region, especially the central part of the county, is characterized by harsh ecological conditions, resulting in low productivity. Farming is only suitable along the borders (Jaetzold et al., 2009). Livestock production remains the key component of agricultural production in Narok South and the lower parts of Narok North, with pastures forming the main feed for livestock. In addition to serving as a means of livelihood, livestock production plays a crucial role in the pastoralists' traditional social setting as a sign of wealth (Kaimba et al., 2011). The county supports one of the richest masses of large herbivores worldwide, including migratory wildebeest and a host of associated grazers, browsers, and predators (Ojwang et al., 2010).

In the county, as is the case with the rest of the country, the political economy context is closely linked to the processes of transformations in the institutions governing land ownership and land use (Amman and Duraiappah, 2004; Campbell et al., 2003; Mwangi, 2009). In the pre-colonial era, the area was mainly home to the Maasai pastoralists who practiced nomadic pastoralism characterised by movement of livestock within seasons in search of pastures, water, and incidence of disease (Campbell et al., 2005; Kimani and Pickard, 1998). Livestock production formed the basis of their economic livelihoods (Campbell et al., 2005; Mwangi, 2007; Nyariki et al., 2009). The livestock production system was defined by individual ownership of livestock with collective use and ownership of pasture and water (Kimani and Pickard, 1998; Mwangi, 2007).

The socio-spatial organizations of the pastoralists comprised the household (the basic unit), the boma (a number of households in the same compound), the neighborhood (a cluster of bomas), and the section (a group of neighborhoods in the same area) (Kimani and Pickard, 1998). The sections provided enough wet- and dry-season pastures and water and were protected against encroachment by other pastoralists and farmers. Movement of herds out of the section occurred only in cases of extreme drought (Kimani and Pickard, 1998). At the time of the European arrival, the indigenous land use systems were dismantled and replaced with exclusive private land ownership systems (Amman and Duraiappah, 2004). The indigenous populations were deprived of the best lands that served as important dry-season and drought retreat and were restricted to the marginal lands (Amman and Duraiappah, 2004; Campbell et al., 2005, 2003; Kimani and Pickard, 1998).

Land adjudication at independence in many instances followed similar processes as those seen during colonialism. High-potential land was allocated to elites and prominent individuals, while the majority of pastoralists settled on the drier savannah lowlands (Amman and Duraiappah, 2004; Campbell et al., 2005). Even where initial distributions involved high-potential land allocation to the indigenous people, special groups and immigrant farmers from other parts of the country bought out the land from poorer land owners and, in most cases, at very low prices (Amman and Duraiappah, 2004; Kimani and Pickard, 1998). For instance, in Narok County, the relatively fertile land was occupied by Kalenjin and Kikuyu immigrants as well as special groups of wealthy and politically connected commercial farmers (Amman and Duraiappah, 2004).

5.2.2 Group ranches and Re-aggregating individualized parcels

Group ranches were initiated in 1968 by the government of Kenya (Kimani and Pickard, 1998; Mwangi, 2007, 2009). A group ranch consists of land that is legally jointly owned by a group, such as a tribe, clan, section, family, or other group of persons, and is managed by a committee elected by the members (Kimani and Pickard, 1998; Mwangi, 2009). The elected committee controlled the resource use, that is, it managed the grazing, water, and tillage (Mwangi, 2009). The group ranches were anticipated to encourage the pastoralists to invest in range improvement and reduce the stocking rates, encourage commercialized livestock production, increase the Maasai's contribution to the national economy, and provide the indigenous people with tenure security and guard against landlessness among pastoralists (Kimani and Pickard, 1998; Mwangi, 2009). The communities welcomed the concept of group ranches to secure their land and avoid the risk of losing more land from encroachment by immigrant farmers (Kimani and Pickard, 1998; Mwangi, 2009). Group ranches were created to enclose sufficient wet- and dry-season pasture and resources (Campbell et al., 2005). However, movement in extreme drought years beyond the ranch boundaries remained necessary, and thus the strict boundaries were not feasible (Campbell et al., 2005; Kimani and Pickard, 1998).

There has been a growing trend of group ranch sub-division into individual holdings (Carpenter and Seki, 2005; Kimani and Pickard, 1998; Mwangi, 2007, 2009; Nyariki et al., 2009). Among the identified factors motivating subdivision of group ranches are the difficulties in enforcing collective interests in resource allocation and the need to protecting individuals' land claims against threats of inappropriate allocation of group land to unauthorized individuals by the management committee (Campbell et al., 2005; Kimani and Pickard, 1998; Mwangi, 2007, 2009; Nyariki et al., 2009). While subdivision may initially have been motivated by poor management and difficulties in enforcing collective interests, research indicates that other factors have been important in motivating the transformation (Campbell et al., 2005; Mwangi, 2007). Other than the need to access capital markets and the pressures from the increasing number of individuals entitled to a share in a fixed land resource, subdivision appears to be an expedient strategy to exploit economic opportunities with altered land-holding systems (Campbell et al., 2005, 2003). For instance, individuals are observed to be eager to exploit opportunities arising from market liberalization and crop market development (Campbell et al., 2005).

Land subdivision in the area has resulted in fragmented rangelands and sales to mostly immigrant farmers, a key cause of rangeland degradation (Amman and Duraiappah, 2004; Flintan, 2011; Galaty and Ole Munei, 1999; Kimani and Pickard, 1998; Rutten, 1992). Average parcel sizes have decreased, while the number of fenced parcels and fragments converted to other land uses, such as crop farming, has increased. Fragmented rangelands result in the loss of flexibility and mobility of livestock. In addition, subdivision reduces the grazing capacity of land

and spread in opportunistic grazing, leading to the overuse of resources in the confined areas (Boone and Hobbs, 2004; Hobbs et al., 2008; Meinzen-Dick and Mwangi, 2009). Furthermore, due to subdivision, the indigenous people are losing the fertile lands and being pushed into the marginal areas (Amman and Duraiappah, 2004; Kimani and Pickard, 1998). Exclusion further exacerbates the processes of environmental degradation, as marginal lands are used intensively beyond their capacity (Amman and Duraiappah, 2004; Kimani and Pickard, 1998). Ultimately, the combined processes of fragmentation, exclusion, and inhibition lead to increasing levels of poverty, both absolute and relative poverty (Amman and Duraiappah, 2004). It is, however, worth noting that there are some group ranches that have resisted subdivision to date (Mwangi, 2007).

Besides the group ranches that have resisted subdivision, an interesting development in the area has been the regrouping of some individual land owners in the area, with friends, neighbours, or kin to pursue joint herd/pasture management in their re-aggregated parcels (Mwangi, 2007). While each individual title holder retains the right to alienate his resource, the regrouping allows access rights to resources, such as pastures, among single-titled owners who have agreed to pursue shared strategies. Livestock benefit from rotational grazing in the shared space given the radical changes in production systems. Aggregation of the individual parcels indicates attempts to enhance sustainability of the production system given variation in the environmental conditions and pasture productivity characterizing the areas (Mwangi, 2007). Because dynamics in the land-holding systems involves rearrangement of use rights with significant effects on sustainable land management, factors behind these changes are of fundamental concern.

5.3 Frameworks

5.3.1 Conceptual Framework

The conceptual framework for this study is based on the theory of collective action (Ostrom, 1990, 2001, 2009), institutional economics (Kirsten et al., 2009a; Meinzen-Dick and Mwangi, 2009), and the capability approach by Sen (1980). In common property resources, rights are held by a defined group. The rights refer to 1) access rights (the right to enter a defined property), 2) withdrawal rights (rights to obtain goods from a resource, 3) management rights (rights to transform the resource and control its use patterns, 4) exclusion rights (rights preventing others to access the resource), and 5) alienation rights (rights to sell or lease or both of the above mentioned rights) (Schlager and Ostrom, 1992; Mwangi and Meinzen-Dick, 2009). These rights can be categorized as use rights and control or decision-making rights (Mwangi and Meinzen-Dick, 2009). The decision whether to cooperate in the joint provision and appropriation of pastoral resources or opt for an exclusive share of the resource pie would alter the rights that an individual can exercise. This would have impacts on the sustenance of the ecosystem.

Studies analyzing individual incentives to cooperate in collective action (Baland and Platteau, 2007; Meinzen-Dick et al., 2002; Ostrom, 2009) show that collective action outcomes depend on the incentive structure available to users. Individuals weigh benefits and costs in specific action situations, which in turn influence their decision. Individuals' incentive structures are on the other hand influenced by a range of factors, such as socio-economic factors, among others (Agrawal, 2001; Dayton-Johnson, 2000; Gebremedhin et al., 2004; Meinzen-Dick et al., 2002; Ostrom, 2009; Willy and Holm-Müller, 2013). Ostrom (2009) illustrates how core subsystems of a social ecological system affect each other as well as link social, economic, and political settings and related ecosystems. The core subsystems – resource systems, resource units, governance systems and resource users – are made up of multiple second-level variables (Ostrom, 2009). The second-level variables interact in processes such as self-organizing activities to produce outcomes. An example of a possible outcome is the ecological performance of a natural resource (Ostrom, 2009). The author further highlights that, in regard to the management of natural resources, when anticipated benefits of managing a resource collectively exceed the perceived costs of organization, users are likely to engage in collective action to manage the resources (Ostrom, 2009). However, second-level variables in a social ecological system have been observed in empirical studies to affect the perceived benefits and costs of users and thus affect the probability of users engaging in collective action (Ostrom, 2009).

As pointed out earlier, the capability concept is associated with the range opportunities that individuals can fully utilize to lead the life they want as well as the constraints that limit individuals to certain choices (Krishnakumar and Ballon, 2008; UNDP, 1997). In other words, capabilities point to an individual’s capacity for action or choice. In the context of natural resource management, capabilities determine the capacity for action and subsequently for change in managing land and land resources (Krishnakumar and Ballon, 2008). Capabilities can therefore be interpreted as causal powers that lead not only to different economic outcomes but also to different natural resource management outcomes (Krishnakumar and Ballon, 2008; Martins, 2006; Sen, 2009). There exists ample literature showing that living conditions and knowledge are important components of basic capabilities and form an integral part of human capabilities (Di Tommaso, 2007; Krishnakumar and Ballon, 2008; Psacharopoulos and Yang, 1991; Sen, 2009; Bérenger and Verdier-Chouchane, 2007; UNDP, 1997).

Empirical evidence shows that living conditions influence human development, defined here as the process of expanding people’s choices and the level of well-being they can achieve (UNDP 1997). Living conditions influence the physical health, mental health, and social and emotional development of an individual, which ultimately affects their ability to achieve (Lundberg, 1991; Marmot et al., 2008; Siebens, 2013; Layte et al., 2010; Gove et al., 1979; Rahkonen et al., 1997; Mann et al., 2012; Di Tommaso, 2007; Krishnakumar and Ballon, 2008). For instance, empirical evidence from medical studies shows that household crowding is significantly related to social relationships and the mental and physical health of an individual (Gove et al., 1979). Similar findings are observed in other studies where living conditions are shown to impact the health of an individual (Rahkonen et al., 1997; Mann et al., 2012). The influences living conditions have on the well-being of individuals also affect the ability of an individual to achieve acceptable levels of functionings. This is illustrated in the empirical findings by Lundberg (1991), and Marmot et al. (2008), in which poor living conditions were observed to affect life chances through skills development, education, and occupational opportunities (Lundberg, 1991; Marmot et al., 2008). Poor living conditions therefore curtail basic capabilities or freedoms that would enable an individual to have the kind of life they want (Bérenger et al., 2007; Krishnakumar and Ballon, 2008; UNDP, 1997). On the other hand, knowledge influences the command that an individual has over resources as well as social factors that in turn affects what the individual can achieve or choose to do (Di Tommaso, 2007; Krishnakumar and Ballon, 2008). The two components are not only able to capture the well-being and role of individuals in influencing economic production (Krishnakumar & Ballon, 2008; Sen, 2009) but are also able to capture basic capabilities in other dimensions such as those in health and social change. For instance, better living conditions are observed to impact positively on the health of households (Gove et al., 1979; Ross et al., 1990). In addition, according to the new institutional economic theory, capabilities, in the form of skills and knowledge, are viewed as a factor that brings about social changes such as changes in institutions (North, 1995). Skills and knowledge acquired by individuals change their perceptions about changing/evolving opportunities that may be exploited and may lead to changes in institutions in an effort to pursue the perceived opportunities. The changes in institutions could be, for example, from collective management to exclusive ownership of resources. Based on the above discussion, literature review, and data availability issues, Fig. 5.1 illustrates how the identified factors facilitate or hinder collective management of pastoral resources.

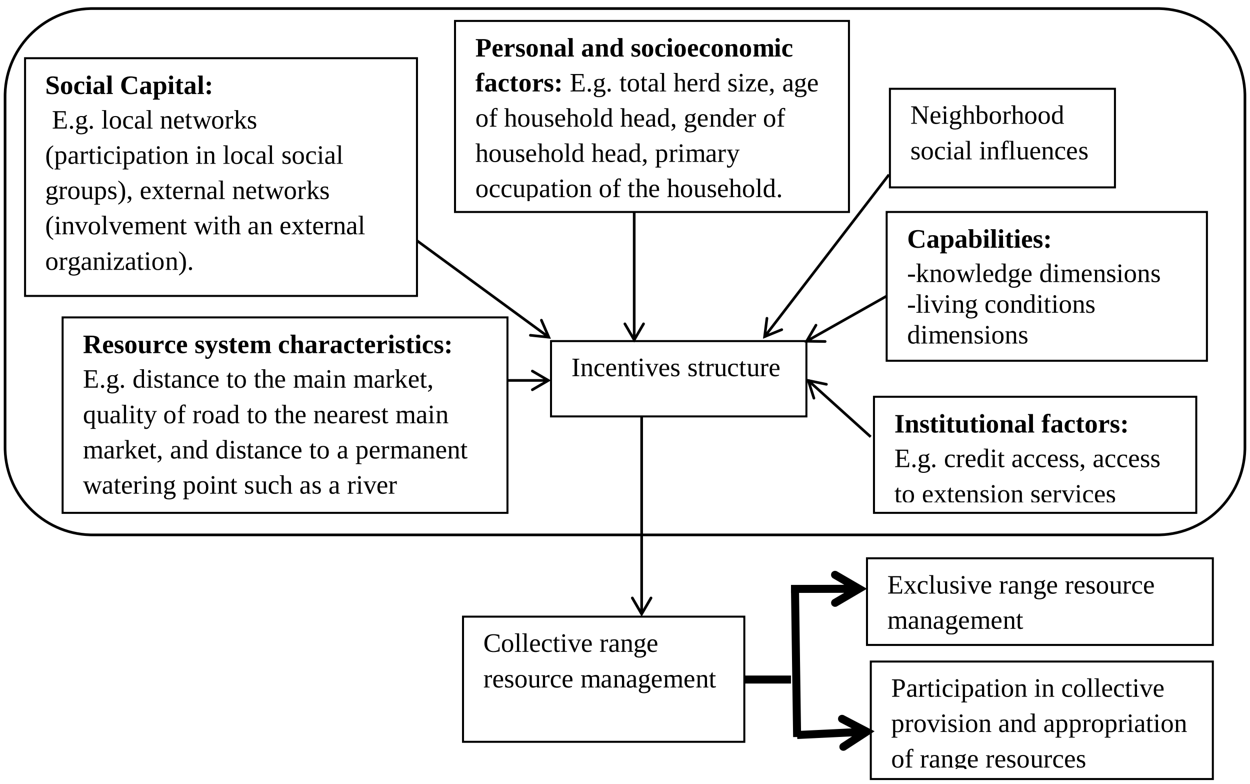


Figure 5.1: Conceptual framework.

Source: Authors' conceptualization.

5.3.2 Theoretical Framework

Households' decisions whether to cooperate in the joint provision and exploitation of pastoral resources are illustrated using the economic theory of land. In this theory, landowners are assumed to maximize utility, leading them to choose land uses that yield the highest benefits (Rashford et al., 2011). Following Nelson and Hellerstein (1997) and Chomitz and Gray (1996), land is assumed to be devoted to the highest-rent use such that a parcel at point l will be devoted to land use k if $R_{lkT} > R_{lhT}$, $h \neq k$. The land use decision can be modeled using a multinomial logit model as shown:

$$prob_{hl}\,(l \text{ devotedto } h) = \frac{e^{X_l B_h}}{\sum_j e^{v_l B_j}} \tag{5.1}$$

Where B = vector of reduced form parameters. Vector X consists of three sets of variables: G =site-specific productivity variables, C = cost-of-access variables, and S =spatial effects of geophysical variables.

Eq. (5.1) can be used to model land use decisions, for instance in arid and semi-arid environments, by integrating additional data such as socioeconomic data (see Ellis et al., 2010). In these ecosystems, collective management of pasture resources is highly favorable compared to exclusive land ownership systems. This mainly arises from the wide gap in the availability and access to physical resources, such as pastures, between communal large-scale production systems and exclusive appropriation systems (Kahi et al., 2006). In addition, due to the high heterogeneity associated with semi-arid and arid areas, collective management systems also ensure access to pastures in all seasons. Furthermore, with limited physical resources, exclusive appropriation systems would require high investments in feed, infrastructure, and labor, making the system unattractive to households (Kahi et al., 2006). However, some factors might increase the benefits associated with exclusive appropriation of land compared to collective management of resources. For instance, increased capabilities may be associated with increased land use options under exclusive land ownership. In cases in which the potential net rents from collective action are less than potential benefits with exclusive appropriation of the resource pie, land users would opt out of the common property resource use.

5.3.3 Empirical Framework

To estimate the effect of capabilities and other factors on decisions regarding whether to participate or not in collective management of pastoral resources, a zero-inflated beta model is employed. The primary motivation for this method lies on the response variable which takes fractional values and has a mass point at 0. First, the zero-inflated beta model allows for the clustering of observations at zero. Second, in estimations where the response variable takes fractional values, the conditional expectation is only defined on the bounded interval (0, 1) (Papke and Wooldridge, 1996; Cook et al., 2008). This implies that the conditional expectation needs to be a nonlinear function of the regressors (Cook et al., 2008). The use of a linear conditional expectation function estimated by least squares, such as the Tobit model or instrumental variables, would produce biased and inconsistent estimates of coefficients and standard errors (Cook et al., 2008; Papke and Wooldridge, 1996). Third, in fractional responses models, empirical evidence shows that the conditional variance must be a function of the conditional mean (Cook et al., 2008). Zero-inflated beta models are shown to be applicable in this case (Cook et al., 2008).

Other than to issues related to the dependent variable, the zero-inflated beta model enables the study to correct for, if any, self-selection bias. A sample selection issue would occur, for example, if households select themselves into participation or non-participation in collective management of range resources. That is, if different factors generate the observations with zero extent values in participation. The zero-inflated beta model allows for non-participation to be generated by a different process. The zero-inflated beta specification consists of three parts (Buis, 2010):

a. a logistic regression model for whether or not the proportion equals 0,

b. a logistic regression model for whether or not the proportion equals 1,

c. a beta model for the proportions between 0 and 1.

In the sample, there are no households with an extent value of one, but a significant number has zero values; there the study employs the zero-inflate option to model the zeros separately. The zero-inflated beta model is formulated as follows (Cook et al., 2008):

$$f(y_i = 0 : X_i) = 1 - C(\alpha' X_i) \text{ for } y_i = 0, \tag{5.2}$$

and

$$f(y_i : X_i) = C(\alpha' X_i)\left[\frac{\Gamma(p + q(X_i))}{\Gamma(p)\Gamma(q(X_i))} y^{p-1}(1 - y_i)^{q(X_i)-1}\right] \text{ for } 0 < y_i < 1 \tag{5.3}$$

where $q(X_i)$ = $p\exp(-\beta' X_i)$, p is a parameter of the beta distribution and $C(\alpha' X_i)$ represents the probability of a household to participate in collective provision and appropriation of pastoral resources.

5.4 Data Collection and Analysis Methods

5.4.1 Data

The data used in this study was collected from a random sample of 360 households in Narok County between November 2013 and February 2014. The area was chosen based on the existing different pastoral systems (pastoral leasing, agro-pastoral, pastoral, pastoral/tourism) forming a good representation of the pastoral systems found in the country. The total number of households selected was based on the formula given by Bartlett et al. (2001). The sample design of the study was based on a multistage stratified random sampling procedure. In the first stage, the study purposively selected 6 divisions based on the presence of pastoral activities to form our sampling strata. In the second stage, with the help of officials from the Kenya National Bureau of Statistics (KNBS) offices in Narok and division administrative officials, two locations were randomly selected with equal probability from each of the divisions. Two sub-locations were then selected randomly with equal probability within each of the locations. Overall, 24 sub-locations were randomly selected within the six divisions. The next step involved selecting a village randomly with equal probability from each of the randomly selected sub-locations. This was done with the help of administrative officials (chiefs). In the last stage, from the shortlisted villages, a sampling frame was prepared for each village with the assistance of chiefs and village elders. A total sample of 360[1] households was then drawn from the villages selected, with the help of village elders and local chiefs, proportional to the number of households. Questionnaires

[1] The sample size is calculated to account for contingencies such as possible missing or failed cases

were administered through personal interviews with household heads and/or their spouses. The survey collected information on participation in collective management of pasture resources, social and financial capital, networking, information and extension, and socio-economic and demographic characteristics, among others.

Principal Component Analysis (PCA) is employed to generate indices on basic capabilities and material wealth of households. To measure capabilities, the study follows Krishnakumar and Ballon (2008), in which basic capability indicators under two dimensions are considered: knowledge and living conditions dimensions. While other dimensions of capabilities can be considered, we believe the two dimensions constitute a strong measure of basic capabilities, as they reflect other dimensions of basic capabilities as discussed earlier. The PCA was conducted in three steps. First, following the existing literature, various observed indicators of the two dimensions of basic capabilities are identified (Barrett, 2010; Krishnakumar and Ballon, 2008; OECD, 2015; Psacharopoulos and Yang, 1991; Sen, 2009; UN Habitat, 2003). Among the indicators considered based on the availability of data included knowledge indicators, quality of dwelling conditions, access to and quality of the basic services conditions, and additional capabilities related to well-being. Second, using PCA, the first principal component variable across households was computed on the observed indicators. Given that the data is not expressed in the same units and hence is not standardized, I derived the eigenvectors (weights) using the correlation matrix to ensure that the data had equal weight and none dominated the others (Vyas and Kumaranayake, 2006). The study makes the assumption that the first principal component, with an associated eigenvalue of 5.158 and accounting for 43.0% of the variation in the original data, is a measure of household basic capabilities (Appendix E.1). Third, using the factor scores (weights) from the first principal component, a dependent variable with a mean of zero and a variance of λ is constructed for each household (Co´rdova, 2009). The variable, with positive as well as negative values, is regarded as the “relative degree of basic capabilities” of a household, and the higher the value, the higher the implied capabilities of that household. Kaiser–Meyer–Olkin (KMO) was used to verify the sampling adequacy for the analysis. Following the literature (Berman et al., 2014; Co´rdova, 2009; Vyas and Kumaranayake, 2006), a similar procedure was followed to generate a relative wealth index variable as a measure of material wealth. The first principal component, with an associated eigenvalue of 3.717 and accounting for 31.0% of the variation in the original data, was taken to be a measure of household wealth (Appendix E.2).

Following Willy and Holm-Müller (2013), the study formulated a neighborhood social influence indicator (Case, 1992; Hautsch and Klotz, 2003) to represent the social pressure in participation in the collective rangeland management as shown:

$$\mathrm{NEISOCINFL}_i = \frac{\sum X_i}{\sum_{i=1}^{N-1} B_k} \tag{5.4}$$

where X_i indicates the behaviors performed by household i that are similar to those of other households in the village (that is, participating or not participating in collective provision and appropriation of pastoral resources) in the previous period, B_k are the behaviors performed by all other households within the village. In the analysis, increased basic capabilities are hypothesized to reduce the probability of a household participating in collective management of pasture resources and also to negatively influence the extent of participation among the participating households.

5.4.2 Description of variables

Table 5.1 presents the descriptive statistics of the variables used in the estimations. The indicators of participation in the collective management of pastoral resources used in the study include: (1) individual land owners/households who have re-aggregated part of the individual parcels of land to pursue collective herd/pasture management and (2) households in group ranches managing land collectively.

The dependent variable measures the extent of participation by a household. This is given by the proportion of land used collectively to total land one owns or has access to. Whereas the extent of participation in re-aggregated parcel is clear (re-aggregated area/total land owned), in the case of group ranches, the extent of participation by a household is determined by the area within the group pastures not converted to other uses, mainly cropping; that is, the share of non-restricted grazing land per household. As indicated by Hobbs et al. (2008), fragments of land converted to other uses, such as cropping, become unavailable for livestock and other herbivores. As such, the extent of joint provision and exploitation of rangeland resources under group ranches is limited by the spatial conversion of land fragments to other uses. Therefore, the extent of participation of households under group ranches who have converted larger areas of land to other uses is lower compared to those with fewer conversions.

5.5 Results

Table 5.2 presents the estimated marginal effects from the zero-inflated beta estimation model. Column one contains the marginal effects of the logit model that seeks to explain the exact 0s. In this study, the section seeks to explain zero extent that occurs with non-participation. Column two contains the marginal effect estimates of the beta-model for the proportions between 0 and 1; it explains the extent of participation when participation is not zero. As expected, the marginal effects on column 2 are relatively low due to the inclusion of proportions only between 0 and 1. Low changes are predictable due to the narrow range over which changes can be made. Lastly, column three presents the marginal effects when the whole sample is considered. The model specification passes the link test.

The regression results suggest that household basic capabilities are statistically significant in determining participation and the extent of participation in collective management of range resources. In the study area, households with higher basic capabilities are more likely to have zero extent of participation by 22.8 percentage points. When participation is not zero, increased basic capabilities reduce the extent of participation by 1.3 percentage points and by 16.6 percentage points when the whole sample is considered. The elements of social capital together with neighbors' influences included in the analysis are also found to significantly influence participation.

Table 5.1: Description of dependent and explanatory variables.

Variable	Description/measurement	Mean/Proportion	Std. Dev.	Min	Max	Expected Sign
Dependent variables						
Pextent	Participation extent measured as a proportion of land used collectively (under joint pasture management) to total land	0.409	0.440	0	.988	
Explanatory variables						
Neisocinfl	Neighborhood social influences index (ratio with range 0–1)	0.228	0.200	0.026	0.875	+/-
Qlrd	Quality of road to the nearest main market (dummy, 1=graveled or tarmac; 0=earth)	0.371	0.484	0	1	-
Dmkt	Distance to the main market (km)	8.277	7.153	1	26	+
Dnriver	Distance to the nearest permanent watering point such as a river (km)	16.949	15.620	0.5	46	+
Genderhh	Gender of household head (dummy, 1 = Female)	0.135	0.342	0	1	-/+
Agehh	Age of household head in years (dummy,1 if Age>=55)	0.200	0.401	0	1	-
Proccup	Primary occupation of the household (dummy, 0= Livestock production; 1=Others)	0.340	0.474	0	1	-
Acescredt	Credit access to the household (dummy,1 = yes)	0.218	0.413	0	1	+
Herd	Herd size	36.030	23.547	1.999	99.039	+
Wealthindex[a]	Level of household wealth	0	2.177	-1.762	9.628	-
Capbindex[a]	Degree of household basic capabilities	0	2.270	-4.555	5.429	-
Hhsize	Household size	6.233	3.024	1	15	+
Acextn	Access to extension services (dummy 1 = yes)	0.507	0.501			+/-
Pvdtrn	Access to training in agricultural production (dummy 1 = yes)	0.178	0.383	0	1	-
Scegps	Participation in social groups (dummy 1 = yes)	0.478	0.500	0	1	+
Invol	Involvement with an external organization (dummy 1 = yes)	0.301	0.459	0	1	+

[a] *Measured using Principal Component Analysis (PCA)*

Source: Field Survey, 2013/2014

Table 5.2: Factors influencing households' decisions to participate in collective provision and appropriation of rangeland resources (pastures).

	Zero/one inflated beta- Marg. Effects		
Variables	**Probability of having value 0** (1)	**Conditional on not having value 0 or 1** (2)	**Proportion** (3)
Neighborhood social influences	-1.708**	-0.053	1.167**
	(0.698)	(0.069)	(0.477)
Quality of road	0.890***	0.004	-0.621***
	(0.089)	(0.062)	(0.069)
Distance to the market	-0.071*	-0.003	0.048*
	(0.038)	(0.002)	(0.027)
Distance to the river	-0.140***	0.004***	0.100***
	(0.030)	(0.001)	(0.021)
Gender of hh head	-0.336	-0.010	0.228
	(0.239)	(0.025)	(0.166)
Age of hh head	0.097	0.005	-0.066
	(0.291)	(0.019)	(0.204)
Primary occupation of the hh	0.384	-0.036	-0.283
	(0.293)	(0.038)	(0.199)
Level of hh wealth	-0.062	-0.004	0.041
	(0.048)	(0.006)	(0.034)
Degree of hh capability	0.228***	-0.013***	-0.166***
	(0.061)	(0.005)	(0.044)
Involvement with an external organization	-0.877***	0.048*	0.644***
	(0.079)	(0.028)	(0.058)
Herd Size	-0.008**	0.005	0.006**
	(0.004)	(0.009)	(0.003)
Household size	-0.037	0.001	0.026
	(0.048)	(0.003)	(0.033
Credit access	0.301	0.003	-0.209
	(0.293)	(0.022)	(0.204)
Participation in social groups	-0.484**	0.005	0.338**
	(0.199)	(0.018)	(0.138)
Contact with extension service providers	0.496*	0.028	-0.333*
	(0.267)	(0.029)	(0.192)
Access to agricultural production training	0.121	0.038	-0.068
	(0.348)	(0.030)	(0.251)
Model summary	Wald chi2(16) = 81.83 *** Standard errors in parentheses, No. of observations 352, *** p<0.01, ** p<0.05, * p<0.1		

In the sample, households with higher neighborhood influences, who participate in social groups or are involved with external organizations are less likely to have zero extent of participation (column 1). These factors are also associated with a higher extent of participation when the whole sample is considered (column 3). However, where participation was not zero, only the involvement with external organizations was found to significantly influence the extent of participation. Households who had networks with external organizations had a higher extent of participation by 4.8 percentage points.

With regard to the role of resource systems characteristics, the model suggests that these variables are statistically significant in determining the probability of households' participation in collective management of range resources. Measures of market access have a significant influence on participation. Access to good roads increases the probability of having zero extent of participation by 89.0 percentage points while increased distance to the market reduces the probability of having zero extent of participation by 7.1 percentage points (column 1). Similarly, when the whole sample is considered, improved road quality reduces the extent of participation whereas as the distance to market increases, extent of participation increases (column 3). The variables, however, do not have a significant effect on extent for proportions between 0 and 1 (column 2). The distance of a household to a permanent watering point such as a river was found to significantly influence both participation and the extent of participation. Increased distance to a permanent watering point is found to reduce the probability that a household has zero extent of participation and at the same increases the extent of participation when the whole sample is considered (columns 1 and 3). Additionally, an additional kilometer away from a permanent watering point is found to increase the extent of participation by 0.004 percentage points when participation is not zero (column 2).

Access to extension agents is the only institutional factor found to significantly influence participation in the study. Contact with extension service providers increases the probability of households' having zero extent of participation (column 1). Contact with extension agents also reduces the overall extent of participation by 33.3 percentage points (column 3). The factor, however, does not significantly influence the extent for the households participating in collective management (column 2). The regression results also demonstrate that socioeconomic factors play a significant role in the collective management of pastoral resources. The herd size of a household is found to significantly influence participation. Increased herd sizes are observed to reduce the probability of households having zero extent of participation (column 1). In addition, an additional unit of livestock increases the overall extent of participation by 0.06 percentage points (columns 3). Herd sizes, however, do not significantly influence the extent of the households' participation in collective management (column 2).

The study employs various other specification techniques, such as the Fractional GLM specification advocated by Papke and Wooldridge (1996) for handling proportional regressions for robustness checks (Appendix F). Similar results to the zero-inflated beta model are found.

5.6 Discussion

The regression results from the zero-inflated beta model indicate differences in the influence of variables on boundary observations (zero participation) from non-boundary observations (non-zero participation). Similar to the findings by Cook et al. (2008), the regression results show existing differences in the factors influencing participation in collective management of range resources from factors influencing the extent of the participation. The probability of a household participating in collective management of range resources is found to be influenced by various variables: neighborhood influences, degree of household basic capabilities, distance to the main market, distance to a permanent watering point, quality of the roads, involvement with external organizations, and participation in social groups. However, distance to the nearest permanent watering point, household basic capabilities, and involvement with external organizations are the only variables found to significantly influence the extent of participation for households participating in the collective management of range resources.

The regression results demonstrate that household basic capabilities play a significant role in the collective management of pastoral resources. As highlighted by Ballet et al. (2015), capability changes can present an obstacle to the collective management of natural resources. Increased basic capabilities reflect the strategic power of an individual or individuals and are essential to transform one form of capital into another form. In this case, greater capabilities increase opportunities for alternative uses of rangeland resources. These findings are in line with the new institutional economic theory according to which capabilities, in the form of skills and knowledge, shape individuals’ perceptions about opportunities that may be exploited (North, 1995). This increases the options/choices that an individual has and ultimately leads to changes in institutions, such as property rights, to facilitate their exploitation (North, 1995). Greater capabilities, therefore, provide exit options for households from managing range resources collectively and generate opportunities for different rangeland uses. In contrast, limited capabilities restrict individuals’ capacity to explore various options, ensuring that collective use of pasture resources is maintained. The effect of increased basic capabilities could be viewed positively as it reduces collective action problems of interdependency among individuals (Kirsten et al., 2009b). As observed, increased capabilities liberate participants to pursue their interests, so that their efforts influence the individual benefits with no wider benefits to all. Increased capabilities are also associated with less transaction costs of monitoring and enforcing participants’ adherence to rules (Kirsten et al., 2009b). On the other side, increased basic capabilities are likely to weaken social cohesion, cultural values, and customs, which are social capital components associated with collective management of pastoral resources. These unquantified social costs are likely to affect cooperation of communities in other areas for joint well-being.

Components of social capital included in the model significantly influence participation in collective management of pastoral resources. The degree of promotion that a household receives from neighboring households is likely to affect their actions along a particular path, such as that of participating in collective management of pastoral resources or adoption of a technology (Case 1992; Willy and Holm-Müller, 2013). As indicated by Willy and Holm-Müller (2013), the degree of promotion (neighborhood influences) could either be positive or negative, depending on which of the two is stronger. In this study, the positive effect is stronger, as neighborhood social influence is found to have a positive effect on collective management of pasture resources. Participation in social groups is also found to facilitate collective management of pastoral resources. Social participation enables households to establish social networks and also involves repeated interactions, leading to higher social capital (Willy and Holm-Müller, 2013). Cooperative efforts are thus likely to be higher in households with higher social capital. This provides fertile ground for collective action (Gebremedhin et al., 2004; McCarthy et al., 2004; Willy and Holm-Müller, 2013). External social networks, measured by a household's involvement with external organizations, also play a significant role in prompting the collective management of pastoral resources. Involvement with external organizations in the management of pasture resources is likely to increase the benefits associated with the ecosystems. External organizations have been shown to provide external support as well develop the capacity of households to utilize the full potential of rangelands, such as with wildlife tourism (Bell and Prammer, 2012; Osano et al., 2013). This enables pastoral communities to exploit rangelands in more beneficial ways, leading to increased economic benefits and thus the value of the ecosystems to rural communities. Increased economic value associated with rangelands in turn could serve as an incentive to increase cooperation levels in the management of the resources to ensure their sustenance and also continued flow of benefits. The above confirms the findings of Dayton-Johnson (2000) and Narloch et al. (2012), which indicate that higher individual benefits associated with cooperation are likely to lead to higher levels of cooperation.

The role of resource system characteristics in collective management of pastoral resources suggests a von Thünen-like model (Fujita and Thisse, 2013; Serneels and Lambin, 2001). In von Thünen's model, land use is determined by land rent – locational rent. In the study, in addition to distance to the market, land rent is determined by additional variables, namely proximity to a permanent water source and quality of roads, as an additional proxy for transportation costs. This is in line with the work by Serneels and Lambin (2001). Quality of the road network and distance to the market have a significant influence on participation in collective action. In line with the empirical work by Gebremedhin et al. (2004) and Carpenter and Seki (2005), increased market access may result in competitive environments undermining collective management of the pastoral resources. Competition, as indicated by the new institutional economic theory (North, 1995), is a key driver for institutional changes, such as redefinition of land use arrangements from collective management to exclusive property rights. On the other hand, larger distances to the market are relevant in reducing the opportunity cost of land and providing fewer exit options to manage the land collectively (Gebremedhin et al., 2004). In addition, as indicated by Rashford et al. (2011), characteristics of a parcel of land, such as closeness to water bodies, are also likely to affect collective management of pastoral resources. Parcels of land near water bodies such as rivers are more responsive to changes in the economic returns, increasing exit options of managing pastoral resources collectively.

Access to extension agents is found to have a negative influence on collective management of pasture resources. As explained in Onemolease and Alakpa (2009), contact with extension agents is likely to lead to the adoption of more agricultural innovations, such as fodder conservation and pasture establishment and thus likely to reduce the need of collective management of pastoral resources. The socioeconomic factors are also shown to play a significant role in collective management of pastoral resources. Households with larger herd stocks are more likely to participate in the collective management of pastoral resources. With large numbers of livestock, collective management of pastoral resources mitigates the consequences of environmental variability characterizing the ecosystems (Mwangi and Meinzen-Dick, 2009).

5.7 Conclusions and Policy Implications

Collective ownership of range resources is a fundamental pillar in structuring the use of pastoral rangelands. These systems allow for joint provision and exploitation of rangeland resources, providing a more equitable way of distributing pasture resources that are highly variable over time and space. In addition, collective management of range resources, unlike exclusive property rights, provide significant returns to scale. Under these systems, pastoralists have access to larger areas capable of providing water and good pastures in both dry and wet seasons, reducing the risks emanating from low and erratic rainfall and variations in pasture productivity characterizing rangelands. Furthermore, exclusive property rights undermine the capacity of pastoral communities to sustainably use the ecosystems as well as deal with risks such as droughts.

However, collective management of natural resources does not always emerge and is affected by various factors. This study used econometric approaches to assess the influence of basic capabilities, among other factors, on the participation and extent of participation in the collective management of pasture resources in southwestern Kenya. Regression results indicate differences in the factors influencing participation in the collective management of range resources from factors influencing the extent of the participation. From the findings, increasing neighborhood influences, participation in social groups, involvement with external organizations, large distances to the main market and to a permanent watering point, and large herd sizes are associated with lower probabilities of zero extent of participation. On the other hand, households who have access to better roads and higher basic capability levels are more likely to have zero extent of participation. With regard to non-boundary observations (non-zero participation), distance to the river, household capabilities, and involvement with external organizations are the only variables with significant influence on the extent of participation.

While increased basic capabilities reduce cooperation levels in collective management of pastoral resources, it has the advantage of liberating participants to pursue their interests and reducing collective action problems of interdependency among individuals. Increased capabilities are also associated with less transaction costs of monitoring and enforcing the adherence to rules associated with collective action. However, increased capabilities may result to unquantified social costs. Less association of communities is likely to weaken or destroy social cohesion, cultural values, and customs of pastoral communities and may affect their cooperation in other areas for joint well-being.

Important policy implications can be drawn from these findings. Identifying the factors that that facilitate or hinder collective management of pastoral resources can make a valuable contribution in identifying efforts needed to mitigate risks likely to be experienced with exclusive property rights. In addition, the results could facilitate the design of more effective pastoral resources conservation programs. The findings suggest that building social capital may have significant benefits for collective management of natural pasture resources. Possible approaches to achieve this are through policies that enhance the presence of external supporting actors at the grassroots in addition to recognizing and facilitating capacity building of local groups. These policies are likely to expand communities' social networks and social participation. In addition, the policies are likely to enable participants to exploit the opportunities available with collective management of range resources, for instance, pastoral tourism and organic livestock production. Furthermore, policies that present short-term rewards for cooperation in management of range resources could increase individuals' benefits associated with cooperation and thus encourage collective management of natural resources. These policies could be either in the form of increased service delivery such as access to livestock markets and information on livestock market prices beyond Narok County.

The effect of other forms of capital such as increased capabilities (ability to achieve) and resource system characteristics indicate that collective action in natural resource management may not always be viable for improved rangeland management. The results highlight the need for policies that encourage the adoption of improved range management technologies in areas where the law of nature (communal management of land) is being abandoned for the capitalist structure (privatization of communal resources). The policies may include conservation agriculture and the production of good quality forages adapted to grazing and drought stress.

The main limitation of the analysis in this study lies in the failure to integrate risks facing rangeland users in the analysis of participation in the collective management of pastures. As highlighted earlier, there are inherent risks associated with the stochasticity of rainfall and variations in pasture productivity in rangelands found in arid and semi-arid areas (Domptail and Nuppenau, 2010; Kimani and Pickard, 1998). The level of these risks depends on the severity of drought, the level of overgrazing, and the fragility/resilience of particular land/parcel. The risk measurement thus provides a sizeable challenge because the risks associated are stochastic (stochastic events) and the related dynamics are not linear but determined by thresholds (Domptail and Nuppenau, 2010; Domptail, 2011). Bio-economic models, however, allow representation of non-liner and threshold dynamics such as those observed in rangelands (Domptail, 2011). In addition, bio-economic models allow for the depiction of land user strategies related to risks, as shown by Janssen and van Ittersum (2007) and employed by Domptail and Nuppenau (2010). Further work using bio-economic models may address this limitation to understand how risks affect pastoral and agro-pastoral farmers' decisions on collective management.

Chapter Six

6 Overall Conclusions and Policy Implications

6.1 Overall Conclusions

Despite rangelands providing significant ecosystem services, research evidence indicates that their stewardship is undermined by various factors. The obstacles hindering sustainable rangeland use practices include limited knowledge on the importance of rangelands in the provision of environmental services, the economic potential of rangelands, and the consequences of rangeland degradation. The consequences of degraded rangelands include declining capacity to sustain livestock and wildlife production, negatives effects on the ability of the world poorest populations to sustain their livelihoods and food security, progressive loss of biodiversity, changes in greenhouse gas emissions and carbon sequestration, changes in species connectivity and means for recovery, and changes in nutrient and water cycling, amongst others.

This study seeks to contribute to find solutions to the challenges that limit sustainable rangeland management through its research in ways to arrest degradation with possible positive feedbacks on ecological, social, cultural, and economic services provided by the ecosystems as well as improve livelihoods. To achieve the stated objective, the study sought to address four specific objectives: (i) to assess the dynamics of grazing systems in the world and the related effects on the productivity of the ecosystems, (ii) to examine the key determinants of SLM adoption in Kenyan rangelands, (iii) to assess the potential role of livestock markets in reducing the ecological vulnerability associated with land use/land cover changes on extensive rangeland systems, and (iv) to identify and assess factors influencing households' decisions to participate in collective provision and appropriation of rangelands' resources. To assess the objectives, the study employed distinct methodologies using rich datasets at different scales and frequencies to obtain comprehensive and robust results.

The assessment of the dynamics of LULCC in global livestock grazing systems has been analyzed using comprehensive desktop-based literature searches, remotely sensed global satellite images, and secondary statistics relevant for rangeland areas around the world. From the synthesis it is evident that, despite native grazing lands being vast globally, the ecosystems are undergoing various transformations which, in most instances, involve losses to other land uses/covers.

Though some conversions are related to biophysical factors such as climatic factors, the key driving forces behind native grazing lands conversions are related to human activities. The study demonstrated that not all losses of native rangelands are pessimistic and neither are all gains associated with better-managed systems. Some transformations were linked to the degradation of the ecosystems, while others involved productive gains. Caution should be taken, however, to ensure the sustainability of the landscapes. Short-term productive transformations should be neither at the expense of long-term ecosystem services nor the resilience of the remaining grazing areas nor the modified landscapes. The review therefore supports better management of native grazing systems including minimal undesirable conversions. Where transformations of the ecosystems are inevitable, the study supports the placement of strategic measures to ensure sustainability of both the remaining native ecosystems and the modified landscapes.

The key determinants of SLM adoption in Kenyan rangelands have been assessed, duly accounting for the simultaneity issues likely to arise. Among the key variables influencing SLM adoption is land degradation. Households are seen to adopt SLM practices in response to land degradation as an intervention measure to reverse and restore degrading lands. The findings indicate that households are likely to adopt SLM practices when they perceive degradation as a significant factor affecting production and their livelihood. This highlights the importance of information and perception issues as factors conditioning the adoption of SLM practices. Stimulating awareness and action among rural households on the benefits versus costs of taking action against land degradation is thus identified as a key factor likely to facilitate the adoption of SLM practices. This is supported by the positive effect that access to extension services has on SLM adoption, in which case extension services are associated with awareness creation. Additional factors influencing SLM adoption include agro-ecological and land characteristics, access to output markets, capacity of a household to invest in sustainable practices, and human capital endowments.

The potential impacts of improved access to livestock markets on land use decisions and productivity of rangelands have been analyzed within the framework of a positive mathematical programming mode and a dynamic ecological-economic rangeland model. The study postulates that the existing market inefficiencies characterizing livestock markets, especially the price disincentives faced by livestock producers, are a major risk rangelands face. In the face of livestock market price disincentives and to satisfy the need to improve their incomes and livelihoods, rural households are likely to explore more profitable rangeland uses such as conversion to crop farming or land leases/sales to immigrant crop farmers. The results of the analysis failed to reject the hypothesis and showed that improved livestock market access affects the economic returns of producers which in turn affect rangeland management decisions. Improved market access in the study was sought through the creation of opportunities for pastoralists to sell livestock more profitably by re-apportioning value-added in the livestock marketing chain, linking them to the terminal markets, and through reduced livestock transportation costs. Increased benefits associated with livestock production lead to fewer conversions of former rangelands to other land uses. The livelihoods of the rangelands' livestock producers improve with better earnings and stabilized assets in the form of livestock units. In addition, livestock producers' vulnerability to ecological climate variability characterizing rangelands is reduced.

Factors facilitating or hindering participation in collective provision and appropriation of pasture resources have been analyzed, duly accounting for differences in the influence of variables on boundary observations from non-boundary observations. Studies on participation and adoption rarely model both the participation and the extent of participation, thus the study makes a relevant contribution by focusing on both. Regression results indicated differences in the factors influencing participation in collective management of range resources from factors influencing the extent of the participation. The findings demonstrate that basic capabilities are important in explaining both participation and the extent of participation in collective management of pastoral resources. Increased basic capabilities are associated with lower levels of households' cooperation in the collective management of pastoral resources. While the effect of capabilities might be viewed as negative, increased capabilities are seen as important in that they liberate participants to pursue their own individual interests. Increased capabilities are also likely to reduce collective action problems of interdependency among participants as well as minimize transactions costs of monitoring and enforcing adherence to rules associated with collective action. On the other hand, increased basic capabilities may result to undesirable social costs such as weakened social cohesion. This may affect the communities' cooperation in other areas for joint well-being. The findings also demonstrate that neighborhood social influence, distance to the main market, distance to the nearest permanent watering point, livestock herd size, involvement with an external organization and social participation have positive influences on the probability of households participating in collective management of pastoral resources. In contrast, the quality of the roads, primary occupation of the household, and access to extension services were found to have a negative influence on participation. In addition to households' capabilities, distance to the nearest permanent water source and involvement with external organizations are the only factors found to significantly influence the extent of participation in collective management of range resources.

6.2 Policy Implications

The current study identifies some areas on which policy seeking to mitigate degrading rangelands could focus:

1. Strategies towards sustainable intensification of agricultural activities, especially in areas already experiencing resource strain from competing land resource uses, emerge as an area of important need. Policies encouraging the adoption of improved range management technologies in areas where the law of nature (communal management of land) is being abandoned for the capitalist structure (privatization of communal resources) would relieve grazing pressures on the remaining extensive rangeland resources. Intensification technologies may include conservation agriculture and production of good quality forages adapted to grazing and drought stress. This requires policy action towards capacity building and training of households on suitable intensification technologies available, practical training on appropriate use of the technologies, access to establishment and maintenance inputs, and training on the appropriate equipment and maintenance.

2. Low adoption rates of SLM practices in rangeland management necessitate policies towards awareness raising, promotion, and training on best practices for SLM in rangelands. These can be facilitated through FFS and extension services. This further calls for polices expanding and reviving FFS and extension services, especially in the marginalized range areas. SLM practices can also be enhanced through policies that enhance extension services through the appropriate training of trainers and research initiatives to identify the best extension packages suitable for rangelands. In addition, policies that promote households' capacity to adopt SLM practices are essential. For instance, improved credit facilities are likely to enhance poor rural households' capacity to invest in SLM practices.

3. There is also a need for policy action towards empowering livestock producers to participate in value-added livestock production and access to high-value product markets and market opportunities. Feasible markets for livestock and livestock products serve as engines for the attraction of investments such as those relating to sustainable rangeland management practices. For instance, policy action empowering livestock producers to participate in high-value product markets, such as niche markets are likely to increase economic incentives and also the capacity of households to invest in SLM practices. Policies towards reducing barriers and constraints limiting livestock producers from participating in value-added livestock production, such as fattening of livestock, and high-value markets are also likely to improve livestock producers' margins. Increased benefits associated with livestock production enhance the competitiveness of livestock production to other land uses, such as crop farming. This is likely to reduce the conversion of grazing vegetation to other LULC.

4. Collective action is found to be crucial in addressing environmental and pasture productivity challenges characterizing the semi-arid rangelands. Collective action is also likely to provide essential pathways for improved incomes and livelihoods of livestock producers, for instance when used as a market-based intervention. There is therefore a need for policies to promote collective action at the community level. Possible approaches towards this include policies towards capacity building of local groups, for example, through training opportunities. In addition, policies that present short-term rewards for cooperation in collective action, such as increased service delivery and enhancing presence of external supporting actors at the grassroots level, are likely to promote collective action.

6.3 Outlook for Further Research

The challenges on how to maintain the capacity of rangelands to provide goods and services in the long term are far from finished, especially with increased pressures from population growth, changing opportunities brought about by markets, policy interventions, technological change, and changes in social organizations and attitudes. This study offers some insights into how to address some of the obstacles that limit sustainable rangeland practices. However, a few gaps still exist that could form a basis for future research.

First, although strategies towards sustainable intensification of agricultural activities have been identified as possible solutions to declining suitable extensive pasture resources, the challenge present for forage researchers relates to how to promote the adoption of forages in pastoral and agro- pastoral settings. Unlike in smallholder systems, forages are least adopted in pastoral and agro- pastoral systems due to the following reasons (McIntire and Debrah, 1986):

- Relative land abundance associated with rangelands. Forage crops are less likely to be adopted in pastoral and agro-pastoral systems where land is relatively abundant compared to smallholder systems with land supply constraints. Land abundance allows for opportunistic free grazing of livestock on natural pastures and is also associated with low labor input per unit of land.
- Heterogeneity of land associated with rangelands. Due to the high heterogeneity of land associated with ASALs, the selection of forages which fit in each niche and into each climatic cycle might entail high costs, among other challenges.
- Need for forages with high tolerance for marginal environments.
- Adoption of forage crops in a pastoral or agro-pastoral setting implies less livestock mobility, more labor input per production unit, and higher short-term climatic risks. This limits adoption of forage crops in pastoral and semi-pastoral systems.
- In wet seasons, natural pastures are in high supply and thus likely to constrain forage demand.

Further research is needed to promote sustainable intensification of livestock production in view of the highlighted challenges.

Second, as highlighted earlier, livestock insurance and cooperation fostered by livestock producer marketing associations can be employed to complement the efforts toward improved access to livestock markets. Higher margins associated with improved livestock market opportunities are capable of creating incentives to stock more livestock. This would have negative effects on the sustainability of rangelands. However, the study reveals potential synergies between collective initiatives, such as livestock producer marketing associations and sustainable rangeland management with improved market access. Other than consolidating supply and improving the collective bargaining power of the livestock producers, marketing associations are capable of fostering cooperation among pastoralists on livestock production strategies, such as stocking rates, so as to obtain better prices at the terminal end markets. Producer associations, therefore, present a viable option to foster sustainable management practices in semi-arid grazing lands in addition to a vehicle for market-based interventions. In addition, livestock insurance would be a critical concept encouraging livestock producers to participate in livestock markets. Insurance would enable the producers to stabilize their livestock accumulation, making them less likely to face drastic reductions in livestock, with increased offtake levels, in the event of a shock from the risky climatic conditions characterizing range areas. In addition, improved access to livestock markets coupled with livestock insurance is likely to lead to crowding in of finance to provide the much-needed credit for adoption of SLM practices. Further research work is necessary to evaluate these possible strategies for adoption and implementation.

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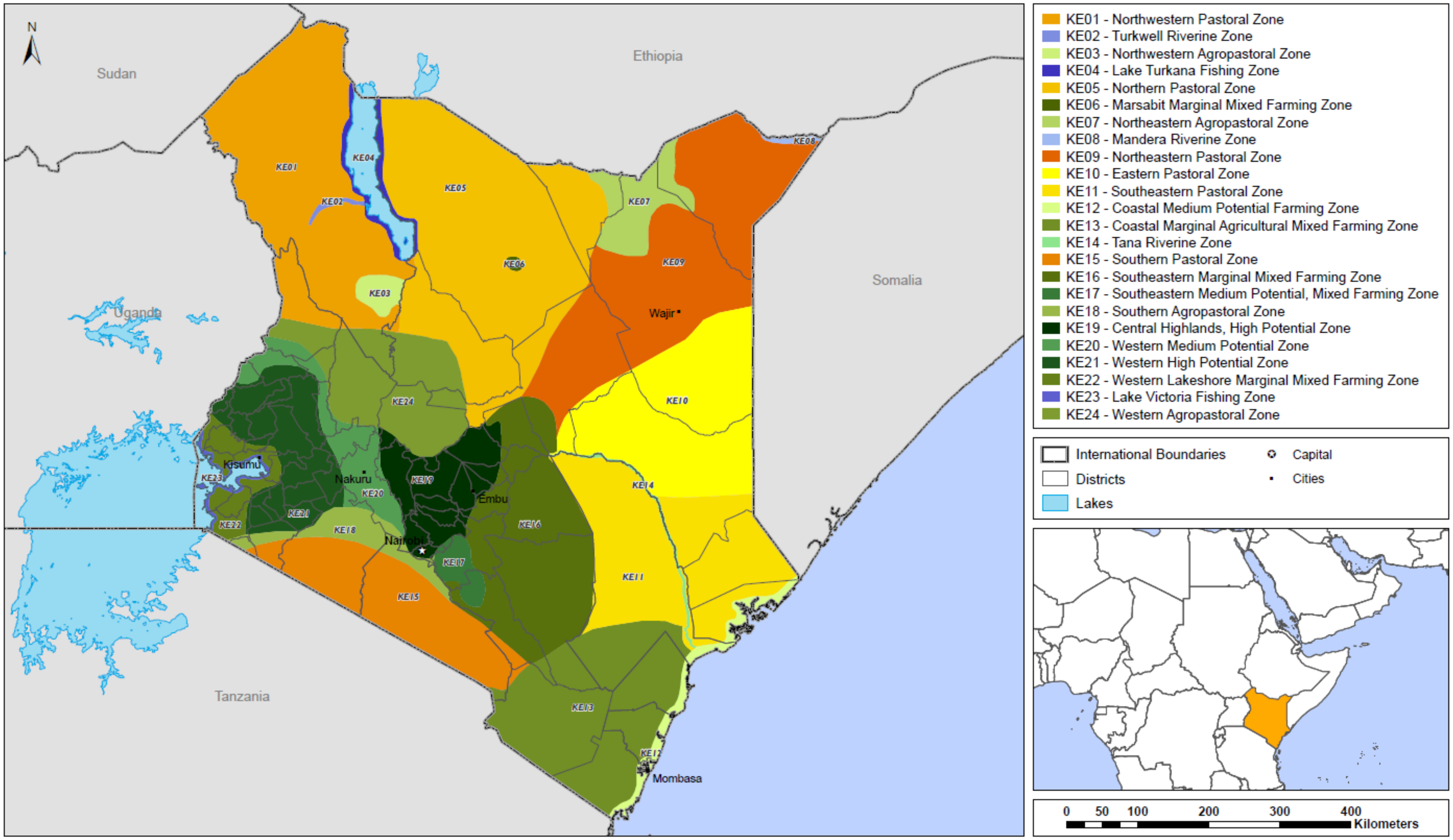
Appendices

Appendix A: Livelihoods zones data for Kenya



Source: FEWS livelihoods zones data for Kenya. Available at: http://www.fews.net/east-africa/kenya/livelihood-zone-map/march-2011.

Appendix B: Parameters used to calibrate the biomass production equation

Parameter	Description	Value	Source
β	Biomass production slope	7.5	De Leeuw et al. (1991)
α	Biomass production intercept	-1000	De Leeuw et al. (1991)
LAM	Herd growth rate (logistic function)	0.6	Estimated using KIHBS 2005/06 data set
PH	Feed required for the maintenance of a TLU(kg DM/TLU per year)	6.25 kg of forage dry matter daily	De Leeuw et al. (1991)
BINS	'Proper-use factor' forage allowance	0.5	Sedivec (1992) ; Gerrish and Morrow (1999)
BOSH	Share of biomass available for livestock after other users/uses have received their share (e.g. feed for other herbivores and non-feed uses such as thatching) (Domptail and Nuppenau, 2010).	0.7	
INTERCEPT	Livestock demand function intercept	201,312.24	Estimated using parameters from Karugia et al. (2009) and Mose et al. (2012).
SLOPE	Livestock demand function slope	0.12	

Appendix C: Adoption of efficient transport system: Double decker truck

Costs Margins in Marketing		**With Double Cabin**	**Without Double Cabin**
Selling Price: (Price at the terminal market)			
	Goat	2,067.00	2,067.00
	Sheep	1,933.00	1,933.00
Total Costs			
	Goat	1,818.00	1,941.00
	Sheep	1,652.00	1,775.00
Margin			
	Goat	249	126
	Sheep	281	158
Increase in margin as a percent of Selling Price			
	Goat	5.95	
	Sheep	6.36	
Average increase in margin as a percent of Selling Price per Shoat (Average of Sheep and Goat)	6.16	6.16	
Breakdown of Marketing Costs of shoats			
Production costs:			
	Goat	1850	1850
	Sheep	1650	1650
Broker Fees@		50	50
Trader Costs@		55	55
Loading@		5	5
Branding@		10	10
County Fee@		20	20
Permits@		50	50
Transport@		**7**	**130**
Off-loading@		5	5
Boma Fee@		40	40
Others@		10	10

Source: Values from Muthee (2006).
**Table presents the savings made by transporting shoats together with livestock by use of a double decker truck*
Average exchange rate: 1 USD $\approx$75 KES[1]

1 Source: https://www.centralbank.go.ke/index.php/rate-and-statistics/exchange-rates-2?

Appendix D: Detailed lists of sets, parameters, scalars, variables, and equations in the model.

PMP MODEL

SETS

I	PRODUCTION PROCESSES
II(I)	INTENSIVE PRODUCTION
J	RESOURCE SUB SET
R(J)	LAND INPUT
P(J)	CROP RESOURCE SUB SET
ITEMS	ITEMS INCORPORATED IN THE SIMULATION
ALIAS (J,L)	

PARAMETERS

PRI(I)	CROP PRICES (KSH PER KG)
Y(I)	CROP YIELD (KG PER HECTARE)
TABLE C(I,J)	COST (KSH PER UNIT) OF FIXED PRODUCTION FACTORS
TABLE A(I,J)	A MATRIX OF TECHNICAL COEFFICIENTS/ QUANTITY OF INPUTS (J) THAT TRANSLATE INTO PHYSICAL OUTPUT PER HECTARE
XBASE(I)	BASE/INITIAL LAND ALLOCATIONS
B(J)	RESOURCE CONSTRAINTS
XB(I,J)	TOTAL BASE QUANTITY OF RESOURCES USED XB(I,J) = A(I,J) * XBASE(I) ;
REV(I)	REVENUE REV(I) = PRI(I)* Y(I) ;
CSL(I)	LINEAR COST: CSL(I) = SUM(J, C(I,J)*A(I,J));
NET(I)	NET RETURN: NET(I) = REV(I)- CSL(I);
PERDIFF1(I)	DIFFERENCE BETWEEN LINEAR PROGRAM LAND USE AND BASELINE OBSERVATIONS PERDIFF1(I)$XB(I,"LAND") = ((LX.L(I)- XB(I,"LAND"))*100)/ XB(I,"LAND") ;
SUB	ELASTICITY OF SUBSTITUTION
ADJ	ADJUSTMENT FOR MARGINAL CROPS ADJ = RESOURCE.M("LAND") * ADJFACT;
OPP(J)	OPPORTUNITY COST OF LAND OPP(J)= RESOURCE.M(J) ; OPP("LAND")= RESOURCE.M("LAND") - ADJ;
LAM(I,J)	PMP DUAL VALUE ON LAND LAM(I,"LAND") = CALIB.M(I) + ADJ ;
TOT(I)	TOTAL OUTPUT TOT(I) = Y(I)*XB(I,"LAND") ;
CST(I,J)	COST OF FIXED PRODUCTION FACTORS PLUS OPPORTUNITYCOST

	CST(I,J) = C(I,J) + OPP(J) + LAM(I,J) ;
ETA(I)	FUNCTION OF ELASTICITY OF SUBSTITUTION ETA(I) = (SUB - 1)/SUB ;
THETA	MINUS ONE OVER ELASTICITY OF SUBSTITUTION THETA = -(1/SUB) ;
BETA(I,J)	SHARE PARAMETERS BETA(II,J)$(SW(J) EQ 1) = 1/(SUM(P, (CST(II,P)/CST(II,J)) * (XB(II,J)/XB(II,P))**THETA) + 1) ; BETA(II,J)$(SW(J) EQ 2) = 1 - SUM(L$(SW(L) NE 2), BETA(II,L)) ; BETA(II,J)$(SW(J) EQ 0) = SUM(R,BETA(II,R))*(CST(II,J)/ SUM(R,CST(II,R)))* (SUM(R, XB(II,R))/XB(II,J))**THETA ;
CN(I)	SCALE PARAMETER CN(II) = TOT(II) / (SUM(J, BETA(II,J)* ((XB(II,J)+0.0001)**((SUB-1)/SUB)))** (SUB/(SUB-1))) ;
NI(J)	RESOURCE COUNTER NI(J) = ORD(J);
MARPRO2(I,J)	MARGINAL PRODUCT MARPRO2(II,J) = BETA(II,J)*(CN(II)**ETA(II))* (TOT(II)/XB(II,J))**(1/SUB) ;
VMP2(I,J)	VALUE MARGINAL PRODUCT VMP2(II,J) = MARPRO2(II,J)* PRI(II) ;
ALPH(I)	COST INTERCEPT ALPH(I) = C(I,"LAND") - LAM(I,"LAND")
GAM(I)	COST SLOPE GAM(I)$(LAM(I,"LAND") NE 0) = (2* LAM(I,"LAND")) /XBASE(I)
PMPTEST(I)	TEST VALUE FROM PMP PMPTEST(I) = ALPH(I)+ GAM(I)*XBASE(I) ;
PMPDIFF(I)	PERCENT DEVIATION IN PMP PMPDIFF(I)$LAM(I,"LAND") = ((PMPTEST(I)- LAM(I,"LAND"))*100)/ LAM(I,"LAND")
VMPDIFF(II,J)	VALUE MARGINAL PRODUCT CHECK VMPDIFF(II,J)$CST(II,J) = ((VMP2(II,J)- CST(II,J))*100)/ CST(II,J);
PERDIF2(I,J)	PERCENT DIFFERENCE BETWEEN CALIBRATED NON-LINEAR MODEL INPUT ALLOCATION AND OBSERVED BASE INPUT ALLOCATION PERDIF2(I,J)$XB(I,J) = (XC.L(I,J) - XB(I,J)) * 100 / XB(I,J) ;

SCALAR

EPSILON	ROUNDING ERROR ALLOWABLE IN THE RESOURCE AND CALIBRATION CONSTRAINTS
ADJFACT	ADJUSTMENT FACTOR FOR MARGINAL CROPS
NJ	NUMBER OF INPUTS
	NJ = SMAX(J, NI(J)) ;

VARIABLES:

VARIABLES USED IN THE PMP CALIBRATION PROCESS

LX(I)	LAND ALLOCATED IN THE LINEAR PROGRAM
LINPROF	LINEAR PROGRAM PROFIT

VARIABLES USED IN THE CALIBRATED MODEL

XC(I,J)	RESOURCE ALLOCATION
TPROFIT	NON-LINEAR TOTAL PROFIT FUNCTION (CALIBRATED);

EQUATIONS:

CONSTRAINED RESOURCES

RESOURCE(J).. SUM(I,A(I,J)*LX(I)) =L= B(J) ;

UPPER CALIBRATION CONSTRAINTS

CALIB(I)… LX(I) =L= XB(I,"LAND") * (1+EPSILON) ;

LINEAR PROGRAM OBJECTIVE FUNCTION

LPROFIT... SUM((I), LX(I)*(PRI(I)* Y(I)- SUM(J, C(I,J)*A(I,J)))) =E= LINPROF;

CALIBRATED MODEL RESOURCE CONSTRAINTS

INPUT(J)… SUM(I, XC(I,J)) =L= B(J);

NON-LINEAR PROFIT FUNCTION IN THE CALIBRATED MODEL

NONLINPROFIT… TPROFIT =E= SUM((II), PRI(II) * (CN(II)* (SUM(J, BETA(II,J)* ((XC(II,J) +0.0001)**((SUB-1)/SUB)))** (SUB/(SUB-1)))))+ XC("GRASS","LAND") *(Y("GRASS")*V("GRASS"))-SUM(I, ALPH(I) *XC(I,"LAND") + 0.5* GAM(I) * SQR(XC(I,"LAND"))) - SUM((I,P), C(I,P)*XC(I,P)) ;

RANGE PRODUCTION

SETS

T	YEARS
P	PRECIPITATION LEVELS
K	TIME PERIODS

W	RAINY SEASONS
BASET(K)	FIRST PERIOD
ROOT(N)	THE ROOT NODE
KW(K,W)	RELATING TIME PERIODS TO RAINY SEASONS
N	NODES: DECISION POINTS OR STATES IN SCENARIO TREE
KN(K,N)	MAP NODES TO TIME PERIODS
ANC(CHILD,PARENT)	ANCESTOR MAPPING
NP(N,P)	MAPS NODES TO PRECIPITATION LEVEL
LEAF(N)	
ITER	MAX NUMBER OF ITERATIONS
I	NODES AT WHICH VALUE FUNCTION IS EVALUATED
ALIAS	(N,PARENT,CHILD)
ALIAS	(I,J)

TABLE

RAINFALL(W,P)	RAINFALL AMOUNT FOR EACH SEASON

PARAMETERS

PR(P)	PROBABILITY DISTRIBUTION OVER RAINFALL LEVELS
NPROB(N)	PROBABILITY OF BEING AT ANY NODE
NDELTA(N)	RAINFALL AT EACH NODE
R(T)	RAINFALL SCENARIOS (AMOUNTS AT THE NODE OF SCENARIO TREE FORM THE RAINFALL SCENARIOS)
DEF	DEFAULT VALUE
BETA(T)	DISCOUNT FACTOR BETA(T) = 1/(1+ IR)**ORD(T); BETA(T) = BETA("1");
TLU0	TROPICAL LIVESTOCK UNITS IN PREVIOUS PERIOD TLU0 = STOCK(I) ;
BETA0	CURRENT BETA BETA0 = BETA("1");
RAIN	RAIN IN CURRENT PERIOD
X(I)	NODE VALUE FOR THE STATE VARIABLE ON THE UNIT INTERVAL X(J) = COS(ARG(J)) ;
IN(I)	INDICES TO CALCULATE THE ARGUMENT OF THE COSINE WEIGHTING FUNCTION IN(I) = ORD(I); IMAX = SMAX(I, IN(I)) ;
AOLD(J)	PREVIOUS POLYNOMIAL COEFFICIENT VALUE FOR LOOP CONVERGENCE CHECK AOLD(I) = ACOEF(I);
STOCK(J)	STOCK LEVEL VALUE AT NODE J FOR GRID POINT CALCULATION

	STOCK(J) = (L+U+(U-L)*X(J))/2;
VAL(J)	STORES THE VALUE OF THE VALUE FUNCTION FOR LOOP CALCULATION
PHIBAR(I,J)	POLYNOMIAL TERMS USED IN THE LOOP CONVERGENCE CALCULATION PHIBAR("1",J) = 1; PHIBAR("2",J) = X(J); LOOP(I$(ORD(I) GE 3), PHIBAR(I,J) = 2*X(J)*PHIBAR(I-1,J)-PHIBAR(I- 2,J)) ;
ARG(J)	ARGUMENT OF THE COSINE WEIGHTING FUNCTION ARG(J) = ((2*IN(J)-1)*PI)/(2*IMAX)
ACOEF(I)	INITIAL POLYNOMIAL COEFFICIENT VALUES FOR VALUE FUNCTION ACOEF(I) = 0; ACOEF(I)$SUM(J,SQR(PHIBAR(I,J))) = SUM(J, VAL(J)*PHIBAR(I,J)) / SUM(J,SQR(PHIBAR(I,J))) ;
DIFF(ITER)	DEVIATION OF CHEBYCHEV COEFFICIENTS FOR EACH VALUE ITERATION DIFF(ITER)= TEST;
CPOLY(ITER,I)	CHEBYCHEV POLYNOMIAL COEFFICIENTS AT EACH ITERATION CPOLY(ITER,I)= ACOEF(I);
CVALUES(ITER,I,*)	COEFFICIENT VALUES FOR CHEBYCHEV POLYNOMIALS CVALUES(ITER,I,'CERROR') = DIFF(ITER) ; CVALUES(ITER,I,'CCOEF_VALUEFCN') = CPOLY(ITER,I);

SCALAR

LAM	GROWTH RATE OF LIVESTOCK HERD
AREA	RANGE AREA IN HA
PH	FEEDING REQUIREMENTS OF A TLU KG DM/TLU PER YEAR
VC	VARIABLE COST PER TLU (INPUT COSTS TO MAINTAIN THE HERD)
IR	THE DISCOUNT RATE
BOSH	'PROPER-USE FACTOR' FORAGE ALLOWANCE
BINS	ADJUSTMENT FACTOR FOR BIOMASS SHARE USED BY OTHER LIVESTOCK AND NON-LIVESTOCK USES
TEST	TEST FOR CONVERGENCE TEST = SUM(I,(ACOEF(I)-AOLD(I))*(ACOEF(I)-AOLD(I)));
TOL	TOLERANCE FOR CONVERGENCE
IMAX	LARGEST INTEGER IN SET I
PI	$\pi = 3.14...$;
U	UPPER LIMIT ON CARRY-OVER STOCK
L	LOWER LIMIT ON CARRY-OVER STOCK

VARIABLES

CVB	CURRENT VALUE BENEFIT
PHI(J)	NODAL APPROXIMATIONS OF VALUE FUNCTION
VALUEFCN	VALUE FUNCTION
SL	OPTIMAL SALES
ANPP	ABOVEGROUND NET PRIMARY PRODUCTIVITY (ANPP, KG DM/HA
SRATE	STOCKING DENSITY
TLU	TROPICAL LIVSTCK UNITS IN NEXT PERIOD
MTLU	MAXIMUM GRAZING CAPACITY
FOD	FODDER
PROFIT	TOTAL CURRENT PROFITS

EQUATIONS

```
ABOVEGROUND NET PRIMARY PRODUCTIVITY (ANPP, KG DM/HA)
RUEEQN..          ANPP =E=-1000 + 7.5*RAIN-SRATE*(-1000+7.5*RAIN) ;
STOCKING DENSITY
STOCKEQN..        SRATE =E= TLU/ AREA
LIVESTOCK DYNAMICS
TLUEQN..          TLU=E= TLU0+( LAM *( 1-( TLU0/MTLU))*TLU0 )- SL;
MAXIMUM GRAZING CAPACITY
MAXEQN..          MTLU =E= FOD/PH ;
FODDER PRODUCTION
FODEQN..          FOD =E= (ANPP* AREA*BOSH)*BINS ;
CURRENTPROFITS
PROFITEQN..              PROFIT =E= SL*(INTERCEPT- SLOPE *SL )-SALES *VC;
POLYNOMIAL RECURSION EQUATION 1
PHI1..            PHI("1") =E= 1 ;
POLYNOMIAL RECURSION EQUATION 2
PHI2..            PHI("2") =E= ((TLU-(L+U)/2)/((U-L)/2)) ;
POLYNOMIAL RECURSION EQUATION 3
PHI3(J)$(ORD(J) GE 3).. PHI(J) =E= 2*((TLU-(L+U)/2)/((U-L)/2))*PHI(J-1)-PHI(J-2) ;
VALUE FUNCTION FOR SIMULATION STAGE
VFN..             VALUEFCN =E= SUM(J, ACOEF(J) * PHI(J)) ;
PRESENT VALUE BENEFIT FUNCTION WITH CHEBYCHEV APPROXIMATION
CVBFCN ..         CVB =E= PROFIT + BETAO*VALUEFCN.
```

Appendix E: Principal Component Analysis

Table E.1: Principal component analysis on degree of capabilities

Variable description	Mean	Std.Dev.	Factor Scores/ Weights for Each Variable
Years of Schooling	5.600	4.845	0.4028
Literate	0.481	0.500	0.3613
Level of education attained	0.713	0.878	0.4008
Main walling material	0.153	0.361	0.2083
Main roofing material	0.572	0.495	0.2951
Toilet facility	0.298	0.458	0.2878
Lighting	0.100	0.301	0.1762
No. of people living in one house (measure of living in crowded conditions)	6.233	3.024	-0.0092
Access to the health center	4.786	4.160	-0.2649
Access to drinking water	2.332	1.592	-0.2815
Source of drinking water(protected and covered)	0.489	0.500	0.2829
Sufficiency of household food consumption	2.916	0.817	0.2696
kmo	0.864		
Largest Eigenvalue,λ	5.158		
Proportion of Variance Explained	0.430		

Table E.2: Principal component analysis on relative wealth index (material wealth index)

Variable description	Mean	Std.Dev.	Factor Scores/ Weights for Each Variable
Plough	0.067	0.250	0.201
Donkey/ox cart	0.019	0.138	0.150
Wheel barrow	0.180	0.385	0.319
Tractor	0.012	0.109	0.219
Cattleshed	0.387	0.488	0.352
Bicycle	0.043	0.204	0.184
Radio	0.385	0.487	0.390
Television	0.070	0.255	0.310
Car	0.031	0.174	0.282
Mobile phone	0.447	0.498	0.406
Water tank	0.091	0.288	0.315
Motorcycle	0.053	0.224	0.199
Kmo	0.764		
Largest Eigenvalue,λ	3.717		
Proportion of Variance Explained	0.310		

Appendix F: Robustness checks- Factors influencing households' decisions to participate in collective provision and appropriation of rangelands resources

Appendix F: Robustness checks- Factors influencing households' decisions to participate in collective provision and appropriation of rangelands resources

	Fracglm		Heckman		Tobit	
Variables	**Participation Extent Coeff.** (1)	**Marg. Effects** (2)	**Selection Eq. Coeff.[a]** (3)	**Outocome Eq.Coeff.** (4)	**Participation Extent Coeff.** (5)	**Marg. Effects** (6)
Neighborhood social influences	1.370**	0.321**	4.088**	-0.003	0.357***	0.245***
	(0.646)	(0.153)	(1.669)	(0.074)	(0.136)	(0.093)
Quality of road	-0.990**	-0.232***	-3.563***	0.011	-0.268***	-0.184***
	(0.400)	(0.090)	(0.996)	(0.107)	(0.088)	(0.059)
Distance to the market	0.030	0.007	0.218***	-0.004	0.008	0.006
	(0.026)	(0.006)	(0.063)	(0.005)	(0.005)	(0.004)
Distance to the river	0.124***	0.029***	0.309***	0.006***	0.027***	0.019***
	(0.011)	(0.003)	(0.060)	(0.002)	(0.003)	(0.002)
Gender of hh head	-0.008	-0.002	0.241	0.041	-0.055	-0.038
	(0.359)	(0.084)	(0.854)	(0.048)	(0.078)	(0.053)
Age of hh head	-0.357	-0.084	-1.016	0.038	-0.086	-0.059
	(0.256)	(0.060)	(0.740)	(0.038)	(0.065)	(0.045)
Primary occupation of the hh	-1.007***	-0.236***	-1.139**	-0.007	-0.296***	-0.203***
	(0.303)	(0.067)	(0.510)	(0.048)	(0.065)	(0.044)
Level of hh wealth	-0.028	-0.007	0.044	-0.005	-0.004	-0.002
	(0.068)	(0.016)	(0.161)	(0.012)	(0.018)	(0.012)
Degree of hh capability	-0.343***	-0.080***	-0.582***	-0.025**	-0.088***	-0.060***
	(0.085)	(0.019)	(0.196)	(0.010)	(0.017)	(0.011)
Involvement with an external organization	2.415***	0.566***	4.524***	0.151**	0.610***	0.418***
	(0.482)	(0.104)	(1.233)	(0.065)	(0.093)	(0.062)
Herd Size	0.005	0.001	0.022**	-0.000	0.001	0.001
	(0.003)	(0.001)	(0.010)	(0.000)	(0.001)	(0.004)
Household size	0.008	0.002	-0.014	0.004	0.000	0.002
	(0.037)	(0.009)	(0.080)	(0.005)	(0.009)	(0.006)
Credit access	0.418	0.098	-0.096	0.028	0.107	0.073
	(0.380)	(0.090)	(0.718)	(0.045)	(0.077)	(0.053)
Participation in social groups	0.698**	0.164**	1.469**	0.021	0.159**	0.109**
	(0.283)	(0.066)	(0.643)	(0.040)	(0.065)	(0.044)
Contact with extension service providers	-0.341	-0.080	-1.175*	0.037	-0.057	-0.039
	(0.235)	(0.055)	(0.615)	(0.041)	(0.062)	(0.042)
Access to agricultural production training	-0.293	-0.069	-0.234	-0.046	-0.074	-0.051
	(0.380)	(0.089)	(0.635)	(0.053)	(0.087)	(0.060)
Constant	-3.527***		-7.523***	0.593***	-0.467***	
	(0.479)		(1.617)	(0.091)	(0.119)	
Mills lambda				0.016		
				(0.076)		
Sigma					0.388***	
					(0.022)	
Model summary[1]	Deviance = 119.0293093 Pearson = 190.0767306		Wald chi2(16) = 28.46**		LR $chi^2(16)$=387.03*** Pseudo R^2 = 0.559	

[1] Standard errors in parentheses, No. of observations 352, , *** p<0.01, ** p<0.05, * p<0.1

Appendix G: Survey Instrument

Pastoralists and Agro pastoralists in Narok County Survey, 2013/2014
Collective Action Initiatives Interview Schedule

INTERVIEW WITH INDIVIDUAL PASTORAL AND AGRO-PASTORAL HOUSEHOLDS

Good morning/afternoon. My name is _________________. I am conducting a survey for ZEF Germany, in collaboration with KARI as part of a larger research initiative on Economics of Land Degradation. The study aims at evaluating the effect of collective action initiatives/groups in the region have on livelihoods and sustainable management of rangelands. I would like to request your participation in this short interview. Any information you provide will be strictly confidential and will not be used for any purpose outside of this research.

STARTING TIME…………………………………………

PART 0. INTERVIEW BACKGROUND

1. Date of interview: Day: …..………………Month: .... Year: ……………….……..……
2. Interviewed by (enumerator's name): ………..
3. Supervised by..4. County...
5. Division …………………………….. 6. Location……………………………………………………
7. Sub-Location……………………………………..8. Village..
9. GPS readings of village: a) Altitude.................; b) Latitude……………; c) Longitude……..……

Appendix G: Survey Instrument

PART 1: RESPONDENT IDENTIFICATION AND VILLAGE CHARACTERISTICS

1. Name of respondent...
2. Marital Status (**Codes A**) ....Sex (**Codes B**)....................Age (years)...........................
3. Relation to household head...
4. Highest Education Level (**Codes C**)..
5. Major family language………...
6. Religion of the household head (**Codes D**)..
7. Primary occupation of the household (**Codes E**)……….……………..…………………………….
8. Secondary occupation of Household (**Codes E**)……………………………………………………
9. Taking into consideration ALL your food sources (own food production + food purchase + help from different sources + food hunted from forest etc.), how would you define your family's food consumption last year? (**Codes F**)..
10. Distance to the nearest neighbour (Km)……………......minutes of walking time……………………
11. Distance to the nearest main market from residence (km)……minutes of walking time………..…
12. Quality of road to the main market (Codes G)………………...
13. Average single transport cost (per person) to the main market using a car (KSh/person).............
14. Distance to the nearest agricultural extension office from residence (km)……..minutes of walking time.
15. Distance to the nearest health center from residence (km)… ……minutes of walking time…..........
16. Distance to the nearest primary school (km)……………………minutes of walking time…...........
17. Distance to the nearest secondary school (km)…………………minutes of walking time…............
18. Main source of drinking water………...(**Codes H**)
19. Main source of livestock water…………………...(**Codes H**)
20. Distance to main water source for drinking from residence (km)……minutes of walking time…..
21. Distance to nearest river from residence (km)………………minutes of walking time……………..

Codes A: 1.Single, 2.married, 3.widowed, 4.separated, 5.divorced
Codes B: 1. Female; 2. Male
Codes C: 1. None; 2.Primary; 3. Secondary; 4. College/Institute; 5. University; 6. Other, specify……………………………
Codes D: 1. No religion/atheist; 2. Orthodox Christian; 3. Catholic; 4. Protestant; 5. Other Christian 6. Muslim; 7. Other, specify………...……
Codes E: 1.Herding, 2.livestock framing 3.crop farming 4.poultry farming, 5.salaried employment, 6.self-employed off-farm, 7. casual laborer on-farm, 8.casual laborer off-farm, 9.household chores, 10.apiculture, 11.aquaculture, 12.other, specify.............
Codes F: 1. Food shortage throughout the year, 2. Occasional food shortage, 3. No food shortage but no surplus, 4. Food surplus.
Codes G: 1= Very poor; 2= Poor; 3= Average; 4=Good; 5= Very good;
Codes H: 1. Piped; 2. Borehole protected and covered; 3. Borehole unprotected & uncovered; 4. Stream; 5. River; 6. Lake; 7. Ponds/dams or floods/Water Pans; 8. Harvested rain water; 9. Others (Specify)……… Note: protected refers to water sources internally plastered and covered with a cap of wood, stone or concrete).

PART 2: CURRENT HOUSEHOLD COMPOSITION AND CHARACTERISTICS

Name of household member (start with respondent)	Sex **Codes A**	Marital status Codes B	Age (years)[1.]	Education (years) **Codes C**	Relation to HH Head **Codes D**	Occupation Codes E	
						Main	Secondary
2	**3**	**4**	**5**	**6**	**7**	**8**	**9**

1. For the under 1year , give age in months

Codes A	**Codes B**	**Codes C**	**Codes D**		**Codes E**	
0. Female	1. Married living with spouse	0. None/Illiterate	1. Household head	5. Son/daughter in-law	1. Farming (crop + livestock)	5. Casual labourer off-farm
1. Male	2. Married but spouse away	1.	2. Spouse	6. Grand child	2. Salaried employment	6. School/college child
	3. Divorced/separated	* Give other education in years (years of education)	3. Son/daughter	7. Other relative	3. Self-employed off-farm	7. Non-school child
	4. Widow/widower		4. Parent	8. Hired worker	4. Casual labourer on-farm	8. Herding
	5. Never married			9. Other, specify……		9. Household chores
	6. Other, specify……					10. Other, specify……

PART 3: SOCIAL CAPITAL, TRUST, NETWORKING AND COLLECTIVE ACTION INITIATIVES: TO BE FILLED FOR HOUSEHOLDS WITH AN ADULT HOUSEHOLD MEMBER IN A COLLECTIV ACTION INITIATIVE/GROUP

SECTION A: MEMBERSHIP IN A COLLECTIVE ACTION INITIATIVE

1. Which adults in your household (including you) are members of a collective action group? **(One group membership per row.)**

Name of family member	Relation to HH head	Type of group the hh member is/was a member of: (**codes A**)	Three most important group functions: **(codes B)**			Year joined (YYYY)	Role in the group **(codes C)**	Still a member now? **(codes D)**	If No in column 8, reason/s for leaving the group (**codes E**), Rank 3		
			1st	**2nd**	**3rd**				**1st**	**2nd**	**3rd**
1		**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

Codes A
1. Conservancy
2.Water User's Association
3. Livestock producer and marketing group/coops
4. Farmers' Association
5. Women's Association
6. Youth Association
7. Saving and credit group
8. Microenterprise development (i.e., milk processing, poultry production, apiculture, handicraft initiatives, etc.)
9. Farmer research group
10. Other, specify……

Codes B
1.Microfinance/ Savings and credit
2. Produce marketing (crop and livestock)
3. Briquette making
4.Tree planting and establishing community nurseries
5. poultry production,
6. apiculture
7.aquaculture
8.handicraft initiatives
9. River bank protection and rehabilitation of eroded sites
10. Tourism Investment /wildlife tourism and recreation
11.Input access/marketing
12. Seed production
13. Develop and finance maintenance of boreholes, earthen dams and water pans
14. Maintaining public spaces, e.g. roads
15Investment in human health,
16. Investment in formal education
17.Grain milling
18.Butcheries,
19 Tanneries
20.Bakeries,
21. Other, specify………

Codes C
1. Official
2. Ex-official
3. Ordinary member

Codes D
1. Yes
0. No

Codes E
1. Left because organization was not useful/profitable
2. Left because of poor management
3. Unable to pay annual subscription fee
4. Group ceased to exist
5. Other, specify……………

SECTION B: MOTIVATING FACTOR

Motivation Factor	Rank three main important factors influencing your decision/hh member decision of joining the group/collective action initiative (1=most important)	For the factors listed in coloumn 2, has the group ever offered any of the serivices/benefits? (Yes=1; No=0)	Do you/hh member still benefit from...*(Yes=1; No=0)[Ask Q for each benefit provided]*
1	**2**	**3**	**4**
Input Provision			
Credit (Cash)/ Access to Loans			
Additional source of income			
Training			
Labor Sharing			
Access to inputs (free or subsidized)			
Learn how to market better			
Provision of market information			
Provision of agricultural extension services			
Learn bee keeping / apiculture practice			
Learn how to process livestock products			
Provision of non-agricultural consumption goods			
Learn aquaculture practices			
HIV/AIDS Training			
Provision Public Infrastructure			
Others, Specify...			

SECTION C: ECONOMIC CONTROL, TRAINING, SOCIAL CAPITAL AND NETWORKING

1. Do the group(s)/collective action initiative(s) that you and /or the other members of your hh belong to provide any training for its members?	(Yes=1, No=0)
2. If the group is providing training, who sponsors the training?	(Government; Non-Governmental Organizations; Group own funds; Others (Specify)…… ……….
3. If the group is providing training, what type of training is it? Please list	………………………………………..
4. Can non-members access this training?	(Yes=1, No=0)
5. If non-members access training, what is the main/most important condition for accessing training for non-members? Please state	
6. Has your household gained any financial benefits from the group(s) that you or any other adult member of your household belongs to? (If Yes continue; if No skip to 7)	(Yes=1, No=0)
7. Approximately how much financial benefit in money did your household receive in the last 12 months?	(Kshs)………...
8. Does the collective action initiative/group provide cash advances?	(Yes=1, No=0)
9. If yes, how frequently have you received cash advance?	(Monthly, Every six months, Other (Specify).............................
10. Are there any criteria for getting cash advance from the group?	(Yes=1, No=0)
11. What is the most important criteria? Please state	…………………………..
12. What happens to defaulters? Please state	………………………………….
13. Who within your household makes decisions about what to do with the financial benefits gained from the group(s)?	(1 = Wife 2 = My husband 3 = Wife and my husband, jointly)
14. Have you spent the financial benefits from the group(s) you and/or your hh members gained from the group(s)? [If YES continue to 14, if No move to 16]	(Yes=1; No=0)
15. How much was spent?	(Kshs)………...
16. On what were the financial benefits spent on?	.........., ..., ...
17. Have you noticed any change in your household's wellbeing since you and/or your hh members joined the group(s)?	(Yes=1; No=0)
18. Have you noticed any change in the ability of your hh to access credit/capital since you and/or your hh members joined the group(s)?	(Yes=1; No=0)
19. Could you explain how your ability to access credit/capital has changed since you and/or your hh members joined the group(s)?	....
20. Have you noticed a change in your ability to create useful networks of people in your community since you and/or your hh members joined the group(s)?	(Yes=1; No=0)
21. Could you explain how your social networks in the community changed since you and/or your hh members joined the group(s)?	....

SECTION D: TRUST: TO BE ANSWERED BY ALL HOUSEHOLDS INCLUDING THOSE NOT IN A COLLECTIV ACTION INITIATIVE/GROUP

10. Number of people you can rely on for support in times of need outside this village. Relative… Non-Relatives.................
11. Do you think you can trust members in this village? (Yes=1; No=0)…………………………………………………………
12. If answer in Question 11 above is yes, then which types of villagers do you trust more? (1.Neighbours; 2. Relatives; 3. Others ....)……..

PART 4: LAND HOLDINGS, LAND CHARACTERISTICS AND LAND USE (LAST 12 MONTHS)

Land category	Area (acreage)	Distance from Household (Km)	Land use type (**Codes A**)	Soil type (**Codes B**)	Soil fertility (**Codes C**)	Slope (**Codes D**)	Visible erosion (**Codes E**)	Vegetation Types **(Codes E)**				Source of water (**Codes F**)
								Trees	Shrubs	Grass	Bare	
1. Own land used												
2. Rented in land												
3. Rented out land												
4. Borrowed in land												
5. Borrowed out land												
6. Re-aggregated land												
7. Collective ownership												
8. Other, specify……												

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**	
1.Crop production 2. Grazing land/pasture land 3. Conservancy 4. Farm forestry 5. Fallow 6. Other, specify……	1.Sandy 2.Clay 3.Alluvial soils /Silt soils (somewhere between sand and clay soils) 4. Loam (composed of sand, silt and clay in relatively even concentration). 5.Black cotton soils(a high content of expansive clay) 6.Red soils 7.Lava soils (soil derived from lava /rich lava soils) 8.Volcanic soils,/Andisols (formed from volcanic ash)	1.Very fertile 2.Moderate 3.Poor 4.Not productive at all	1.level 2.Slopy 3.Steep 4.Composite (land with composite forms)	1. = <10% 2= 10-50% 3. >50%	1.Piped 2. Borehole protected and covered 3. Borehole unprotected & uncovered 4. Stream 5. River 6. Lakes	7. Ponds/dams or floods. 8.Water Pans 9. Harvested rain water Note: protected refers to water sources internally plastered and covered with a cap of wood, stone or concrete)

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PART 5: PRODUCTION AND MARKETING

SECTION A: PRODUCTION OF CROPS AND AMOUNTS HARVESTED (SEASONAL AVERAGE)

Three Main Crops Produced (Codes A)	**Inputs Used**															**Amount Produced**		
	Seeds			**Inorganic fertilizer**			**Manure**			**Herbicides and Pesticides**			**Labour**			Unit Measure **(Codes E)**	Qty	Total Production
	Source **(Codes B)**	Qty (Kg)	Total Cost (Ksh)	Source (**Codes C**)	Qty (Kg)	Total Cost (Ksh)	Source (**Codes C**)	Qty (Kg)	Total Cost (Ksh)	Source (**Codes C**)	Qty (Kg/ Liters)	Total Cost (Ksh)	Source (**Codes D**)	Qty (Hours)	Total Cost			
1	**2**	**3**			**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Crop 1: …																		
Season 1																		
Season 2																		
Crop 2: ….																		
Season 1																		
Season 2																		
Crop 3: ………																		
Season 1																		
Season 2																		

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SECTION A: PRODUCTION OF CROPS AND AMOUNTS HARVESTED (SEASONAL AVERAGE)… CONT'

Three Main Crops Produced (Codes A)	**Amount Consumed**			**Amount Given Out (friends /relatives e.t.c)**		
	Unit Measure **(Codes E)**	Qty	Total	Unit Measure **(Codes E)**	Qty	Total
	18	**19**	**20**	**21**	**22**	**23**
Crop 1: …………….						
Season 1						
Season 2						
Crop 2: …………….						
Season 1						
Season 2						
Crop 3: …………….						
Season 1						
Season 2						

Codes A: 1.Wheat 2. Maize 3. Beans 4.Tomatoes 5.Cassava 6.Sorghum 7.Millet 8. Pigeon Pea 9.Others Specify…**Codes B:** Own saved 2. Gift from family/neighbour 3. Farmer to farmer seed exchange 4. On-farm trials 5. Extension demo plots 6. Farmer groups /Coops 7. Local seed producers 8. Local trader 9. Agro-dealers/agrovets 10. Bought from seed company 11. Provided free by NGOs/govt 12. Govt subsidy program 13. Other (specify)………. **Codes C**: 1.Own 2. Bought 3. Given by another farmer 4.Government donation 5.Other(specify) **Codes D:**1.Family labour 2. Hired Labour

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SECTION B: MARKETING OF CROPS (SEASONAL AVERAGE)

Three Main Crops (Codes A)	Who Sold **(Codes A)**	Market type **(Codes B**	Unit Measure **(Codes C)**	Qty	Price /Unit (Kshs)	Buyer **(Codes D)**	Time taken to get to the market (minutes)	Mode of transport **(Codes E)**	Actual transport cost (KSh.)
	1		**19**	**20**	**21**	**23**	**25**	**26**	
Crop 1: …………….									
Season 1									
Season 2									
Crop 2: …………….									
Season 1									
Season 2									
Crop 3: …………….									
Season 1									
Season 2									

Codes A	**Codes B**	**Codes C**		**Codes D**	
1.Wife	1. Farmgate	1. Farmer group	6. Rural grain trader	1. Bicycle	5. Oxen/horse cart
2.Husband	2. Village market	2. Farmer Union or Coop	7. Rural wholesaler	2. Hired truck	6. Back/head load
3.Collective action initiative/group	3. Main/district market	3. Consumers or other farmers	8. Urban wholesaler	3. Public transport	7. Other, specify….
	4.Institutions/Organizations	4. Rural assembler	9. Urban grain trader	4. Donkey	
		5. Broker/middlemen	10. Exporter,		
			11. Other, specify…….		

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SECTION C: LIVESTOCK, ACQUISITION AND DISPOSAL (LAST 12 MONTHS)

Animal	**Initial**	**Births No.**	**Selling**								**Buying**			**Received Gifts No.**	**Deaths No.**	**Given Out / Shared No.**	**Slaughtered No.**	**Stolen No.**	**Total**
	Initial Stock/Standing number at the beginning of 12 months period		Who Sold (Codes A)	Market type (Codes B)	Qty	Price /Unit (Ksh)	Buyer (Codes C)	Time taken to get to the market (minutes)	Mode of transport (Codes D)	Actual transport cost (KSh.)	Qty bought No.	Average per unit price (KSh/ unit)	Total Amount Kshs.						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1. Cattle																			
2. Goats																			
3. Sheep																			
4. Camel																			
5. Donkeys																			
6.Pigs																			
7. Poultry																			
8. Rabbits																			
9. Other, specify..																			

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SECTION D: LIVESTOCK PRODUCTS: PRODUCTION AND DISPOSAL ACTIVITIES ON A DAILY BASIS (DAILY AVERAGE)

Type of Product	Amount Produced			Amount Consumed		Amount Shared/Given Out		Amount Sold							
	Unit Measure **(Codes A)**	Qty	Total (L)	Qty	Total (L)	Qty	Total (L)	Who Sold **(Codes B)**	Market type **(Codes C)**	Qty	Price /Unit (Kshs)	Buyer **(Codes D)**	Time taken to get to the market (minutes)	Mode of transport **(Codes E)**	Actual transport cost (KSh.)
1	**2**	**4**	**5**	**7**	**8**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**19**	**20**
Cattle Milk															
1.Dry Season															
2. Wet Season															
Goats Milk															
1.Dry Season															
2. Wet Season															
Sheep Milk															
1.Dry Season															
2. Wet Season															
Camel Milk															
1.Dry Season															
2. Wet Season															

Codes A	6. Soda Bottle (300ml)	**Codes B**	**Codes C**	**Codes D**	6. Rural grain trader	**Codes E**	5. Oxen/ horse cart
1. Litre	7. Soda Bottle (500ml)	1.Wife	1. Farmgate	1. Farmer group	7. Rural wholesaler	1. Bicycle	6. Back/head load
2. 500 ml	8. Small Cup (250ml)	2.Husband	2. Village market	2. Farmer Union or Coop	8. Urban wholesaler	2. Hired truck	7. Other, specify….
3. 250 ml	9. Headcount	3.Collective action initiative/group	3. Main/district market	3. Consumers or other farmers	9. Urban grain trader	3. Public transport	
4. Kilogramme	10.Crates		4.Institutions/Organizations	4. Rural assembler	10. Exporter,	4. Donkey	
5. Treetop bottle(750ml)	11. Others Specify			5. Broker/middlemen	11. Other, specify…		

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SECTION E: OTHER LIVESTOCK PRODUCTS: PRODUCTION AND DISPOSAL ACTIVITIES (LAST 12 MONTHS)

Type of Product	**Amount Produced**			**Amount Consumed**			**Amount Shared /Given Out**			**Amount Sold**								
	Unit Measure **(Codes A) / No.**	Qty	Total	Unit Measure **(Codes A)/No.**	Qty	Total	Unit Measure **(Codes A) /No.**	Qty	Total	Who Sold **(Codes B)**	Market type **(Codes C)**	Unit Measure **(Codes A)/No**	Qty	Price /Unit (Kshs)	Buyer **(Codes D)**	Time taken to get to the market (minutes)	Mode of transport **(Codes E)**	Actual transport cost (KSh.)
1	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1. Ghee																		
2. Eggs																		
3. Honey																		
4. Cattle Meat																		
5. Goat Meat																		
6. Sheep Meat																		
7. Cattle Hides																		
8. Goat Skin																		
9. Sheep Skin																		
10. Camel Hides																		
11. Others, Specify																		

Codes A
1. Litre
2. 500 ml
3. 250 ml
4. Kilogramme
5. Treetop bottle (750ml)
6. Soda Bottle (300ml)
7. Soda Bottle (500ml)
8. Small Cup (250ml)
9. Headcount
10. Crates
11. Others Specify

Codes B
1. Wife
2. Husband
3. Collective action initiative/group

Codes C
1. Farmgate
2. Village market
3. Main/district market
4. Institutions/Organizations

Codes D
1. Farmer group
2. Farmer Union or Coop
3. Consumers or other farmers
4. Rural assembler
5. Broker/middlemen
6. Rural grain trader
7. Rural wholesaler
8. Urban wholesaler
9. Urban grain trader
10. Exporter,
11. Other, specify…….

Codes E
1. Bicycle
2. Hired truck
3. Public transport
4. Donkey
5. Oxen/horse cart
6. Back/head load
7. Other, specify….

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PART 6: TRANSFER AND OTHER SOURCES OF INCOME DURING (LAST 12 MONTHS)

Sources	Who earned/ received? 0= None; 1=Women 2=Men; 3=Both	No. of units worked/ received(days, weeks, months, years)	Amount per unit (Cash & in-kind)		Total income (cash & in-kind)		Total income (KSh)
			Cash **(KSh)**	Payment in kind **Cash equivalent**	Cash **(KSh)**	Payment in kind **Cash equivalent**	
1	**2**	**3**	**4**	**5**	**6= 3x4**	**7=3x5**	**8= 6+7**
1. Leased Parcel							
2. Selling Firewood							
3. Selling Charcoal							
4.Sale of crop residues							
5.Sale of fish/fish farming							
6.Sale of hay							
7.Sale of dung							
8.Farm Labour wages							
9.Non-farm labour wages							
10. Non-farm business							
11. Drought/flood relief							
12.Safety net or food for work							
13. Remittances (sent from non-resident family and relatives living elsewhere)							
14. Other, specify							

PART 7: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND EXTENSION

SECTION A: INFORMATION AND EXTENSION

1. Do you have access to extension services? (1.yes; 2. No)…………………………………………………….
2. If yes, fill in the table below

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Issue	Three main items/issues that you received training/information on […...] during the last 12 months (**1=most important**)	Main information source, Rank 3 **(Codes A)**			Main type of extension approach used, Rank 3 **(Codes B)**			Number of contacts during the last 12 months (days/year)	Household perception on the quality of information **(Codes C)**
		1st	2nd	3rd	1st	2nd	3rd		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. New varieties of fodder crops									
2. New varieties of crops									
3. Field pest and disease control									
4. Trees/tree management/agro-forestry									
5. Soil and water conservation									
6. Minimum tillage									
7. Leaving crop residue in the field									
8. Adaptation to climate change									
9.Information on destocking									
10. Crop storage pests									
11. Output markets and prices									
12. Input markets and prices									
13. Collective action/farmer organization									
14. Livestock production (new breeds; indigenous breeds e.t.c)									
15. Information on livestock-crop integration									
16. Others, specify…………..									

Codes A
1. Government extension service
2. Farmer Coop or groups
3. Neighbour farmers
4. Seed traders/Agrovets
5. Relative farmers
6. NGOs
7. Other private trader
8. Private Company
9. Research centres
10. Farmers Field Schools (FFS)
11. Faith-Based Organizations (FBOs)
12. Community-Based Organisations (CBOs)
13. Other, specify……

Codes B
1. Farm visits
2. Farmer research groups seminars/talks
3. Farmer field schools
4. Farmer-to-farmer exchange visits
5. Mobile phone
6. Radio/TV
7. Newspaper
8.Other ,specify……….

Codes C
1= Very poor
2= Poor
3= Average;
4=Good
5= Very good

3. Do you own a mobile phone? (1.yes; 2. No)…………………………………………………….……………
4. If yes, how often to do you use it to receive extension information? (1. Often; 2. Rarely; 3. Never)……………

SECTION B: ACCESS TO FINANCIAL CAPITAL, HOUSEHOLD CREDIT NEED AND SOURCES (LAST 12 MONTHS)

Expense Item	Rank the three main needs of finance **(codes A)**			Amount in local currency	Needed credit? **(Codes B)**	If **Yes** in column 6, then did you get it? **(Codes B)**	If **No in column 7**, then why not? **Rank 3 (codes C)**			If **Yes in column 7**			
	1st	2nd	3rd				1st	2nd	3rd	Source of Credit, **(Codes D)**	How much did you get **(KSh)**	Did you get the amount you requested **(Codes B)**	Annual interest rate charged **(%)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Buying seeds (per year)													
2. Buying fertilizer(per year)													
3. Buy herbicide and pesticides (per year)													
4. Buy farm equipment/implements (per													
5. Buy oxen for traction(per year)													
6. Buy other livestock (per year)													
7. Invest in irrigation system(per year)													
8.. Non-farm business or trade(per year)													
9. To pay land rent(per year)													
10. Buy food													
11.Transport costs (per month)													
12.Electricity (per moth)													
13.Water (per month)													
14.Cooking fuel (per month)													
15.Education (per year)													
16.Health care (per year)													
17.Entertainment (per year)													
18. Other Consumption needs (exclusive of the consumption needs listed above)													

Codes A
1. Own Farm Income 2. Own Non –farm Income 3. Income from farmer groups' microenterprise initiatives 4. Income from conservancies 5. Credit

Codes B
0. No
1. Yes

Codes C
1. Interest rate was high 2. Too much paper work/ procedures 3. I have no asset for collateral 4. No money lenders in this area for this purpose 5. Lenders don't provide the amount needed6. Other, specify..

Codes D
1.Farmer group 2. Money lender 3. Microfinance, 4. Bank 5. SACCO Loan 6. Relative/Friends 7. AFC 8..Merry go rounds, 9. Other, specify..

SECTION C: HOUSEHOLD FINANCIAL NEEDS FOR FOOD CONSUMPTION

5. Household food consumption financial needs (last month)

Product	Consumed amount per month	Unit Kg/litres	Price per unit
Meat			
Rice			
Wheat Flour			
Bread			
Maize Flour			
Cooking Oil			
Eggs			
Sugar			
Butter			
Potato			
Carrot			
Onion			
Cassava			
Cabbages/Sukuma wiki/Spinach			
Other Vegetables			
Fruits			
Alcohol and tobacco			
Other (specify) “____________”			

SECTION D: HOUSEHOLD SAVINGS

Name of Saving family member	Relation to HH head	Has bank account (0=No; 1=Yes)	Saving with (**Codes A**)	Range of Total amount saved during the last 12 months (KSh) **(Codes B)**
1		**2**	**3**	**5**

Codes A		**Codes B**	
1. Saving at home (personal)	5. Merry go-round	1. Zero/None	3. 10,001-20,000 Kshs
2. Commercial or other banks	6. Mobile phone banking (e.g. M-Pesa)	1.1-5,000K shs	4. 20,001-50,000
3. Rural micro-finance	7. Saving by lending to money lender	2. 5,001-10,000 Kshs	5.>50,000
4. SACCO (credit society)	8. Other, specify…………..…		

PART 8: RISK, LIVELIHOOD SHOCKS AND COPING STRATEGIES

1. Have you noticed any long-term changes in temperature over the last 10 years? (1. Increased, 2. Decreased, 3. Stayed the same, 4. Don't know)……….
2. Have you noticed any long-term changes in rainfall over the last 10 years? (1. Increased, 2. Decreased, 3. Stayed the same, 4. Don't know)..
3. Have you noticed any long term changes in rainfall patterns /variability over the last 10 years? (1. Yes, 2. No 3. Don't know)…..
4. Have you noticed any other changes in climate over the last 10 years?(1=yes, 2=no)….. If yes, please specify………
5. Further questions on risk, livelihood shocks and coping strategies.

Risk factor	Rank three important risk factors[…] affecting household livelihood (1=most important)	Important coping strategies before/after occurrence (mitigation/adaptation) […], **Codes A**; Rank 3			How did […] affect production of main food crop of the household **(% reduction)**	As a result of […] did you lose (part of) your income **(% reduction)**	Do you think […] will become more important in future due to climate change **Codes B**	If **Yes**, how often do you think […] will occur in the next ten years?
		1st	2nd	3rd				
1	**2**	**3**	**4**	**5**	**9**	**10**	**11**	**12**
1. Drought								
2. Too much rain or floods								
3. Inadequate water harvesting facilities								
4.Crop pets/diseases								
5. Livestock diseases or death of livestock								
6.Declining grazing pastoral areas								
7. Large decrease in crop output prices								
8. Large decreases in livestock output prices								
9. Large increases in crop input prices								
10. Large increases in livestock input prices								
11. Large increase in food prices								
12. Theft of assets or livestock								
13. Reduced/failure household business income								
14. Reduced/loss of employment income								
15. Conflict								
16. Others (Specify)………….								

Codes A
1. Re-aggregation of parcels of land
2.Selling of livestock
3. Herd splitting
4. Changing livestock species
5. Planting drought tolerant pastures
6.Plant disease/pest tolerant Crop varieties
7. Crop diversification
8. Out Migration
9.Soil and water conservation
10. None
11. Planting drought tolerant crops
12. Leasing land
13. Selling land
14. Sale of charcoal
15. Selling livestock
16.Replanting
17. Selling other assets
18.Eat less (reduce meals)
19. Sale of firewood
20. Borrowing
21. Casual labour
22.Petty trade
23. Out-Migration
24.Dietary changes
25. Other, specify..

Codes B
0. No
1. Yes

PART 9: HOUSEHOLD ASSET OWNERSHIP AS A WELFARE INDICATOR

1. Indicate the ASSETS that the household owns at the moment.

Item	Number	Current Unit value	Total current value	Item	Number	Current Unit value	Total current value
Cow shed (s)				Solar panel			
Ox plough				Irrigation equipment			
Food store				Generator			
Refrigerator				Sewing machine			
Well (water well)				Farm house(s) **(see notes 1 and 2 below)**			
Milking shed				Toilet (**see note 3 below**)			
Water tank				Panga			
Water pump				Jembe			
Water trough				Vehicle(s)			
Milking shed				Tractor			
Feed troughs				Tractor trailer			
Wheel barrow				Motorbike			
Donkey/ox cart				Mobile phone			
Bicycle				Fixed land line			
Television				Electricity (access & wired from station)			
Radio				Batteries			
Spade/shovel							

Notes:

1. Main walling material of main residential house (**CodesA**)……………………………………………….....................................
2. Main roofing material of main residential house (**CodesB**)……………………………… ……………………………
3. Type of toilet used **(Codes C)**...

Codes A		**Codes B**	**Codes C**	
1. Burned bricks	3. Stone	1. Grass thatch	1. Flush toilet private	3. Pit latrine private
2. Unburned bricks	4. Earth	2. Iron sheet	2. Flush toilet shared	4. Pit latrine shared
	5. Wooden (timber)	3. Tiles		5. Bucket latrine
	6. Other, specify……	4. Other, specify**……**		6. No toilet/use open air

ENDING TIME..........................