RESILIENCE IN THE RANGELANDS?
RESPONSES TO CHANGE IN THE AMBOSELI SOCIAL-ECOLOGICAL SYSTEM OF KENYA

ELIZABETH ANNE CARABINE

SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF SHEFFIELD

JUNE 2014

ABSTRACT

Over the past century arid and semi-arid systems have been undergoing an accelerating process of change. Rapidly shifting land-use is leading to fragmentation of rangelands, driven by socio-economic factors including population growth, globalisation, competition for land, tourism, intensification of production and political pressures. Increased climate variability and frequency of extreme weather events adds a further layer of complexity. The Amboseli system exemplifies the multiple stressors facing communities in these semi-arid contexts. In 2009, the area suffered the most severe drought in 50 years, during which an estimated 85% of livestock was lost to the Maasai pastoralists that inhabit the area. This interdisciplinary research used mixed methods and modelling approaches to investigate the impacts of and responses to this shock, as well as implications for longer-term processes of land-use change and climate change.

The key findings of this research show first that the psychological impacts of the 2009 drought have implications for place-identity and cultural norms, both critical aspects of resilience in social-ecological systems. Second, this shock has thrown institutions into tension. In the context of multiple stressors, new power dynamics and shifting worldviews in Amboseli are giving rise to actions that may prove maladaptive in the longer term. Third, the decision-making processes leading to shifts in livelihoods and land use are determined by this multiple stressor context as well as access to resources and access to sources of power and authority. These are important components of resilience in Amboseli. Fourth, climate change and land-use change are likely to interact over the long-term to impact on vegetation structure and function in complex ways that will interplay with the local-scale dynamics described in the previous points to influence the resilience of Amboseli.

ACKNOWLEDGEMENTS

This research was funded by an ESRC/NERC Interdisciplinary Studentship, for which I am very grateful. I also received financial support from the University of Sheffield Learned Society Fund, which provided the opportunities to disseminate my findings at international conferences.

I would especially like to thank my supervisors, Chasca Twyman, John Wainwright and Colin Osborne, for their unwavering encouragement, guidance and inspiration. The postgraduate research students and post-docs of the Osborne lab also offered invaluable assistance, as did my fellow Geography students.

Steve Higgins and Simon Scheiter of the Institute of Physical Geography at the Goethe Universität Frankfurt am Main kindly allowed me the use of their aDGVM and offered vital guidance during my time with them. The Biodiversity and Climate Research Centre (BiK-F) provided funding for this collaboration.

I sincerely thank the communities of the Eselenkei, Mbirikani and Olgulului Group Ranches for permitting me to stay with them, for teaching me about their incredible system and for their friendship. The Lion Guardians programme provided critical support and introduced me to the people and places of the Amboseli system, for which I am indebted to them.

My parents have been a huge support throughout this journey and I thank them for their love and patience. Finally, this thesis would not have been possible without my husband, a constant companion, excellent research assistant and always the voice of reason.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1.1 Introduction

This study seeks to investigate the dynamics of land-use change and climate change of semi-arid systems, specifically the Amboseli system in southern Kenya, and the implications of these drivers of change for the social-ecological resilience of the system. In 2009, southern Kenya and northern Tanzania suffered the most severe drought in recent history and the Maasai pastoralists who inhabit the area lost approximately 85% of their livestock in one season. Amboseli is a semi-arid grassland system currently undergoing accelerating change. The responses of these communities to the drought and wider processes of change have implications for the social and ecological resilience of semi-arid systems like Amboseli.

As global concern over climate change and climate variability increases, attention is turning to the urgent need for the vulnerable populations to adapt to the impacts. In 2014, the Intergovernmental Panel for Climate Change (IPCC) issued the *Fifth Assessment Report of Working Group II: "Climate Change 2014: Impacts, Adaptation, and Vulnerability"* (IPCC, 2014a). Highlighting the high exposure to risk and low adaptive capacity of the African continent, the report warns of "*loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions."* (IPCC, 2014a: 12). Reynolds et al. (2007) have described the 'drylands syndrome' in terms of the key attributes of unpredictability, resource scarcity, sparse populations, remoteness and the 'distant voice' of politically marginalised groups. The IPCC finds with a high level of confidence that climate risk will be associated with extreme weather events increasing with warming temperatures and the uneven distribution of risk onto marginalised and poor communities. Thus, arid and semi-arid lands are among the most vulnerable systems to climate change, both in terms of social and ecological impacts and processes of change and adaptation need to be better understood. The arid and semi-arid lands of Kenya, including Amboseli, clearly illustrate the drylands syndrome. In their Dryland Development Paradigm, Reynolds et al. (2007) call for greater recognition of the social-ecological dynamics and local ecological knowledge that shape these systems.

The *Fifth Assessment Report* differs from the *Fourth Assessment Report*, published in 2007, in its emphasis on the cultural aspects of climate change, including the climate risks faced by cultural systems and the role of beliefs, norms and values in mediating vulnerabilities and responses to change. This more holistic view has been formed in the light of thousands of studies, such as this one, carried out since 2007. Recent research has also highlighted the importance of cultural dimensions of climate change (Adger et al., 2013). Whereas previous research and policy in arid and semi-arid lands and other contexts have focused on the material aspects of climate change (i.e. lives and livelihoods), the impacts of climate change on cultural assets and the role of culture in adaptation must also be acknowledged (Ibid.). Understanding the social, cultural and psychological impacts of a single extreme weather event, in this case the 2009 drought in the Amboseli system can provide insight into the likely impacts of multiple, interacting stressors, including climate change and land-use change, in the long-term. It is these kinds of dynamics that will be critical in addressing Africa's adaptation deficit and managing climate-related risks through adaptation, at both community and national levels.

Attention is turning to the potential of grassland systems, including semi-arid grasslands, to mitigate climate change. If managed sustainably, these ecosystems can contribute significantly to the storage of carbon in soils and vegetation at the same time as providing secure livelihoods for those 1 billion people who depend on them (FAO, 2009). The concern is that accelerating land-use change in rangelands like Amboseli will lead to loss of their potential to store carbon even before these dynamics are well understood (Ibid.).

The development research community is also taking renewed interest in arid and semi-arid lands as sites of dynamic, resilient growth and development (Catley et al., 2013). The importance of arid and semi-arid lands for food production, peacebuilding and innovation is increasingly recognised in policy circles in Kenya and elsewhere (Elmi and Birch, 2013). However, the socio-economic dynamics of these systems are complex and there is an urgent need to better understand the transitions taking place, in terms of institutions, worldviews and cultural shifts, if the development of these systems is to be supported.

While the last most severe drought experienced in the Amboseli system was in 1961, the 2009 drought in southern Kenya and northern Tanzania was preceded by a series of droughts since a severe event in 1999 and was closely followed by a very severe drought and humanitarian crisis across East Africa in 2011. The failure of the rainy season preceding the latter of these drought events has been attributed to anthropogenic climate change (Met Office, 2013). As this PhD reaches completion, a new drought threat looms over Kenya with early warnings of humanitarian crisis being issued for the northern regions in March 2014. Below normal March to May rains in 2014 are likely to slow recovery in pastoral areas of the already stressed Kenyan rangelands (FEWS-NET, 2014).

1.2 Overview of research approach

Semi-nomadic pastoralism has proven a highly resilient livelihood strategy to cope with climate variability. The Maasai of the Amboseli system maintain a livestock-based production system that is particularly resistant to the processes of change undergoing much of East Africa’s rangelands. However, the combination of these stressors with climate change may push this system to the limits of its resilience, even beyond a ‘tipping point’, leading to maladaptive outcomes.

This research employs an interdisciplinary approach to explore resilience and uses agent-based and dynamic vegetation modelling approaches as an integrating tool. In devising the methodology for this research, I originally viewed modelling as the primary analytical focus, envisaging a fully coupled social-ecological model, informed by qualitative data, and the outputs of this model forming the main interpretive findings of the research. However, as I returned to Amboseli for my PhD fieldwork in 2011 and then 2013, the grounded theory approach of my qualitative data collection and analysis uncovered aspects of resilience that I was not anticipating to be main foci of the work. At this time, the fine balance between capturing the story of the 2009 drought from the perspective of the inhabitants of Amboseli and making generalisable observations of relevance to similar systems shifted slightly for me as a researcher. While modelling has been used as a highly useful integrating tool, this has been a process of elucidating the specific responses of the Maasai of the Amboseli system, while providing insight into the social-ecological dynamics of similar semi-arid systems and implications for resilience to climate change and other stressors.

1.3 Outline of thesis structure

In Chapters 2 and 3, I outline the theoretical context and conceptual framework for understanding the Amboseli social-ecological system, as well as the interdisciplinary methodological approach to address the research aim.

Chapters 4 to 7 present the findings of the research. Chapter 4 explores the lived experience of the 2009 drought from the perspective of the Maasai of Mbirikani and Eselenkei Group Ranches, with particular focus on the socio-cultural and psychological responses of these individuals and communities in the immediate aftermath of the drought.

In Chapter 5, these local livelihood responses are analysed in the context of broader processes of change and the implications for the resilience of the Amboseli system are discussed. In doing so, particular attention is given to the power dynamics affecting patterns of land use and livelihoods among the Maasai.

Chapter 6 discusses the approach taken to combine actor-based and systems-based enquiry in developing a theory of decision-making and the behavioural rules that underpin this. Particularly, the ways in which the distillation, abstraction and modelling of these rules as a process in itself has interfaced with the qualitative, participatory field research to develop a deeper understanding of the social and ecological dynamics of the Amboseli system.

In Chapter 7, the implications of land-use decisions, in combination with climate change, for the structure and function of vegetation are explored. In doing so, the impacts of climate change and land-use scenarios on the biomass and carbon fluxes of trees and grass populations and the ecosystem as a whole are simulated in a set of experiments carried out with an adapted vegetation model.

Finally, in Chapter 8 I synthesise the findings of these chapters and draw out the main contributions to knowledge.

CHAPTER 2. UNDERSTANDING SOCIAL-ECOLOGICAL SYSTEMS AND CHANGE: THE THEORETICAL CONTEXT

2.1 Introduction

This chapter describes the key characteristics of semi-arid grasslands ecosystems and the livelihoods of the pastoralist communities that depend on them. I go on to discuss processes of land-use change and climate change on these social-ecological rangeland systems, with specific reference to East Africa. Finally, the theory and concepts of resilience in social-ecological systems and adaptation to climate change are explored, with an explanation of how these concepts, and the tensions between them, can inform studies of responses of social-ecological systems to change.

2.2 Rangeland systems

Rangelands cover 30–40% of the Earth's land surface and support 1 to 2 billion people, approximately 40% of who are located in sub-Saharan Africa (FAO, 2009). Predominantly, people use rangelands for livestock production. As well as supporting those who inhabit them, rangelands also provide ecosystem services at a global scale, with potential to sequester the equivalent of between 1.3 and 1.5 gigatonnes of atmospheric carbon dioxide if managed sustainably (FAO, 2009). These systems have huge potential to contribute to action to mitigate global climate change. Carbon finance or payments for ecosystem services (PES) schemes have mostly focussed on forest systems to date, but attention is turning to the potential of rangelands to host similar initiatives for climate change mitigation and development (Svejcar et al., 2008, Conant, 2010, Dougill et al., 2012, Stringer et al., 2012).

In this study, semi-arid grasslands are defined as terrestrial ecosystems with annual average rainfall below 700 mm, which are dominated by herbaceous and shrub vegetation. In the context of Africa, these tropical systems characterised by the coexistence of trees and grass are often defined as savannahs, a transitional habitat type between open grassland and closed canopy forest (Scholes and Archer, 1997). The factors determining the coexistence of both tree and grass life forms in savannah ecosystems are not fully understood (Sankaran et al., 2008). However, key determinants include the availability of resources, i.e. water and nutrients (Bell, 1982, Scholes, 1990), and frequent disturbance, primarily caused by herbivory (Scholes and Archer, 1997) and fire (Bond and Keeley, 2005, Bond et al., 2005). The complex interactions between these factors produce dynamic, patchy landscapes which are characterised by heterogeneity, non-linear responses and unpredictability in time and space which make these systems particularly susceptible to environmental change and human-induced disturbances such as grazing, anthropogenic fire and timber or firewood harvesting. Sankaran et al. (2005) suggest that the transition from water-limitation to disturbance-limitation in African savannah communities occurs where mean annual rainfall is approximately 650-700 mm. In sub-Saharan Africa, savannah vegetation is increasingly being cleared for livestock production and / or cultivation (Thornton et al., 2011) and such land-use change can modify savannah vegetation dynamics and lead to ecological regime shifts (Williams et al., 2007, Stafford Smith et al., 2009). Scheiter and Higgins (2009) predict large ecosystem regime shifts across Africa by 2100, with elevated carbon dioxide and temperature driving approximate shifts of 35% and 45% from grassland to savannah and savannah to woodland respectively. The model used in this study (the adaptive Dynamic Global Vegetation Model, or aDGVM) agrees well with the broad patterns of vegetation distribution given by different vegetation maps, correctly predicting the vegetation in 64% of simulated cells (*k*-value[1] 0.54). While this is a more accurate estimate than six other comparable models, there is still a relatively high degree of uncertainty. The ways in which local and global drivers combine to alter savannah structure is not fully understood (Roques et al., 2001, Wigley et al., 2010). At regional and local levels, such effects have the potential for serious impacts on ecosystem services and livelihoods.

[1] The k-value quantifies the agreement between simulated and observed patterns.

Savannah ecosystems are intrinsically linked to the human populations operating within them (Costanza et al., 1993, Folke et al., 2007, Naveh, 2000, Du Toit, 2010). Arid and semi-arid environments are characterised by the key attributes of unpredictability, resource scarcity, sparse populations, remoteness and dislocation from centres of power, giving rise to distinct cultures and institutions (Reynolds et al., 2007, Stafford Smith et al., 2009). These populations have few livelihood or income-generation options and tend to be one of the most vulnerable sectors of society as a result (FAO, 2009). Under such conditions, nomadic pastoralism has historically been the most socially, culturally and economically optimal livelihood strategy which has also acted to conserve ecosystem services, protect habitat and wildlife, and preserve traditional cultural values (FAO, 2009, Behnke et al., 1993a, Sabates-Wheeler et al., 2008, Niamir-Fuller, 1998).

Pastoralists in the marginal arid and semi-arid environments of Africa have developed highly resilient grazing systems that exploit the low and variable productivity of the range. As well as adopting mobile, nomadic lifestyles, these pastoralists herd a mix of grazers and browsers in their stock (i.e. cattle, camels, sheep and goats) to best capture available resources. Even traditional agro-pastoralists have relied on some degree of transhumance e.g. in the Sahel (Niamir-Fuller, 1998). However, these systems have been undergoing an accelerating process of change over the past century. There are two major causes of change in arid and semi-arid pastoral systems. The first is land-use change, specifically fragmentation caused by socio-economic factors, and the second is climate change and variability (Behnke, 2008, Stafford Smith et al., 2009, Hobbs et al., 2008a, Galvin, 2009, Homewood, 2008).

2.3 Land-use change in the rangelands

Fragmentation is a reduction in scale over which human management takes place (Behnke, 2008, Stafford Smith et al., 2009), resulting in a disconnection of previously interdependent spatial units. Processes by which fragmentation of a landscape can occur include the introduction of physical or administrative barriers such as fences, land privatisation; the decoupling of a landscape through loss of a key linking resource, e.g. movement corridors; and compression of activities into specific locations close to key resources e.g. settlement around a borehole (Hobbs et al., 2008b). Fragmentation of arid and semi-arid ecosystems restricts the access of people, livestock and wildlife to spatial and seasonal heterogeneity in resources. Vulnerability to stresses and shocks such as drought can therefore increase with decreasing mobility (McPeak and Little, 2005). Furthermore, increasingly fragmented landscapes require increasingly intensive inputs to mitigate against stresses such as drought as the traditional coping and buffering mechanisms of the system are eroded (Galvin, 2009).

The socio-economic factors that are driving fragmentation of rangelands include human and livestock population growth, globalisation, conflict, competition for land, changes in land tenure and land use, intensification of production, sedentarisation of nomadic pastoralists and institutional changes and climate change (Behnke, 2008, Galvin, 2009). When pastoralists depend only on livestock for their livelihood incomes there is an advantage in managing the rangeland as a contiguous commons system. However, when alternative livelihood strategies become equally or more important, there is more incentive to take ownership of a patch of land (Galvin, 2009). Furthermore, the widening gap between rich and poor and the related inequalities in power dynamics, as affected by many internal and external socio-economic factors, is creating unprecedented social stratification (*ibid.*). This stratification encourages individualistic strategies over community interests, in turn favouring the privatisation of common-pool resources (*ibid.*). Due to social changes, local-level social capital may have become insufficient to manage grassland resources. However, new cross-scale interactions are emerging enabling access to resources at different scales, which can increase livelihood security against environmental uncertainty (Adger et al., 2006, Osbahr et al., 2008).

Globalisation is now influencing formerly remote and isolated communities. Social capital that was once geographically-bounded is now spreading across larger areas due to changing flows of people, resources and information which provides alternative incomes e.g. remittances from urban areas or overseas. Vulnerability to change is similarly 'tele-connected' as livelihoods become more networked and therefore more interdependent on other actors in a larger system (Adger et al., 2009). In many rangeland systems, the tourism industry and international nature conservation interests are driving fragmentation into different land-uses. For example, the communal group ranches of Maasailand in Kenya and Tanzania are more frequently making land-use decisions based on options to set-aside land for wildlife conservation and eco-tourism in the hope of generating substantial incomes and alternative wage-based livelihoods for members. Moreover, McCabe (2006) has shown how the fear of the spread of protected areas is driving Maasai pastoralists in the Siminjiro plains of Tanzania to shift to cultivation to ensure higher compensation rates should their land be demarcated.

Fragmentation is therefore the product of socio-economic decisions about land-use and livelihoods made in response to changes both within the system itself e.g. pastoralists desiring control over land, and externally to the system e.g. policy or market-driven changes. The drivers of change have induced adaptation of livelihood strategies as traditional pastoralist and agro-pastoralist societies respond to that change. The most prevalent livelihood options in the rangelands of sub-Saharan Africa are diversification into agriculture and intensification of livestock production, including increased proportion of smaller stock (Homewood et al., 2001, Hobbs et al., 2008b, Galvin, 2009). These activities can be both drivers of and responses to fragmentation. Hobbs and colleagues (2008b) also show that people may respond to changes in land tenure by attempting to expand the size of the managed resource through land reform or consolidation of fragmented units within the system. Similarly, they may develop new and existing social networks to negotiate access to key resources at certain times. Alternatively, they may exit from pastoralism and agriculture altogether and search for alternative livelihoods, most likely located outside the system.

In Kenyan Maasailand, fragmentation through increasingly privatised land tenure has been occurring for several decades (Grandin, 1987, Grandin, 1992, Galaty, 1994, Mwangi, 2007, Homewood et al., 2009). Studies of this shift have documented the impacts, including dispossession of land, influx of insiders, breakdown of institutions (Galaty, 1994), individualisation of production, social decline (Grandin, 1992), rising inequity, declining wildlife populations and ecological degradation (Homewood et al., 2009). These have been regarded as negative changes in terms of livelihoods and social-ecological resilience, both in the literature and by communities (Southgate and Hulme, 2000). Some positive impacts have been documented also, including improvements in service provision, i.e. education and healthcare (Grandin, 1992), and increased access to off-farm incomes (Homewood et al., 2009).

2.4 Climate change in Africa

In November 2013, Working Group I of the Intergovernmental Panel on Climate Change (IPCC) published their *Fifth Assessment Report* (AR5). Climate models have improved since the publication of the *Fourth Assessment Report* (AR4) in 2007. For AR5, projections of changes in the climate system are made using a set of global climate models that simulate changes based on a set of scenarios of anthropogenic forcings, known as Representative Concentration Pathways (RCP) under the framework of the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme (IPCC, 2013).

As this PhD research was largely completed upon publication of AR5, analyses have been carried out using the available data from AR4, published in 2007. For example, the modelling approach presented in Chapter 7 used Special Report Emissions Scenario (SRES) A1B, a predecessor to the RCPs from AR4, to simulate climate change. A discussion of the implications of this can be found therein. However, the findings of AR5 as they relate to East Africa, do not conflict with the findings of AR4, rather present a greater degree of certainty in observed and projected trends and in the likely impacts of climate change. This certainty is due in part to improved models and in part to the large body of evidence that has proliferated since AR4. Qualitatively, the interpretation of results in this thesis has taken into account the findings of AR5 and acknowledges synergies between these and the conclusions of this study. Given the relevance and improved understanding of climate change in

AR5, I am presenting these findings where applicable in the next sections. Indeed, the text in the following subsections is largely extracted and summarised from AR5.

2.4.1 Climate trends for Africa

Temperatures in Africa are projected to rise faster than the global average increase during the 21st century. Increases in mean annual temperature over all land areas of Africa are very likely in the mid- and late-21st century periods for RCP2.6 (low emissions) and RCP8.5 (high emissions). Ensemble mean changes in mean annual temperature exceed 2°C above the baseline over most land areas of the continent in the mid-21st century for RCP8.5 and exceed 4°C across most land areas in the late-21st century for RCP8.5. Changes in mean annual temperature for RCP8.5 follow a pattern of larger changes in magnitude over northern and southern Africa with relatively smaller changes in magnitude over central Africa. The ensemble mean changes are less that 2°C above the baseline in both the mid- and late-21st century for RCP2.6. Projected temperature rise is very likely to exceed the 1986-2005 baseline by between 3 and 6°C across the sub-regions of Africa by the end of the century under RCP8.5 (high emissions scenario). Precipitation projections are more uncertain than temperature projections and exhibit higher spatial and seasonal dependence that temperature projections.

2.4.2 Observed and projected temperature changes in East Africa

The equatorial and southern parts of East Africa have experienced a significant increase in temperature since the beginning of the early 1980s (Anyah and Qui, 2012). There has also been an observed increase in seasonal mean temperature in many areas of eastern Africa in the last 50 years (IPCC, 2014a). Warming and increased frequency of extreme warm events have been observed for countries bordering the western Indian Ocean between 1961 and 2008 (*ibid*). Projected maximum and minimum temperatures over equatorial eastern Africa show a significant increase in the number of days warmer than 2°C above the 1981-2000 baseline by the middle and end of this century under A1B and A2 (medium-high emissions scenarios used in AR4) (Anyah and Qui, 2012).

2.4.3 Observed and projected precipitation changes in East Africa

Precipitation in eastern Africa shows a high degree of temporal and spatial variability dominated by a variety of physical processes. Some studies indicate decreased rainfall over eastern Africa between March and May/June in the last three decades, due to rapid warming of the Indian Ocean (Williams and Funk, 2011). Summer monsoonal precipitation has declined throughout much of the Horn of Africa over the last 60 years (*ibid*). The CMIP3 models suggest that by the end of the 21st century in eastern Africa, there will be a wetter climate with more intense wet seasons and less severe droughts during October-November-December and March-April-May (*ibid*). These results indicate a reversal of historical trends in these months. Regional climate model studies suggest drying over most parts of Uganda, Kenya and South Sudan in August and September by the end of the 21st century. Truncated boreal spring rains in the mid-21st century have been projected for Ethiopia, Somalia, Tanzania and southern Kenya while the boreal autumn season is lengthened in southern Kenya and Tanzania (IPCC, 2013). The CMIP5 ensemble projects likely increases in mean annual precipitation over areas of central and eastern Africa beginning in the mid-21st century for RCP8.5 (IPCC, 2013).

2.4.4 Observed and projected extreme temperature and rainfall in East Africa

Extreme precipitation changes over eastern Africa such as droughts and heavy rainfall have been experienced more frequently during the last 30-60 years (Williams and Funk, 2011). A continued warming in the Indian-Pacific warm pool has been shown to contribute to more frequent East African droughts over the past 30 years during the spring and summer seasons (IPCC, 2013). It is unclear whether these changes are due to anthropogenic influences or multi-decadal natural variability. Projected increases in heavy precipitation over the region have been reported with high certainty in the IPCC *Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) (IPCC, 2012) and an increase in the number of extreme wet days by the mid-20th century has been indicated.

2.5 Climate change impacts on rangelands

The IPCC Working Group II AR5, published in March 2014, provides evidence that climate change will interact with non-climate related drivers and stressors to increase the vulnerability of semi-arid systems in Africa (high confidence) (IPCC, 2014a). Deteriorating livelihoods in arid and semi-arid lands, due to high and persistent poverty, has been identified as a risk (*ibid*). Risk of reaching tipping points for crop and livestock production in small-scale farming and/or pastoralist livelihoods currently is estimated as medium with potential to increase to very high risk levels by 2080-2100 with 4°C warming, regardless of adaptation. Under long-term 2°C warming and in the near-term, high risk levels may be reduced to medium through adaptation action (*ibid*). However, adaptation options are judged by Working Group II to be limited due to persistent poverty, declining land productivity, food insecurity and limited government support due to marginalisation (*ibid*).

2.5.1 Impacts on semi-arid grassland ecosystems

A risk for Africa identified in IPCC Working Group II AR5 is shifts in biome distribution, and severe impacts on wildlife due to diseases and species extinctions (high confidence) (IPCC, 2014a). At present, the risk of adverse shifts in biome distribution is estimated at a high level with potential to reduce to a medium level through adaptation (*ibid*). In the near-term (2030-2040), the risk level is very high, with potent to reduce to a high level through adaptation. In the long-term (2080-2100), risk levels are very high with 4°C warming with potential to reduce to a high risk level through adaptation, and high with potential to reduce to a medium risk level through adaptation with 2°C warming (*ibid*).

Although the primary drivers for changes in ecosystems in Africa are land-use changes including the shifts towards agriculture, livestock grazing and fuelwood harvesting (Bond and Midgley, 2012), climate change is already having an impact and are expected to be substantial in the future (high confidence) (IPCC, 2014a). Evidence points to shifting ranges of ecosystems, including grasslands, shrublands, savannahs and woodlands, due to elevated carbon dioxide and climate change, beyond the effects of land-use change and other non-climate stressors (high confidence) *(ibid*).

2.5.2 Impacts on livestock production

Another risk for Africa identified in the IPCC Working Group II Assessment Report 5 is adverse effects on livestock linked to temperature rise and precipitation changes that lead to increased heat and water stress, and shifts in the range of pest and diseases, with adverse impacts on pastoral livelihoods and rural poverty (medium confidence) (IPCC, 2014a). At present, the risk of adverse effects on livestock is estimated at a medium level with potential to reduce to a low level through adaptation (*ibid*). In the near-term (2030-2040), the risk level is high, with potent to reduce to a low level through adaptation. In the long-term (2080-2100), risk levels are very high regardless of adaptation with 4°C warming, and very high with potential to reduce to a medium risk level through adaptation with 2°C warming (*ibid*).

Livestock production will be indirectly affected by water scarcity through impacts on feed crop production (*ibid*). In East Africa, the availability of maize stover per head of cattle could decrease by 2050 (Thornton et al., 2010).

Rising temperature can also affect livestock (IPCC, 2014a). In lowland areas, like Amboseli, increased temperatures could lead to reduced stocking of dairy cows in favour of cattle, shifts from cattle to sheep and goats and decreasing reliance on poultry production (*ibid*). In highland areas of East Africa, livestock keeping could benefit from warming temperatures (Thornton et al., 2010).

Climate changes are also likely to bring more frequent and severe disease outbreaks in agricultural systems (Kumssa and Jones, 2010). There is greater understanding of how climate change will potentially affect crop and livestock pests and diseases and agricultural weeds since Assessment Report 4 published in 2007 (IPCC, 2014a). Interactions between climate change and other environmental and production factors could intensify damage to crops from pests, weeds and diseases. In lowland and dryland areas of Africa, climate change may affect the distribution of economically important pests (low confidence) (*ibid*). Increases in temperature more than 2°C and changes in precipitation may alter the distribution of the main tick vector species of East Coast Fever disease in cattle (*ibid*).

2.5.3 Impacts on pastoralist livelihoods

Arid and semi-arid grassland systems are characterised by variable and unpredictable climates and people have always adapted their livelihoods to exploit these conditions and cope with stress (Sabates-Wheeler et al., 2008). However, climate changes and climate variability are set to increase at rates higher than experienced before. In sub-Saharan Africa, where less predictable rainfall and environmental stress are already acting on vulnerability, the increased extent and duration of drought events will have a negative impact on the resilience of livestock and agricultural systems and therefore on livelihood security (Thornton and Gerber, 2010). Critically, climate changes are beginning to occur within timescales of relevance to people (Reynolds et al., 2007, Galvin, 2009, Stafford Smith et al., 2009) i.e. climate change is 'speeding up' to the timescale of years or decades, particularly in arid and semi-arid environments. Climate has been described as a 'slow' variable, occurring over large spatio-temporal scales and acting to constrain faster variables at smaller scales e.g. vegetation cover (Stafford Smith et al., 2009). Faster variables often represent immediate goods and services within a system and any shift in the dynamics is likely to have significant impacts on natural resource-based livelihoods.

Some predict that the impacts of climate change will have negative impacts on agriculture in Africa and that livelihood strategies will have to change to ensure future incomes and food security. Jones and Thornton (2009) used a climate model to estimate the probability of failed growing seasons in 2050 compared to current trends in order to identify likely zones of livelihood transition towards livestock production. Their results showed that the decreased reliability of the growing season in parts of East and southern Africa led to an approximate decline of 10-20% in crops by 2050, even more where extreme weather events occur. They suggest this will facilitate a large-scale shift from the production of crops towards livestock as a more viable livelihood option. Thornton and colleagues (2010) go on to elaborate those projections of mixed crop-livestock systems in East African arid and semi-arid environments show a decline in the productivity of maize and bean crops up to 2050, due to climate change. They present this as further evidence that livelihood decisions will favour livestock-based production, changes in crop types or abandonment of cultivation altogether.

Taking into account shifting market conditions, increased livestock production may also be driven by economic interests. Livestock are an important resource globally, providing food, income, nutrition, employment, insurance, traction, clothing and other uses to millions worldwide (Herrero et al., 2009). The demand for such products may double by 2050, mostly in developing countries (Herrero et al., 2009) which will likely facilitate growth in the livestock sector within developing countries to meet demand (Thornton, 2010). An illustration of this is provided by Norton-Griffiths (2006), explaining how pastoral production in Kenya is becoming increasingly integrated into the national economy which is increasing land rents for livestock. However, on a global scale, a shift away from mixed crop-livestock systems towards livestock production may have implications, particularly as it is estimated that mixed systems account for approximately half of global food production (Herrero et al., 2010).

The impact of environmental change on livelihood options is likely to significantly exacerbate poverty in systems where ecosystem services are critical to delivering services (Comim et al., 2009). Thornton and colleagues (2007) used integrated assessment methods to test the hypothesis that household capacity to adapt to external stresses is governed by flexibility in livelihood options, using four case studies including pastoralists in northern Tanzania, agro-pastoralists in southern Kenya, communal and commercial ranchers in South Africa and mixed crop-livestock farmers in western Kenya. Their results supported the hypothesis, demonstrating that a diversity of options such as intensification, diversification and non-agricultural activities can act as coping strategies in times of environmental stress especially for poorer households. The authors stress the importance of identifying feedbacks between the ecological impacts of change and livelihood systems over time.

Based on the studies discussed above, it would be reasonable to assume that while livelihood systems in arid and semi-arid lands have in the recent past diversified and shifted towards cultivation where conditions allow, climate changes may encourage a shift back towards the land-uses that have proven most adaptive to climatic variability in the past, livestock production. However, a large-scale return to traditional pastoralism is highly unlikely as both ecological and social-institutional capacity will have been eroded or lost during a prolonged period of change and policy and market instruments are unlikely to support it. It is impossible to predict how drivers of change will combine to influence livelihood options and decisions in the future, but the possible scenarios outlined above could provide a starting point for exploring the possible impacts of climate and land-use changes on livelihood security.

2.6 Resilience in the rangelands?

Clearly, understanding the responses of social-ecological systems to change is important if these ecosystems and the services they provide are to be preserved, and this is an area of research that spans the natural and social sciences. Increasingly, researchers have been beginning to explore the interdisciplinary relationships between adaptation and resilience in the context of environmental change (Nelson et al., 2007, Osbahr et al., 2010, Sallu et al., 2010, Adger, 2008, Miller et al., 2010). In order to appreciate this approach, it is necessary to look into the background of these two concepts.

2.6.1 Social-ecological resilience

Resilience can be defined as the amount of change a system can undergo and still retain the same function and structure while maintaining the capability for self-organisation and adaptation (Nelson et al., 2007, ResilienceAlliance, 2010, Walker et al., 2004). Self-organisation occurs when larger-scale processes such as vegetation structure and function emerge in response to local-scale interactions, such as grazing (Mueller et al., 2014). The ability of a system to self-organise, build capacity and undergo cyclic change maintains heterogeneity within both the social and biophysical elements of the system, therefore increasing the availability and diversity of options in responses to external shock (Berkes, 2002, Adger et al., 2006, Walker et al., 2004). The study of resilience has stemmed from the natural sciences, particularly ecology (Folke, 2006) and has increasingly been informed by the social sciences (Folke, 2006, Miller et al., 2010, Holling, 1986b, Berkes and Folke, 1998) in areas such as natural resource management and institutional analysis. Resilience theory recognises that complex and dynamic interactions occur within and between scales (Levin, 1992, Levin, 1999, Holling and Gunderson, 2002), both temporal and spatial (Folke et al., 2007). Therefore, common misfits in scale in social-ecological systems can occur in both the spatial and temporal dimensions (Folke et al., 2007). Increasingly the meaning of 'global' and 'local' are being redefined by greater inter-connectedness between scales (Wilbanks, 2007, Adger et al., 2009) whereby global overarching processes, such as changes in atmospheric carbon dioxide, are interacting with adaptive behaviour and agency at the local level. Cross–scale interactions are therefore a challenge in understanding and predicting system dynamics (Wilbanks, 2007, Peters et al., 2007, Osbahr et al., 2008).

Increasingly, resilience-thinking is being applied in studies of climate-change adaptation and livelihood security (Boyd et al., 2008). Walker (2006) applies resilience-thinking to rangelands, hypothesising that these, and many other, social-ecological systems have alternate stable states at different scales and that any loss of resilience in a rangeland ecosystem reduces the capacity to adapt to stresses such as climate change. Moreover, there are multiple, interacting thresholds in grassland ecosystems that cause a cascading effect of transitions in state as thresholds interact with external drivers. For example, climate shifts or policy change can cause a 'flip' at the regional level which will cascade down to the patch level and beyond with consequences for the social, economic and environmental elements of a system. These theories have contributed to the on-going discourse on rangeland degradation, which has strongly influenced past land management in Africa (Vetter, 2005, Homewood, 2008, Sullivan and Rohde, 2002, Behnke et al., 1993b, Ellis and Swift, 1988), by elucidating concepts of thresholds, alternate stable states and feedback loops.

2.6.2 Adaptation to climate change

Adaptation to climate change is the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC, 2014a). Adaptive capacity is the ability to effectively respond to the direct and indirect effects of climate change (*ibid.*), including shocks and stresses. Adaptive capacity can be described as the means of securing the resources needed to reduce sensitivity to climate hazards, to cope and to recover from a shock, and therefore depends on broader socio-economic, cultural, institutional and political considerations such as income levels, the nature and strength of social networks, access to financial resources such as insurance, governance, institutions, power relations and any other factor that affects the ability to deal with climate-related hazards (Tanner and Horn-Phathanothai, 2014). In the past, pastoralists have had what can be described as a relatively high adaptive capacity in their ability to inhabit semi-arid areas (Ericksen et al., 2013). However, the unprecedented shocks and stresses they are likely to experience under wider processes of climate and non-climate related drivers might be too great for usual responses to cope with. In some cases, responses to shifting risks may be maladaptive, and result in increased vulnerability to climate impacts. In others, transformational adaptation may be needed to cope (Tanner and Horn-Phathanothai, 2014).

Transformation is a conceptually complex but critical aspect of resilience thinking. Defined as a physical or qualitative change in form, structure or meaning within a system, transformation is a process that enables resilience at larger scales (Folke et al., 2010). In theory, building the resilience of a social-environmental system may require a deliberate regime shift from an undesirable state characterised by inadequate capacity to adapt to change, to an alternative state with a more sustainable trajectory (Walker et al., 2004). What results will likely be a fundamentally different system in terms of social, economic and ecological dynamics. Other definitions take into account the inadvertent, as well as deliberate, nature of transformation (Nelson et al., 2007).

Adaptation involves attempting to reduce vulnerability and can be defined as the decision-making process and the set of actions undertaken to maintain the capacity to deal with current or future predicted change (Nelson et al., 2007). It is a concept that has increasingly been applied to problems of natural resource management (Walker et al., 2004) and climate change (Adger et al., 2005, Lemos et al., 2007, Stringer et al., 2009). The study of adaptation and, conversely, vulnerability has relatively diverse and complex origins in the disciplines of geography, human ecology, political economy and political ecology among others (Miller et al., 2010). Key areas for research in adaptation include the identification of system thresholds, limits and barriers to the implementation of adaptation and how actor-networks access resources and make adjustments and the consequences of these actions for social-ecological resilience at different scales (Nelson et al., 2007). These ideas will be expanded upon in the next section.

A further related concept that is beginning to gain attention in the literature is maladaptation. Maladaptation is a concept that has not been yet well explored in the literature and about which there is little consensus. In its *Fifth Assessment Report*, the Intergovernmental Panel on Climate Change (IPCC) defines maladaptive actions as those that may lead to risk of adverse climate-related outcomes, increase vulnerability to climate change, or diminished welfare, now or in the future (IPCC, 2014a). The IPCC has changed its definition slightly to recognise that maladaptation arises not only from inadvertent adaptation action, but also from deliberate decisions where short-term outcomes are prioritised over long-term threats.

While there is general agreement that maladaptation involves action to adapt to change that increases vulnerabilities or reduces adaptive capacity (Adger et al., 2005, Doria et al., 2009), there is disagreement over what causes such action (IPCC, 2014a). Some have described maladaptation as occurring due to inaccurate predictions and unexpected impacts leading to errors in assessing risk (Tompkins et al., 2005), while others see it as action based on misunderstandings of the dynamics and complexity of systems, leading to wrong decisions (Satterthwaite et al., 2009, Pittock, 2011) or short-term decisions (World Bank, 2010). This is a risk particularly pertinent to arid and semi-arid systems, where adaptation action can seek to stabilise conditions, rather than work with the dynamics inherent in social-ecological systems (Thomsen et al., 2012). In some cases, perceptions of climate change might cause a shift from adaptive action to inaction or maladaptive behaviour as beliefs about the magnitude of climate change increases (Niemeyer et al., 2005). The framework for maladaptation outlined by Barnett and O'Neill (2010) seeks to encompass the characteristics of maladaptation to include actions that increase emissions of greenhouse gases, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt or commit systems to path dependency.

Maladaptation has been used to describe case studies in arid systems, in the Sahel for example (Heyd and Brooks, 2009). In the context of arid and semi-arid lands, some studies have warned against the simplistic use of maladaptation resulting from certain type of livelihoods. The risk is that actions may be classified mistakenly as maladaptation (Agrawal and Perrin, 2008). For example, the movement of semi-nomadic pastoralists in space and time is regarded as a traditional and effective way of dealing with climate variability (Ibid.), but is increasingly being described by some as maladaptive (IPCC, 2014a). However, other studies attribute the breakdown of traditional pastoralism in Sudan to wider social and political changes that have led to restrictions on movement, asset-stripping and increased conflict and violence (Young et al., 2009).

2.6.3 Towards an interdisciplinary approach

The concepts of resilience and adaptation are closely related despite differences in their epistemology. Both study the responses of systems to stress and are increasingly crossing over between disciplines (Turner et al., 2003). However, as Adger (2000) points out, it is not wise to transfer resilience thinking directly to the social sciences without giving particular thought to some fundamental differences between the two. A significant difference is that resilience theory takes a systemsorientated, dynamic, adaptive capacity approach to change whereas adaptation typically focuses on the agency of actors to respond to change (Nelson et al., 2007, Stringer et al., 2009). Actor-based analysis looks at processes of decision-making whereas systems approaches examine implications of these processes on the rest of the system (Miller et al., 2010). Considering a problem from only one of these perspectives can lead to the omission of important factors which can only be viewed from the other.

Janssen et al. (2006) proposed that a network perspective focusing on system structure should be employed in the analysis of the resilience of social-ecological systems. However, there is also a risk that resilience approaches can overlook the importance of the normative aspects of social-ecological systems. The meanings people ascribe to their system can be strong motivations for action, which can be overlooked in more objective studies. Perceptions of the problem and how to address them are subject to multiple framings by different stakeholders and ecosystem services are valuable to different groups for different reasons (Adger, 2008). Therefore, building resilience can be perceived as incompatible with normative concerns. There could also be potential trade-offs between maintaining the potential for a system to adapt and re-organise over long temporal scales, and the adaptation of people and livelihoods to environmental change i.e. increased adaptation at one location may decrease resilience at another (Nelson et al., 2007). Similarly, adaptation actions could turn out to be maladaptive due to lack of consideration across different temporal or spatial scales (Adger and Barnett, 2009) and it is important to understand at which scales such effects may be identified and addressed.

These ideas also resonate with debates in the field of livelihood studies. In a critique of the sustainable livelihoods approach that has dominated since the late 1990s, Scoones (2009) has identified what he sees as key failures associated with the emphasis placed on local, qualitative and interdisciplinary solutions to tackle poverty. These include an under-appreciation of the roles of globalisation, climate change, land-use change and power dynamics in understanding drivers of livelihood strategies. These issues are interlinked to some degree and Scoones (2009) argues that they could be addressed with more specific attention to the challenges of knowledge, politics, scale and dynamics if livelihoods perspectives are to be 're-energised' for the future.

There is potential to draw upon systems thinking in understanding social-ecological dynamics across scales and to draw upon actor-orientated approaches to understand issues of knowledge and power (Miller et al., 2010), although examples of how these approaches can be implemented in practice are scarce. However, the growing body of literature emerging on what appears to be an interdisciplinary convergence towards a unified resilience-based framework for exploring environmental and social sustainability highlights the importance of carrying out research to test these ideas.

The questions of how land-use change and climate change interact and affect resilience require consideration of all parts of social-ecological systems over spatial and temporal scales, ranging from global climate to regional vegetation dynamics and local decision-making processes. The conceptual and methodological approaches required to achieve a comprehensive understanding of these social-ecological systems, must combine perspectives from the natural and social sciences. Integrating elements of these disciplines to tackle the problems of global change calls for what Norgaard (1989) described as 'methodological pluralism', including both quantitative and qualitative methods.

For these reasons, I have chosen an interdisciplinary approach in undertaking my research, combining the ontology and epistemology of the natural and social sciences and employing mixed methods to address the research aims. This interdisciplinary conceptual framework is discussed in the next section.

2.7 Overview of conceptual framework for this research

There are several categories of research framework that have been employed to assess resilience or vulnerability in semi-arid systems. These can be summarised into three broad approaches as follows (Fraser et al., 2011): use of expert opinion and data to establish background narratives of a system (Crane, 2010, Sallu et al., 2010); qualitative or conceptual modelling of a system (Li and Huntsinger, 2011, Quinn et al., 2011, Ravera et al., 2011, Sendzimir et al., 2011); and, quantitative analysis to create future scenarios (Dougill et al., 2010, Manez Costa et al., 2011). Other studies have moved beyond the case study to look at arid and semi-arid systems across regions, for example Catley et al. (2013) worked with stakeholders to develop a qualitative conceptual framework that described future scenarios across the arid and semi-arid lands of the Horn of Africa. Scenarios can be developed for a range of reasons in a range of ways, ultimately the objective is to assess the variation in possible futures to provide insights into the range of potential outcomes (Rounsevell and Metzger, 2010). Increasingly, agent-based models are being applied to social-ecological systems as a means to move beyond the case study and produce more generalisable models of resilience, although this is recognised as a significant challenge (Rounsevell et al., 2012). This review of research frameworks demonstrates that there are several ways to conceptualise and model semi-arid social-ecological systems, each with its own set of limitations and strengths.

In seeking to understand the social and ecological responses of the Amboseli social-ecological system to extreme shocks and larger scale stressors, an interdisciplinary approach to understanding social-ecological resilience has been employed. This guiding conceptual framework is illustrated in Figure 2.1.

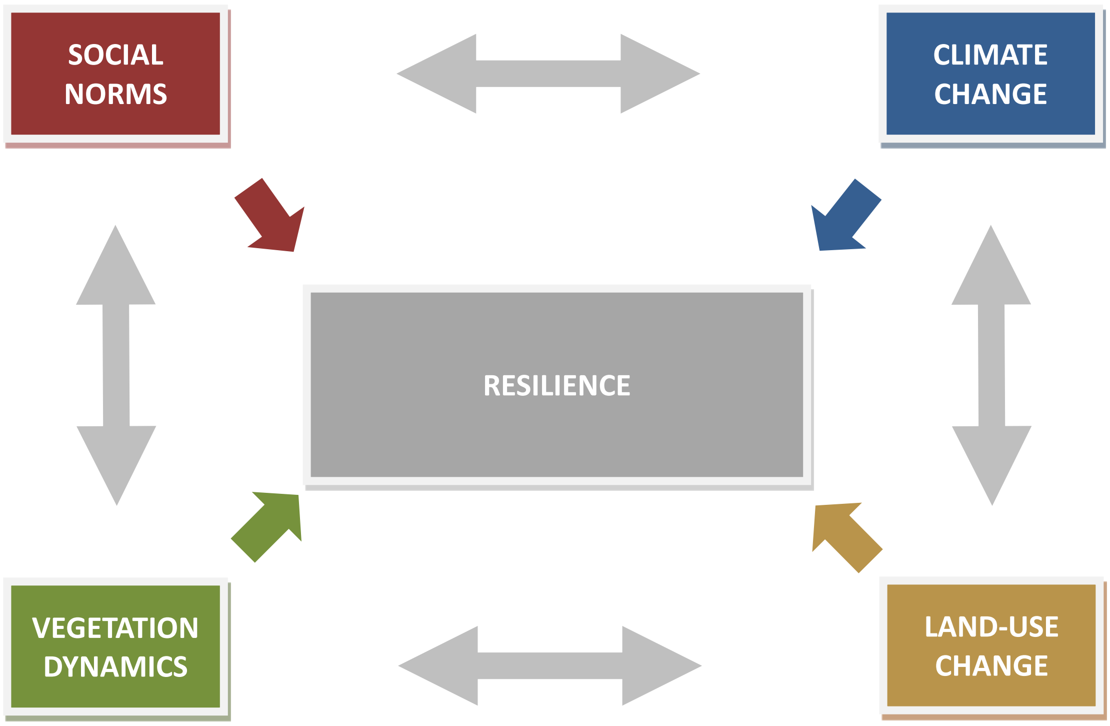


Figure 2.1: Conceptual framework for research methodology

Here the social and ecological components of the system and main drivers of change that have been identified earlier in this chapter are shown as dynamic and interacting elements influencing the overall resilience of the system. Modelling techniques, including participatory agent-based modelling and dynamic vegetation modelling, were used as an integrating tool to examine the ways in which people and environments interact over space and time. This integrating approach allowed exploration not only of the dynamics within the social and ecological components of the system, but also the interactions between them. This is a development of previous studies which have focused primarily on either the impacts of society on the environment or *vice versa* (e.g. Robinson, 2009). Chapter 3 describes the integration of quantitative and qualitative data using models, which allows analysis across spatial and temporal scales and, with the inclusion of participatory methods, combine actor-based and systems-based enquiry to explore some of the tensions of these approaches that are currently a topic for debate in the literature.

2.8 Summary

This chapter has reviewed the key literature exploring the main drivers of change in rangeland social-ecological systems, namely land-use change and climate change, and how these act and interact to impact on the resilience of these social-ecological systems. An overarching conceptual framework, informed by this literature, has been devised to guide the research. In the next chapter, I will discuss the research aim as guided by the conceptual framework, and the interdisciplinary methodology employed to address the research questions.

CHAPTER 3. AN INTERDISCIPLINARY METHODOLOGY FOR UNDERSTANDING THE AMBOSELI SOCIAL-ECOLOGICAL SYSTEM

3.1 Introduction

This chapter outlines the aim of the research and the methods selected in addressing this aim. This methodology is guided by a conceptual framework, which is linked to the concepts of adaptation and resilience discussed in Chapter 2. An overview is provided here, as well as a description of the process undertaken in integrating the components of the interdisciplinary methodology.

3.2 Research aim

The aim of the research was to investigate the combined impacts of climate change and land-use change on the structure and function of semi-arid grassland systems and the livelihoods of the pastoralist societies that depend upon them, and the implications of these impacts for the resilience of these social-ecological rangeland systems.

In order to achieve this aim, the following objectives were addressed:

1) To investigate responses to the 2009 drought as a particularly extreme weather event and the implications of these responses for the adaptive capacity of pastoralists in the Amboseli social-ecological system.

2) To identify the multiple stressors acting on the Amboseli system, including wider processes of land-use change and climate change.

3) To elucidate the socio-economic, cultural and ecological factors driving land-use decisions, the interactions of these with climate change and implications for the social-ecological resilience of the Amboseli system.

3.3 Study area

The study area selected for this research is the Amboseli system of south-eastern Kenya (see Figure 3.1 for a typical view of the rangeland and Figure 3.2 for a location map). The primary reason for selecting this study area was that I had previously spent a year (November 2009 to September 2010) working for a conservation organisation operating over 1,700 km^2 of this system. During this time, I shared my time living between three different group ranches and witnessed first-hand the unfolding of the most severe drought since 1961 and the impacts of this shock on the people, wildlife and landscape of the Amboseli system. It was this experience that prompted my interest to further research the drought, its impacts and the implications of land-use change and climate change for the Amboseli system.

Figure 3.1: View towards the Chyulu Hills and Ol Donyo Wuas, Mbirikani Group Ranch

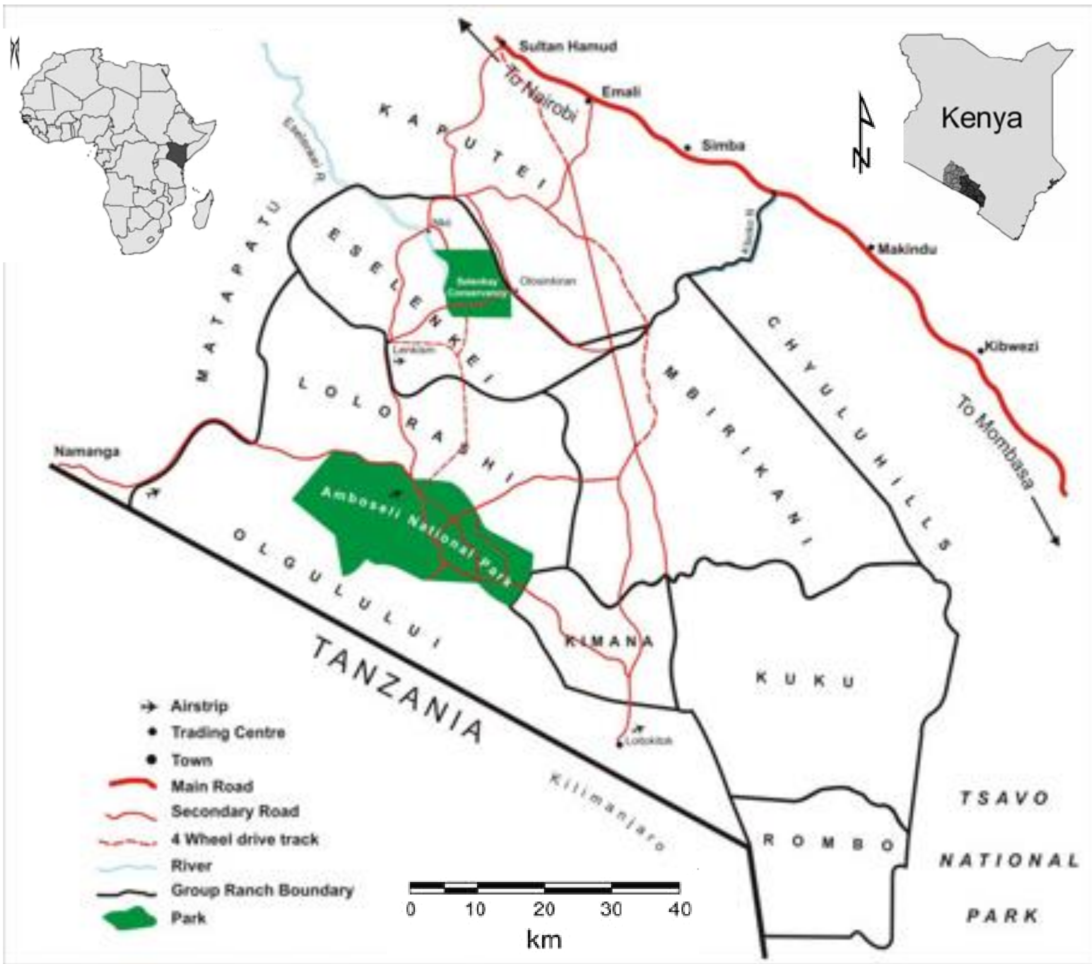


Figure 3.2: Map of the Amboseli system (source: (Lion Guardians, 2010))

The Amboseli system, located close to the border with Tanzania, is part of a large swathe of semi-arid grassland inhabited almost exclusively by members of the Maasai tribe. The Amboseli system is home to a particular sub-group (or *section*) of the Maasai tribe, known as the *Ilkisongo,* who manage the land for livestock production and some other supplementary livelihood activities. Land tenure in the area is designated under the Land Group Representatives Act (1968), dividing the area into group ranches. The Amboseli system, as defined here, is comprised of three communally-managed group ranches, Olgulului (the northern part of which is known as Lolorashi)[2], Eselenkei and Mbirikani. Also within the system is Amboseli National Park, which is managed by the Kenya Wildlife Service. The land tenure and

[2] Henceforth, Lolorashi (Olgulului North) and Olgulului South will be referred to as Olgulului Group Ranch.

management of this area, as well as the characteristics of the *Ilkisongo* Maasai, are discussed in greater detail in Chapters 4 and 5.

The area experiences a bimodal distribution of rainfall averaging 350 mm annually. The rainy seasons typically occur between the months of November to January (known as "the short rains") and March to June ("the long rains"), although the onset and volume of rains is variable between years. Also heterogeneous across space and time are soil conditions, topography, geology and vegetation. The key characteristics of the Amboseli system are outlined in Table 3.1.

Table 3.1: Key characteristics of the study area

	Eselenkei Group Ranch	**Mbirikani Group Ranch**	**Olgulului Group Ranch**
Division	Loitokitok	Loitokitok	Loitokitok
Land tenure	Communal group ranch (GR) with Selenkay wildlife conservancy leased by the community to an ecotourism operator.	Communal GR with Ol Donyo Wuas conservancy leased by the Group Ranch Committee to a high-end tourist operator. Since 2009, the terms of the lease have been under negotiation for significant expansion. The Chyulu Hills National Park is to the east of the GR.	Communal GR with Amboseli National Park within its boundaries. Private tourist operators manage Kitirua Conservancy. Small areas of Olgulului have been subdivided into plots for agricultural production. Olgulului borders Tanzania to the south. Maasai are free to cross this border for herding.
Area	Approx. 800 km^2	Approx. 1,360 km^2	Approx. 1,570 km^2
Ethnicity	*Ilkisongo* Maasai		
GR members	Approx. 1,250 (Ntiati, 2002)	Approx. 4,600 (Ntiati, 2002)	Approx. 3,400 (Ntiati, 2002)
Main livelihoods	Primarily livestock-based production with some income from Selenkay Conservancy.	Primarily livestock-based production with some small business in towns and cultivation. Income and significant employment opportunities with Ol Donyo Wuas, other lodges/tourism operators and conservation projects.	Primarily livestock-based production with some a range of businesses and tourism-related activities in towns and some cultivation. Income and significant employment opportunities with a larger range of tourism operators and conservation projects.

Annual average rainfall	350mm, bimodal distribution (Altmann et al., 2002)
Soils	Poor-draining black cotton soil in floodplains and calcareous loam and sandy soils at higher elevations (Touber, 1983, Gachimbi, 2002, Katampoi et al., 1990)
Vegetation	Predominantly *Acacia-Commiphora* savannah with gradient of grassland to open woodland habitat. Grasses generally dominated by perennial *Sporobolus spp.* with *Cynadon dactylon* stands around swamps (Githaga et al., 2003).

(Table 3.1 continued)

3.4 Research design

In this section, I describe the different elements of the methodology including methods used and analytical approach to address the research objectives (see Table 3.2 for an overview). A mixed methods approach was selected in order to capture the social-ecological elements and dynamics incorporated in the conceptual framework (see Figure 2.1), and to learn more about the impacts of climate change and land-use change on the resilience of the Amboseli system. Qualitative methods including semi-structured interviews, participant observation and informal discussions were used to capture a rich, context-specific understanding of the system from the perspective of the Maasai. Quantitative modelling approaches were used to explore interactions and trends over longer timescales and to capture more generalisable findings with relevance beyond the Amboseli case study (see Chapters 6 and 7). In reading through this description of methods, it is important to note that the overall research process was iterative, with these different elements of interpretation feeding into each other throughout.

3.4.1 Establishing context

Prior to the first period of PhD fieldwork in 2011, a review of historical and current policy pertaining to Kenya's semi-arid areas and livestock sector was carried out. These policies included the *Kenya Vision 2030: Northern Kenya and other Arid Lands* (2009), *Ministry of State for Development of Northern Kenya and other Arid Lands: Strategic Plan 2008-2012* and *The Constitution of Kenya* (2010). At the same time, the available literature on Maasai livelihoods, ecology and land use was reviewed to develop an understanding of the wider context, historical legacy and possible trends and stressors that might influence land-use change in the study area. These exercises enabled the mapping of the policies, stakeholders and issues relating to the Amboseli system to establish context going into this study.

Table 3.2: Research objectives mapped to methods

Research objective	Information required	Methods of obtaining information	Period
1. To investigate responses to the 2009 drought as a particularly extreme weather event and the implications of these responses for the adaptive capacity of pastoralists in the Amboseli social-ecological system.	Livelihoods, assets and incomes over time. Attitude towards employment and education. History and mobility of grazing. Significant past events, particularly droughts. Decision-making. Land tenure and uses. Resources and seasonal availability and use. Herd management. Access and problems of access to resources.	Semi-structured interviews with Eselenkei and Mbirikani members and other stakeholders [3.4.2.1]. Participant observation and informal discussions in Eselenkei, Mbirikani and Olgulului Group Ranches [3.4.2.2]. Agent-based modelling approaches - development of agent architecture [3.4.2.3, 3.4.3.1].	2011 2009 – 2010, 2011 and 2013 2011
2. To identify the multiple stressors acting on the Amboseli system, including wider processes of land-use change and climate change	Roles of customary and political institutions and interactions between these. Risks and stresses as perceived by Maasai, how these change over time in response to context and how prioritised. New and existing markets, services, access and commodities.	Policy review, historical literature review and stakeholder mapping [3.4.1]. Participant observation and informal discussions with Eselenkei, Mbirikani and Olgulului Group Ranches [3.4.2.2]. Agent-based modelling approaches – iterative development of behavioural rules in participation with research participants [3.4.3.2, 3.4.3.3].	2011 2009 – 2010, 2011 and 2013 2011, 2012 and 2013

3. To elucidate the socio-economic, cultural and ecological factors driving land-use decisions, the interactions of these with climate change and implications for the social-ecological resilience of the Amboseli system.	Input parameters. Scenarios of climate change and ambient climate. Scenarios of land use change.	Development of grazing sub-model for aDGVM from qualitative data and literature review [3.4.5, Chapter 7]. aDGVM simulations with climate change from IPCC SRES A1B and land use scenarios developed from qualitative data [Chapter 7].	2011 2013

3.4.2 Understanding land use and livelihoods in Amboseli

Qualitative data were collected at each of the Eselenkei, Mbirikani and Olgululgui Group Ranches using a mixed methods approach (Barbour, 2006, Crang and Cook, 2007) including participant observation, informal discussion and semi-structured interviews. At the outset, research was conducted across the three Group Ranches. In subsequent field visits, research was focussed in on Eselenkei and Mbirikani Group Ranches only (see section 3.5 for further explanation).

3.4.2.1 Semi-structured interviews

Semi-structured interviews were conducted in Mbirikani and Eselenkei Group Ranches only. Purposive sampling was used to identify interview respondents from each settlement area of the two Group Ranches. After an initial round of interviews, data saturation was reached and included 'multiple realities' developed a picture of livelihood strategies and land use decisions in the system (Baxter and Eyles, 1997). Given the relative similarity of ethnicity, land use and livelihood strategies within the system, the sample was broadly representative of the total population. Topics included in interview schedules were family structure, livelihoods, natural resource use over space and time, external actors (e.g. services and institutions), perceived socio-economic and environmental changes and the drivers of this change, and plans for the future. See Appendix 1 for a guide to semi-structured interview topics. A technique used frequently was discussions of scenarios and "*what if?*" situations, which I found helped to increase participation, depersonalise discussions, protect privacy of other participants and to frame issues more effectively.

Additional individual interviews were also held with key members of the community including group ranch officials and traditional chiefs to gain more detailed information and an overview of political responses to perceived change within the system. To elicit the expert knowledge within the system, other actors in the system were interviewed, including the Amboseli Community Warden (Kenya Wildlife Service), the directors of research projects (Maasailand Preservation Trust, Amboseli Elephant Project, Living with Lions, International Livestock Research Institute, African Conservation Centre) and tourist operators.

3.4.2.2 Participant observation and informal discussion

Participant observation is a useful method for properly contextualising and analysing both material and normative processes which form the experience of actors within a system (Crane, 2010, Smajgl et al., 2011, Drury et al., 2011). Participant observation and informal discussions were carried out across the two Group Ranches over a period of six months in 2011. From the outset, the field research was carried out in a relatively unstructured manner and this flexibility increased during the course of fieldwork. The reason for this approach was my existing familiarity with the system and the majority of research participants.

In the first instance, specific communities in the Mbirikani and Eselenkei Group Ranches were identified based on previous knowledge of the system and discussions with research assistants and contacts. As part of this stage, field walks were carried out with members of Eselenkei, Mbirikani and Olgulului Group Ranches prior to and after the drought. This helped to gain an understanding of how users, particularly herders, perceived the landscape after the 2009 drought and their decision-making processes in utilising the resources within it (Thomas and Twyman, 2004). Broad-scale baseline information and observed changes were surveyed during these walks. The information gained on these walks was triangulated through informal discussions with a range of different user groups including women, warrior age-sets (*ilmurran*), junior elders (*ilkidotu*) and senior elders[3] in order to gain multiple perspectives. This exercise was repeated also on numerous drives with research participants, which provided the opportunity to reflect on changes in the landscape at a scale not usually experienced by the participants. Informal discussions were held with tens of individuals every day during fieldwork and time was split between Mbirikani and Eselenkei Group Ranches, with some preliminary work in Olgulului Group Ranch.

3.4.2.3 Analysis and interpretation

Thematic analysis of interview and field notes was undertaken (Slim and Thompson, 1994). Particular care was taken to avoid biases, high-inference descriptors (Baxter and Eyles, 1997) and jumping to conclusions too early (Jackson, 2001) by sequentially coding the material by hand, starting first with descriptive codes and then more analytical coding to establish meaning as well as content (Cope, 2003). In undertaking this analysis, particular emphasis was placed on reconstructing the experiences of the research participants, with a view to incorporating emic interpretations of the system (Crane, 2010). Data were analysed iteratively so that researcher and participant perspectives could be appropriately integrated (Heckbert et al., 2010) and material was re-read several times over the course of the second and third year of this research to enable reflection on these issues.

Due to cultural constraints in the study area, interviews were not recorded using audio equipment. Rather, comprehensive interview notes were taken and field notes taken during participant observation and informal discussions. I also kept a field diary on a daily basis to ensure any other information was captured.

3.4.3 Agent-based modelling approach

Agent-based models (ABMs) are virtual representations of observed systems and include actors (agents) that are governed by certain rules which define their

[3] There are a range of categories in the senior elder age-set but these are essentially one group with regards to decision-making

interactions with each other and their environment (Epstein, 2007). Agents are typically goal-directed, governed by bounded rationality (Simon, 1997, Grimm and Railsback, 2005, Wainwright and Millington, 2010) and adapt their behaviour depending on other agents, their environment and previous decisions (Heckbert et al., 2010, Mathews et al., 2007). ABMs have frequently been used to explore social-ecological systems and problems of land-use change (Bousquet and Le Page, 2004, Parker et al., 2003, Mathews et al., 2007, Huigen, 2004, Bithell and Brasington, 2009, Valbuena et al., 2010, Robinson and Brown, 2009). Several studies have also used this approach for rangeland systems (Milner-Gulland et al., 2006, Rouchier et al., 2001, Walker and Janssen, 2002, Galvin et al., 2006).

The ABM methodology takes an abductive approach in that modelled systems give rise to self-organising and emergent properties from which theories can be constructed and can allow for agents to respond on the basis of the meanings they ascribe to their systems. At the same time, ABMs incorporate objective processes that are observable in the real-life system and can be used to evaluate model performance. The degree to which an ABM represents the system according to the perspectives of the agents (*emic*) or the researcher (*etic*) depends on the methods and analysis used (Crane, 2010). This research used a participatory modelling approach, involving stakeholders in model-building and interpretation which captured a more emic representation of the system while allowing stakeholders to view their resource management problems from different viewpoints (Guyot and Honiden, 2006, Nguyen-Duc and Drogoul, 2007, Parker et al., 2003, Mathews et al., 2007, Voinov and Bousquet, 2010).

Qualitative research methods, including those presented in the previous section, offer a valuable but relatively new approach to developing ABMs (Millington et al., 2008, Yang and Gilbert, 2008, Polhill et al., 2010, Huigen, 2004, Smajgl et al., 2011). Ethnographic methods can generate detailed information about group dynamics while increasing the opportunity for reflexive, inductive theories to emerge. While ethnographic data can be highly empirical, ABM also offers a means of identifying general patterns and processes that will have relevance in a general range of settings whilst operating within the parameters of the particular case study

(Janssen and Ostrom, 2006). It is important in developing any model, to consider the trade-off between goodness of fit to the specific case study and the ability to generalise. The use of qualitative data and narrative approaches to the explanation of model results is an area of growing interest within ABM community, with special interest groups working together to advance this area of research (see contributions to ESSA 2013 special track "Using qualitative data to inform behavioural rules" in Kaminski and Koloch, 2013).

To date, the majority of ABMs of land-use cover and change represent farming systems in either temperate or tropical contexts (see Chapter 2 for examples). This concentration is largely because of the origins of this subfield of ABM in the geographical sciences, developed in conjunction with spatial technologies such as Geographical Information Systems and remote sensing. Pastoralist systems like Amboseli pose additional conceptual and operational challenges to modellers due to their spatial heterogeneity and characteristic dynamics. The few existing ABMs of pastoralist systems have focussed on conflict between farmer and pastoralist groups or on measurable flows of assets derived from survey data (e.g. Milner-Gulland, 2006). Given the growing emphasis on non-material factors in land-use decision-making and climate change adaptation, there is potential to build on this work using new approaches to ABM incorporating qualitative data.

To build behavioural rules for the ABM, a tested methodology was followed (Yang and Gilbert, 2008, Smajgl et al., 2011, Janssen and Ostrom, 2006), which includes the following steps.

3.4.3.1 Gain an understanding of the social-ecological system, including the bounds of the system, and identify different classes of agents and their attributes

Based on knowledge of the study area, field research and previous studies, primary agents were identified that shared common attributes such as ethnicity (Maasai) and livelihood (primarily livestock-based). However, these primary agents were differentiated in their motivations and options by criteria which included clan, wealth, proximity to protected area boundaries, age of household head, land tenure of household etc. A set of secondary agents were identified that influence the motivations and options of the primary agents (Smajgl et al., 2011), e.g. customary and political institutions, private landowners, markets, tourists, which were also identified with input from the key contact interviews described in the previous section.

3.4.3.2 Develop the behavioural rules for different agent typologies and specify parameters

To develop rules for agent behaviour, I considered the mechanisms used by agents to make decisions (e.g. individual choice or collective consensus), how agents' perceptions are linked to their actions (e.g. how perceptions of the landscape affect herding strategies), how agents influence or control each other (e.g. via age and clan institutions, political authority) and what information is passed between agents (e.g. good grazing areas, weather conditions, prices) and by what means (e.g. clan networks, mobile telephones) (Wainwright and Millington, 2010, Bousquet and Le Page, 2004). This information was abstracted from the qualitative data obtained in the field and rules were developed in participation with stakeholders (see Chapter 6 for further details).

The ABM was developed in open source NetLogo software (Wilensky, 1999). The NetLogo model development environment is relatively simple in terms of code and it also has a useful visual output element, and is widely used in ecological (Grimm and Railsback, 2005) and social science (Gilbert, 2008) simulations.

3.4.3.3 Test the behavioural rules with research participants

A second period of fieldwork was carried out in January-February 2012. The aim of this visit was to explore whether the interpretation of qualitative data and subsequent development of rules held meaning for participants (Bousquet et al., 2002). This process not only tested the development of behavioural rules, but also increased opportunities for knowledge-sharing and collaborative learning (Voinov and Bousquet, 2010).

In this final field visit, interviews and discussions were held with subsets of the original participants, either individually or in groups, to explore and reflect verbally on the findings of the research so far. During these discussions, a series of "*if-then?*" and "*what-if?*" questions were used to interrogate the model procedures and check explicit and implicit assumptions. In most instances, illustrative diagrams did not prove useful in structuring discussions with participants, who are unfamiliar with this medium, and therefore were not generally used. Rather, questioning followed the model design process step by step. In this way, process order and parameters discussed in Chapter 6 in the ABM were tested with participants to see whether they seemed reasonable representations from their perspectives.

This part of the modelling process became a major focus and led to significant adjustments to the overall approach. It was during this period of fieldwork that I first realised the modelling *process* was producing interesting findings in itself. The process of distilling specific rules, and more specifically the difficulties inherent in doing so, began to prove more interesting to me than the *outputs* of putting well-defined rules together as a comprehensive set of interactions in a full ABM. These issues are discussed in detail in Section 3.5 below and in Chapter 6.

3.4.4 Modelling vegetation dynamics – the adaptive Dynamic Global Vegetation Model

Dynamic Global Vegetation Models (DGVMs) are concerned with vegetation function, representing the dynamics of biomass, carbon, nutrients and water cycling within ecosystems and with the atmosphere. DGVMs are therefore particularly useful in exploring the responses of ecosystems to disturbance and global change at different scales. To explore the impacts of livestock grazing and land-use change in the Amboseli system, I used the existing adaptive Dynamic Global Vegetation Model (aDGVM) which is designed specifically to represent the mix of tree and grass vegetation that is characteristic of savannah ecosystems (Scheiter and Higgins, 2009). Alternative DGVMs do not adequately represent savannah habitats, typically underestimating the extent of these areas due to their insensitivity to the biotic and abiotic factors that determine the relative abundance of grass and woody vegetation species, particularly competition and fire (Scholes and Archer, 1997, Higgins et al., 2000, Sankaran et al., 2004, Sankaran et al., 2005, Bond et al., 2005, Bond, 2008, Sankaran et al., 2008, Bond and Midgley, 2012). Building on existing DGVMs, the aDGVM presents a novel individual-based approach incorporating carbon allocation, leaf phenology and fire components, which allow for more adaptive simulated responses of individual plants to changing environmental conditions. The aDGVM is arranged across three scales (leaf, individual plant and stand) and models the processes outlined in Table 3.3 below.

Table 3.3: The processes modelled by the aDGVM at each level (adapted from Scheiter and Higgins, 2008)

Process Level	Processes modelled
Leaf	▪ Linked photosynthesis and stomatal conductance sub-models
Individual plant (assuming same physiological properties and bio-physical influences for trees and grasses)	▪ Biomass pools of plant ▪ Plant allometry ▪ Canopy photosynthesis and stomatal conductance ▪ Respiration ▪ Carbon balance and allocation ▪ Leaf phenology ▪ Biomass turnover and decomposition ▪ Evapo-transpiration
Stand dynamics for a continuous layer of grasses and discontinuous layer of trees (in 1 hectare units), incorporating: Individual trees; Super-individual grass below tree canopies; and, Super-individual grass between tree canopies. In effect, this represents tree and grass populations embedded within an abiotic microclimate (i.e. an ecosystem)	▪ Total evapo-transpiration and soil water balance ▪ Light competition ▪ Tree population dynamics (reproduction, seed bank and death) ▪ Grass fires and tree topkill

In a comparison with six other DGVMs, the aDGVM showed better agreement with the consensus vegetation maps for Africa, particularly for the savannah transitional zones, producing an overall κ-value of 0.61 compared to 0.32-0.5 for the other models (Scheiter and Higgins, 2009, Cramer et al., 2001a). This improved ability to predict current vegetation patterns in Africa is attributed to the individual-based modelling approach and more mechanistic representations of leaf phenology and carbon allocation which allow for more adaptive responses to disturbance and environmental change (Scheiter and Higgins, 2009). The aDGVM can therefore predict current vegetation patterns in Africa better than the available alternative models can and is therefore the most suitable choice of model to investigate the impacts of climate and land-use changes on several scales in African savannah ecosystems. As the authors note, the aDGVM provides a flexible framework by which to quantitatively explore how land-use and climate change interact to modify grass-tree dynamics, due to its process-based design.

The aDGVM structure assumes a study site to be homogeneous within a one hectare stand and is described by the following parameters: temperature; precipitation; wind speed; atmospheric pressure; soil carbon; soil nitrogen; wilting point and field capacity. See Figure 3.3 for a diagram of the model components.

The aDGVM can be run using generally available gridded soil data (GSDTG, 2000) and climate data (New et al., 2002). Site-specific data can also be used for model parameterisation. The model can be run with different climate change scenarios and with or without natural fire. One limitation of the aDGVM is that it is not spatially explicit. The model can produce outputs on a daily time-step on a one hectare scale grid but the cells are not interconnected which limits the ability of the model to simulate some important processes, e.g. surface water runoff. Spatially implicit models have been used frequently in semi-arid environments where conditions are assumed to be highly heterogeneous (Peters et al., 2006). Although such models do not incorporate processes that occur between neighbouring grid cells, they are less intensive and costly to run with less risk of error associated with inclusion of unnecessary or poorly estimated parameters. Including a large number of parameters that are difficult to estimate, particularly over larger spatial scales, can have greater error associated with them and are more difficult to evaluate (Oreskes et al., 1994, Rykiel, 1996). As with all models, the aDGVM is a simplification of reality but is nonetheless a useful model for exploring the cross-scale interactions between climate, vegetation and human-induced disturbance. Interpretations of model results will need to consider the exclusion of spatially explicit processes, as well as other simplifications that are inherent in complex models of this kind.

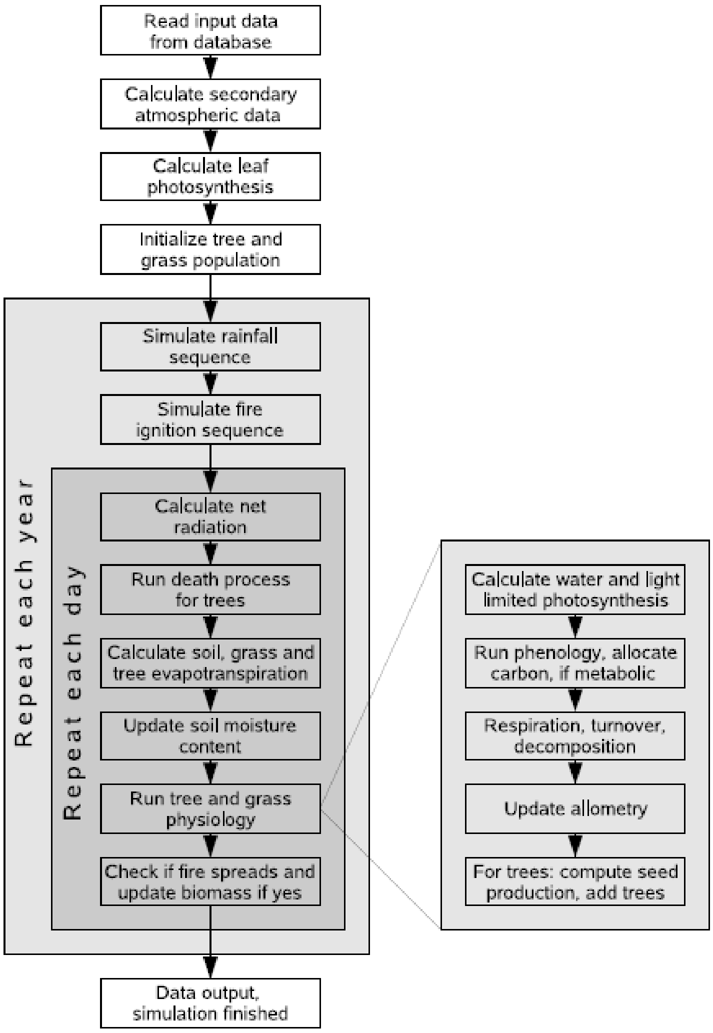


Figure 3.3: aDGVM model components (source: Scheiter and Higgins, 2008)

The aDGVM provides a flexible framework by which to quantitatively explore how land-use and climate change interact to modify grass-tree dynamics, due primarily to its process-based design (Scheiter and Higgins, 2008a). In fact, site-specific simulations carried out for Kruger National Park showed how known tree biomasses (Higgins et al., 2007) were better explained by grazing patterns than any other variable. In previous simulations, grazing rates have been kept constant or altered in line with known historic shifts in stocking rates, but grazing has not been explored as a dependent variable in itself.

3.4.5 Adapting the aDGVM to simulate livestock grazing

For this research, I developed a novel grazing sub-model to simulate the removal of grass and tree biomass by a livestock population. This sub-model was coupled to the aDGVM. It is partially based on the elephant impact model described in Scheiter and Higgins (2012), designed to explore the impact of elephant populations in Kruger National Park, South Africa.

Key parameters of the elephant-impact model have been altered or removed and others added to more accurately represent the foraging behaviour of livestock. The amount of biomass removed depends on the number of livestock, represented as a population of cattle and a population of goats in a defined area. Cattle are grazing herbivores, preferring moist grasses. Goats are mixed feeders, capable of utilising grass or browse (shrubby vegetation) depending what resources are available. Removing the required fraction of aboveground grass biomass simulates Grass consumption by both cattle and goats. Browsing by goats is also simulated by removal of fractions of the leaf and stem aboveground biomass of trees.

To run the aDGVM with the grazing sub-model, these additional input parameters have been developed: livestock visitation frequency (times per year), habitat selectivity factor, maximum consumption per tree (goats only), number of cows, number of goats, diet partitioning factor (goats only), daily biomass requirement (cows), daily biomass requirement (goats) and area (hectares). Chapter 7 contains details of the grazing sub-model design, parameters and implementation.

For this research, the grazing sub-model, coupled to the aDGVM, was implemented with the gridded soil and rainfall data for the coordinates of the Amboseli system. It was also implemented under the SRES A1B climate change scenario. In a series of simulation experiments, two-way fully factorial experimental design was developed to test the effects of climate change and land use scenarios on the structure and function of vegetation. Impacts on total tree biomass, total grass biomass and number of trees in the area were assessed, as were carbon dynamics represented by grass net primary production, tree net primary production and net ecosystem exchange. The land-use scenarios described in the experimental design of Chapter 7 were informed directly by the outcomes of the qualitative data analysis and agent-based modelling process.

3.5 Methodological challenges and adjustments

At the outset, the intention was to carry out qualitative data collection in all three of Olgulului, Eselenkei and Mbirikani to get as broad a picture of the system as possible. In practice during the first period of fieldwork in 2011, there was heavy rainfall that caused serious localised flooding across the system and particularly parts of Olgulului, making movement across these areas very difficult. As I continued with fieldwork in Eselenkei and Mbirikani, I began to focus in on interesting findings related to the different characteristics of these group ranches (see Table 3.1). For example, Eselenkei has less opportunity for diversified income at household or community level and it is more difficult to access markets and other services compared to Mbirikani (see Chapters 4 and 5 for more detailed descriptions of group ranch characteristics). Olgulului by comparison is different again, with land use and livelihoods influenced heavily by the Amboseli National Park and the tourism and conservation interest it generates. Recognising these differences and in the context of fieldwork conditions at the time, I revised my fieldwork plan to focus on comparing Mbirikani and Eselenkei group ranches in more detail.

Influenced by my background in the natural sciences and quantitative methodologies, it was my intention to implement a relatively formal approach to data collection, with more focus on semi-structured interviews, participatory rural appraisal and focus groups. This intention was in part due to my relative lack of previous experience in carrying out qualitative methods. As a natural scientist by training, I was both excited by and apprehensive about the grounded theory approach driving these qualitative methods and how this would play out in practice. However as I proceeded, following themes of interest and triangulating qualitative data, I felt strongly that the informal approach was so rich and interesting that I decided to continue in this line, which threw up interesting issues with the research participants themselves. These communities are so familiar with the social survey approach to data collection that some individuals, including the group ranch leadership, were slightly perturbed at the lack of formal questionnaire in my research. However, after I explained my approach and continued informal discussions and observation, many participants commented on the value of this approach and how they had enjoyed the process of explaining topics of interest in their own words.

This shift of focus did have implications for the ABM approach. As I proceeded through the iterations of data collection, analysis and interpretation, it became clear that the process of distilling and abstracting behavioural rules from the qualitative data provided an invaluable extra level of analysis. The process of testing assumptions and parameters of these rules with research participants in the second period of fieldwork was invaluable in providing further insight into key social-ecological dynamics. Therefore, I decided that a focus on modelling as a *process*, rather than a means of producing *outputs*, would best meet the research aim. The justification for these decisions is discussed fully in Chapter 6.

Related to this change of emphasis, the intention at the outset was to fully couple the aDGVM with a comprehensive ABM. As the focus shifted in the ways described above and the qualitative data analysis uncovered unexpected findings, I decided to use the aDGVM in a slightly different way, testing specific dynamics of interest for the system rather than simulating the entire system in great detail. Also, I was intending to use local rainfall and soil data for Mbirikani as inputs to the aDGVM, rather than the gridded global data. I obtained local rainfall data records for both nearby Makindu and Amboseli National Park as well as high-resolution soil maps from the Kenya Soil Survey. However, as I worked with these local data and grappled with the development of useful scenarios to test with the aDGVM, I decided to use the global data and climate scenarios, because I felt that the relatively coarse resolution of the aDGVM and lack of spatial connectivity in the model would have mismatched with the resolution of the detailed local data. Further decisions about input parameters are justified in Chapter 7.

3.6 Ethical considerations

Relationships with participants were underpinned by the fact I had shared in the lived experience of the 2009 drought, and had built a level of trust based on mutual dependence and assistance during those difficult times. The idea that I had returned to understand better the drought and its impacts was well accepted by the participants, as during the course of my fieldwork they themselves were doing the same. Education is valued very highly among the Maasai, they are familiar with PhD researchers, and approved of the aims of mine as a subject they themselves would be interested in. My PhD research started out from the position of 'one who has returned', and thus provided me with a strong basis for research from the outset.

3.6.1 Arranging access

This research is covered by research permission issued by the Kenyan Ministry of Science and Technology (Permit number: NCST/RRI/12/1/ES011/59). At the group ranch level, I first obtained the informed consent of the local leadership (group-ranch committee) before commencing research in the area, which is in line with local customs. Due to my previous relationship with the communities involved and their interest in the specific aim of my research, the group-ranch leadership chose to waive their usual unofficial research permit fee and asked me to commence only after they had had time to inform their communities about me and my research. Without the blessing of the group-ranch leadership, no-one would have agreed to participate in my research and I would not have been allowed to remain on the group ranches.

Prospective research participants were informed collectively or individually (as appropriate) about the nature and purpose of the research and what the data was to be used for. I took great care to repeatedly explain that I was now independent of any other organisation or authority. I did not use consent forms as many Maasai cannot read or write, and all have a deep suspicion of formal documentation having repeatedly lost land and rights in this way. Therefore, verbal agreement was taken as consent. No audio or video recordings were taken at any time during the research. The reason for this was the reservations of participants and the group-ranch leadership to discuss sensitive issues, such as politics, resource use and land tenure, in this manner. Rather, I took notes during discussions, with the consent of participants.

During participant observation, I began by spending time with individuals and households I already knew well. I had previously lived in these communities and had a good idea from the outset of the members of the community who would be willing to participate and who could provide valuable data for my research. The approach to participant observation was highly reflexive. Leading on from the participant-observation process, purposive sampling was used to identify respondents for semi-structured interviews, particularly where individuals were regarded as key informants on the research questions.

I resided within the communities for the duration of fieldwork and had regular contact with members. I explained to them what my research entailed and asked who would be willing to participate. After this, other individuals became interested in what I was doing and approached me to participate and share their stories, leading to a snowball sampling. I never approached people I did not know in their homes or forced my presence upon people in any way. In my experience, research of this kind is an interesting, even fun, process that people in these communities are keen to engage in as long as they are comfortable with the research aim and researcher. There is a possibility that this approach led to exclusion of some subsets of the population, although I am confident that this has not occurred to such an extent as to bias my data.

For research assistance, I worked with several individuals already known to me. I paid them a rate I already knew to be a fair price. I had previous contacts in each location so started by making contact with these individuals when travelling through the areas. No financial or in-kind payments were offered to research participants, nor was it sought.

Interviews were held with other stakeholders including conservation organisations, the local Kenya Wildlife Service authorities, tourist operators and other researchers. I already personally knew most of them and I had a very thorough working knowledge of the politics within and between these organisations and how these could potentially impact on community research participants from the outset. I took the utmost care to ensure confidentiality of participants and to avoid becoming involved in any of the aforementioned power dynamics. I achieved this to some extent by camping independently, travelling in my own vehicle (rather than the project vehicles I used to use), although it is not possible as a researcher to completely remove yourself from other research projects operating in these communities.

3.6.2 Positionality and reflexivity

While my presence in the system for the year prior to this PhD brought many advantages, which are discussed below, I was also very aware that it might reflect on my positionality as an independent researcher. I took great care to explain to research participants that I was no longer part of the conservation organisation I had previously worked for and was interested in discussing topics outside of the remit of that organisation. This process did take some time at the beginning of the first period of fieldwork, but did not appear to have an adverse effect on the research process other than routinely taking time to discuss conservation and human-wildlife issues as well as those related to my research. Further, my independence was clearly marked by the fact I was driving my own vehicle without any organisational logos.

My husband was also present with me throughout most of the PhD field research. He lived and worked with me in the system during 2009-2010 and had his own good relationships with many research participants. There were several advantages to being accompanied by my husband for the PhD fieldwork. First, we have always been perceived as a couple and a family unit, overcoming potential problems with being a lone female researcher. Second, he acted as a very valuable research assistant, providing another trusted set of eyes and ears to reflect on the events of each day, often remembering or observing small details that I may have forgotten on my own. Finally, having assistance with the logistical challenges of camping and vehicle maintenance freed up considerably more time for me to dedicate solely to research.

In terms of the positionality of my research assistants, Maasai customs are very effective at managing this to some extent. For example, as a researcher I was only allowed to receive assistance from members of the respective group ranches I was working on, or from individuals regarded as sufficiently well-respected to travel between group ranches to discuss the topics of interest. I was able to get these dynamics as right as possible from the outset as I had had prior relationships with these individuals and customs from my previous work. It also meant that I was less susceptible to attempts by authoritative individuals to 'hijack' the research process by installing research assistants into the process. It was judged to be right that I work with *ilmurran* (the age-set of young, male warriors), as these are the members of the community responsible for safety and security (including mine) and for the activities under investigation, namely herding.

Fortunately, I was able to operate without a research assistant at times, as I was able to navigate the system and communicate with many individuals in Kiswahili with just my husband and myself. This situation gave me a degree of freedom to pursue research to my own timetable, and to switch between research assistants with minimal impact on the research. In fact, I would say that the research benefitted from this flexible approach and the inputs of multiple assistants. I found this minimised misunderstandings becoming entrenched and provided a more rounded perspective in my own interpretation of data.

In some cases depending on the participant, I was able to conduct informal discussions in Kiswahili. In other cases where participants spoke only Maa, I used research assistants to translate conversations. The latter was my preference if I had a translator present, as it is my experience that Maasai prefer to articulate their thoughts and arguments in their own language, particularly regarding grazing and Maasai culture, with Kiswahili representing a more formal language for use in certain contexts, e.g. meetings with government officials or other stakeholders.

On occasions, sensitive or emotive subjects did arise during discussion, which I recognised as having potential to cause distress to participants. In particular, issues related to recent drought events, conflict with wildlife and political tensions did arise. No attempt was made to raise or pursue sensitive political issues on my part unless the participant wished to do so. If a participant did appear to be distressed in any way by the research process or unwilling to discuss particular issues, I terminated the interview or changed the subject.

3.6.3 Confidentiality

Any participants mentioned or quoted in this research have been anonymised. No interviews or discussions were recorded. Rather, I recorded field data in research diaries, in notes during semi-structured interviews and more formal discussions and in notes written each evening reflecting on any informal conversations or observations. These documents are in my possession in the form of notebooks.

3.6.4 Communicating models

While the majority of participants were not literate or familiar with spatial diagrams, all of them had a degree of understanding of scientific research, having been exposed to many researchers from different disciplines over recent years. Therefore, participants did not question the desire to understand their activities, implicitly accepting outsider interest in their culture and practices, which they encounter routinely through tourism, research and non-governmental organisations. Many participants, and certainly those who have been educated or exposed to outsider interest, through employment for example, have very good understandings of the issues in which researchers are interested such as natural resource use, livestock management and climate variability, which provides researcher and participant with a general level of shared understanding. Furthermore, due to a relatively high level of research exposure, the local leaders and almost all participants expect researchers to feed back on the process in which significant time and assistance has been invested. Thus, the process of communicating the design of the behavioural rules and ABM process in the second field visit was challenging but also, I believe, accurate in terms of participant understandings of the topics under discussion and their responses to questions about how decision-making is carried out in their households and communities.

3.7 Summary

In this chapter, I have described the aim and objectives of my research and the interdisciplinary methodology employed to address these. Also discussed are the challenges encountered during the course of the research and how these were overcome, as well as the ethical implications of this work. In the next four chapters, I will present the results of the analysis and findings of the research.

CHAPTER 4. TRAUMA AND SHOCK IN AMBOSELI: THE 2009 DROUGHT

4.1 Introduction

This chapter explores the lived experience of a severe drought in 2009 from the perspective of the Maasai of Mbirikani and Eselenkei Group Ranches. Returning to the Amboseli system in 2011, I noticed a distinctly different mood in this post-drought phase compared to 2009 and 2010 when the drought event was unfolding. Initially, I did not think much of it in terms of my research but this general 'mood' began to reoccur in the analysis of my qualitative data, emerging as a strong theme. These observations led me to explore the theory around the psychological and cultural impacts of natural disasters, environmental shocks and chronic stress.

In this chapter, I first describe the 2009 drought in terms of the historical context, hydrological severity and from the perspective of the Amboseli community. Drawing on the literature describing the dynamics of eco-cultural systems (e.g. Albrecht, 2007, Pilgrim and Pretty, 2010) and place identity (e.g. Breakwell, 1996, Freque-Baxter and Armitage, 2012), I then present evidence of the lived experience of the drought, the psychological and cultural impacts and subsequent adaptation responses. While primarily focussing on the responses of the Maasai community, I document also the psychological and cultural responses of other groups including tourists and conservation organisations, which along with other non-Maasai actors are widely referred to by Maasai as "*outsiders*[4]". Finally, the implications for the resilience of the Amboseli system are discussed.

I argue that the 2009 drought was a significant shock, which has impacted on the Amboseli eco-cultural system (whereby emergent human cultures have shaped and been shaped by local ecosystems to produce place-based cultures), affecting place

[4] Where participants have been quoted in this chapter, the text has been italicised. This is to distinguish more clearly between new results and quotations from the literature.

identity, cultural resilience and the well-being of the Maasai communities and their interactions with the landscape.

4.2 Place identity and resilience in eco-cultural systems

There is a growing recognition of the importance of potential psychological impacts of climate change (Zamani et al., 2006, Doherty and Clayton, 2011, Lewicka, 2011, Stain et al., 2011, Adger et al., 2013). Several disciplines are advocating the exploration of multiple meanings and cultural narratives that people attach to landscapes and how these ties can be affected by shocks and stresses, thus moving beyond more conventional material and socio-economic analyses of the impacts of environmental change (Ayantunde et al., 2011). It is argued, that changes in co-evolved eco-cultural systems (Pilgrim and Pretty, 2010) can impact on people's relationship with the land, causing impairment of their attachment to a particular place, loss of social identity, and decline in individual and community well-being (Pretty, 2011). As a landscape becomes altered through sudden shocks or chronic stresses to the environment, the sense of place associated with the landscape may be impacted with significant consequences for the interrelationships within an eco-cultural system (Pilgrim and Pretty, 2010). The lived experience of extreme variation in the environment can threaten the self-identity of the individual (Prohansky et al., 1983).

The Millennium Ecosystem Assessment has recognised the importance of the cultural services provided by ecosystems, including spiritual and religious values, aesthetic values, recreation and ecotourism. The report states that the "nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience" (MEA, 2005: 40), including knowledge systems and social relations are vital to human well-being. In addition to vital supporting and regulating services, savannah ecosystems also provide important cultural services. In common with other pastoralist societies, Maasai have developed socio-cultural functions, including institutions, norms, beliefs and knowledge systems, which enable them to mediate these cultural services and manage their environments (Jacobs, 1965, Homewood and Rodgers, 1991). Socio-cultural functions are therefore essential to the cultural resilience of the system (Crane, 2010, Adger et al., 2013) and to the sustainability of livestock-based livelihoods (Ayantunde et al., 2011, Catley et al., 2013).

Several theoretical concepts have been developed and applied to the responses of communities to shocks and stresses in their home environments, and how psychological impacts may affect the resilience of eco-cultural systems. The positive emotional bonds people experience with the locations in which they live were first described as 'topophilia' over 40 years ago (Tuan, 1974). More recently, the concept of 'solastagia' was termed by Albrecht in his study of Australia's Aboriginal communities suffering the effects of environmental destruction brought about by mining activities (Albrecht, 2005, 2006, 2007, 2010, 2011). This concept has been developed over the past few years in several contexts including drought-prone communities in Africa and Australia (Albrecht et al., 2007, Albrecht, 2010, Tschakert and Tutu, 2010, Albrecht, 2011, Stain et al., 2011) and Inuit communities in Canada (Cunsolo Willox et al., 2012). The origins of the term solastalgia are in the concepts of nostalgia, solace and desolation, defined as:

> the pain or sickness caused by the on-going loss of solace and the sense of desolation connected to the present state of one's home and territory. It is the 'lived experience' of negative environmental change manifest as an attack on one's sense of place. It is characteristically a chronic condition tied to the gradual erosion of the sense of belonging (identity) to a particular place and a feeling of distress (psychological desolation) about its transformation (loss of well-being). In direct contrast to the dislocated spatial and temporal dimensions of nostalgia, it is the homesickness you have when you are still located within your home environment (Albrecht, 2010: 227).

The argument follows that chronic environmental stress such as drought can cause solastalgia through the 'lived experience' of environmental change (Albrecht, 2010). Therefore the connection of self to the land, or a sense of place and place identity (Albrecht et al., 2007), or identity as an extension of the self and environment (Prohansky et al., 1983), are critical elements in the coping strategies, adaptive capacity and resilience of communities to environmental shocks and climate change. Identity defines who or what an individual is but also involves belonging to social groups (social identity) and places (place identity) (Twigger-Ross et al., 2003: 203). Place identity can be defined as:

> those dimensions of the self that define an individual's personal identity in relation to the physical environment by means of a complex pattern of conscious and unconscious ideas, beliefs, preferences, feelings, values, goals and behavioural tendencies (Prohansky, 1978: 155).

According to Breakwell's model of identity (1996), place identity incorporates dimensions of self-esteem, distinctiveness, continuity and self-efficacy. In their review, Fresque-Baxter and Armitage (2012) have identified several additional key dimensions of place identity from the literature including emotional attachment, environmental skills, security, sense of belonging, rootedness, familiarity, social connections and commitment to place. These dimensions of place identity can provide a framework by which to assess individual and community responses to environmental shock.

Although the interrelationships between place-identity theory and resilience have not been widely explored, there is growing recognition that responses to change are mediated by culture, which is often rooted in place (Adger et al., 2013). Environmental shocks can lead to simultaneous losses of structure, function and resilience in a system (Rapport and Maffi, 2011). A shock such as a severe drought therefore has the potential to disrupt the socio-cultural and institutional structure of an system to the point where it is unable to perform functions such that adaptive capacity is reduced (Rapport and Maffi, 2010). Therefore a drought shock can damage the social (Norris et al., 2008) and cultural (Crane, 2010) resilience of a community to cope, impacting on the community resilience and well-being promoted by a sense of identity and place (Hess et al., 2008). A traumatic response occurs when a shock exposes a failure of the rules, norms or behaviour used to cope with that shock (Longstaff, 2005). It is at these critical points in a specific place and time that a progressive loss of resilience leads to a 'tipping point' within a system (Holling, 1986a). Although droughts have been a common feature of African savannah systems through time and pastoralists have long demonstrated adaptive capacity in coping with these events, one drought event potentially can act as a 'tipping point' if system resilience has been eroded. The extent to which the 2009 drought might have triggered such a tipping point will be discussed in this Chapter.

4.3 The 2009 drought

East Africa experiences a bimodal annual precipitation cycle with what are known as 'short rains' from October to December and 'long rains' from March to May, due to movement of the inter-tropical convergence zone (ITCZ). In general, the short rainy season is more variable between years than the long rainy season (Mutai and Ward, 2000) as the El Niño-Southern Oscillation (ENSO) has more influence over the short rains (Ericksen et al., 2013). In Kenya, El Niño (warmer southern oceans) generally results in higher than average precipitation in the short rains but below average precipitation in the long rains (Mutai and Ward, 2000). La Niña events (cooler southern oceans) lead to less precipitation in the short rains. Kenya's climate is also influenced by the Indian Ocean temperatures, which can also affect rainfall patterns in the absence of ENSO events (Mutai and Ward, 2000).

In the arid and semi-arid lands of Kenya, the population dynamics of livestock depend on short-term 'boom and bust' cycles (Devereux and Tibbo, 2013: 217) in response to drought and longer term rangeland conditions (Ericksen et al., 2013). El Niño years give rise to greater precipitation and consequent increases in forage availability, resulting in livestock population growth (Zwaagstra et al., 2010). However, in the El Niño year of 2006, this pattern did not follow because it was both preceded by severe drought and followed by severe droughts in 2007-2009 from which livestock herds could not recover even with the beneficial effects of El Niño (Ericksen et al., 2013).

In the 2009 hydrological year (November to October), average rainfall in Amboseli National Park was 141 mm, the lowest precipitation level recorded since 1977 (see

Figure 4.1) (Altmann and Alberts, 2011). Additionally, analysis of satellite photography taken since 1980 showed potential forage availability, as estimated by the Normalised Differential Vegetation Index (NDVI), was at its lowest level for thirty years (see Figure 4.2) (Zwaagstra et al., 2010). Although human mortality during 2009-2010 was relatively low compared to recent famine crises in the Horn of Africa and northern Kenya, more than 50% of the Kajiado District population were dependent on government food relief during and after the 2009 drought (Zwaagstra et al., 2010). In this sense, the 2009 drought can be classified as a natural disaster in accordance with the World Health Organisation (1992: 2) definition of a disaster as “a severe disruption, ecological and psychological, which greatly exceeds the coping capacity of the affected community”.

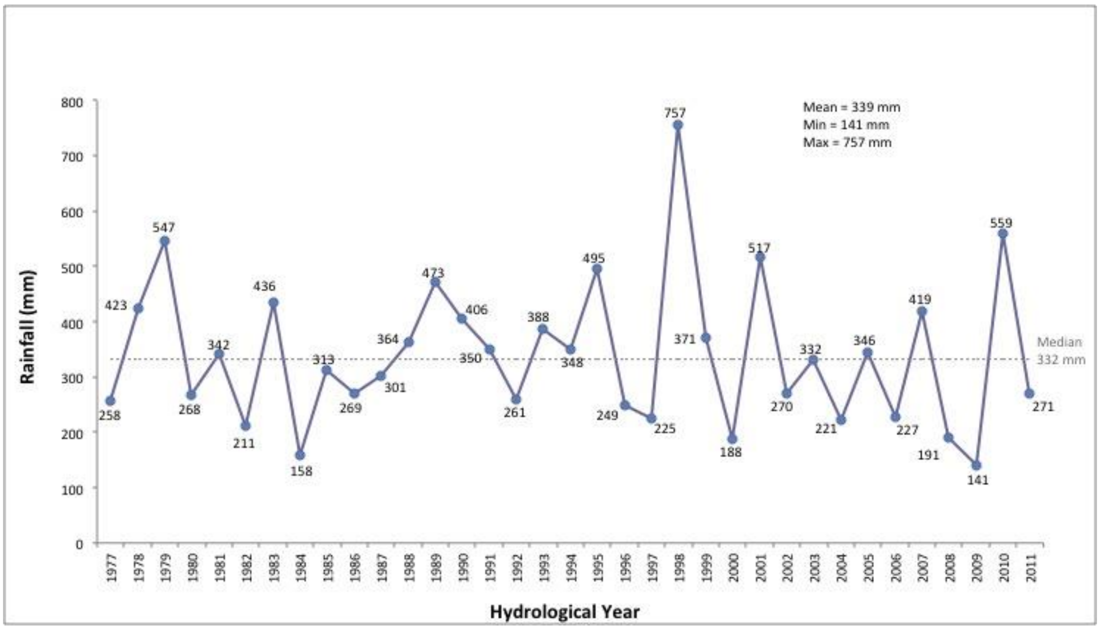


Figure 4.1: Annual rainfall for Amboseli National Park by hydrological year (Nov-Oct) 1977-2011 (source: Altmann and Alberts, 2011)

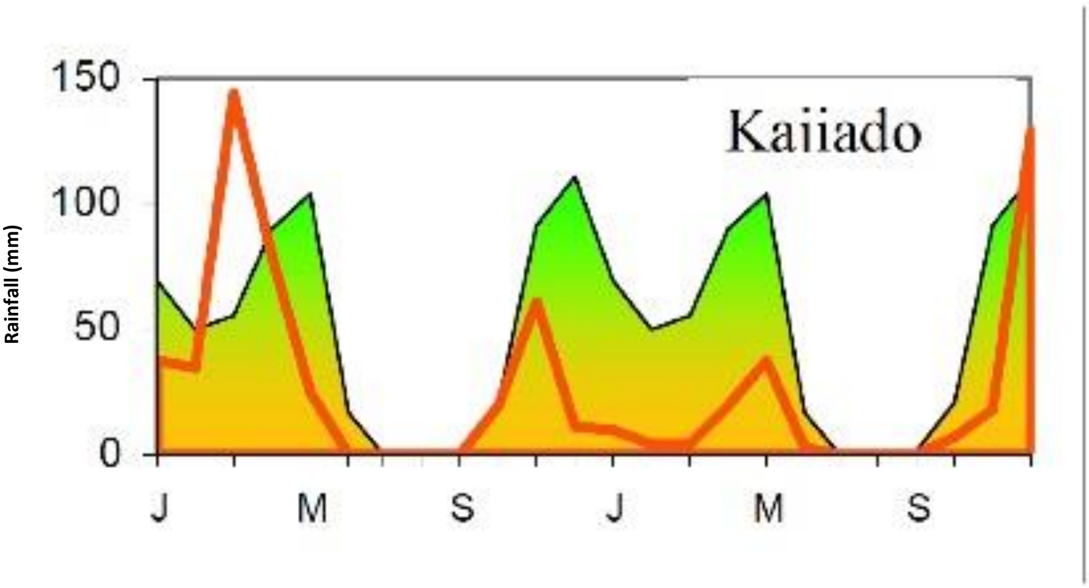


Figure 4.2: Average monthly rainfall 2008-2009 (red line) relative to longer term means for Kajiado District (shaded area), according to the Early Warning Bulletins (source: Zwaagstra et al., 2010)

4.4 Coping with the drought

The 2009 drought was particularly severe in its impact on the Amboseli social-ecological system, resulting in the loss of approximately 85% of livestock and wild herbivores (KWS and TAWIRI, 2010), which has been catastrophic for the livestock-based production system of the Maasai. On the Mbirikani Group Ranch, only two of the approximate 5,000 residents managed to retain their herds (Ntimama[5], 23/10/2011). It was explained to me that these individuals were able to preserve their herds because they were able to pay for access to private ranches near the Taita-Taveta hills, which have mostly been bought by non-Maasai élites from elsewhere in Kenya. Therefore, these two powerful and wealthy individuals were able to access resources beyond Maasailand to increase their resilience to the drought.

The 2009 drought is considered by the large majority of participants I spoke with during my fieldwork as the worst drought in nearly half a century, even described

[5] All names of Maasai participants provided in this thesis have been anonymised.

as '*the worst drought ever'* (Ole Kapalelei, 13/10/2011). Speaking with Lemayian, an elder in Mbirikani Group Ranch, he explained that he was a *murran* at the time of the 1961 drought, the last most severe drought in his experience. He explained that before the drought:

> *There was plenty of grass, the livestock and wildlife was happy, people were happy. Then there was a terrible drought, all the cows died and then floods came.* (Lemayian, elder, Mbirikani, 25/10/2011)

The Maasai then had to depend heavily on government food relief, delivered by helicopter, but people died because there was no irrigation or knowledge about farming. He said he felt at the time that his life would never be the same and that the shock of the drought was too severe for the Maasai to recover and resume their usual way of life. He claims the 2009 drought was more severe than 1961 in its impact on the environment and livestock:

> *The drought has especially affected cows. It was the very worst drought ever, nothing in Maasai history has been as bad as that.* (Lemayian)

However, he also feels his community are better prepared to recover this time as they have diversified their livelihood activities and are no longer as reliant on food relief. He believes people will increase their herds as before but it is better to have a variety of incomes such as employment and farming as this allows people to earn money faster and buy cows. With the benefit of hindsight, he is able to feel optimistic about the future. When asked if there will be more frequent drought in the future, he responded:

> *Only God knows what will happen in the future, anything can happen and the only way to be prepared is to expect anything and to buy plots and farm.* (Lemayian)

While we spoke, Lemayian's son, a *murran,* was present. He did not share his father's optimism, expressing a fear that he and many of his age-mates would be excluded from farming opportunities as they do not have the capital to start, especially now that they had lost their herds. In this instance, Lemayian's lived experience of the 1961 drought has assisted him in coming to terms with the current predicament of his people. In Maasai culture, the elders act as a repository of such knowledge and collective memory (Spear, 1993) which has helped the Maasai to persist in their harsh environment. Furthermore, I found there was some difference between drought severities as measured by hydrological indices and as perceived by research participants. For example, Lemayian clearly believes that the previous most severe drought was in 1961, rather than 1972-76 which has been reported by researchers (Campbell, 1999, Western et al., 2009). In this case, the lived experience of the 1961 drought stands out as more severe to Lemayian than successive years of low rainfall in the 1970s.

The definition of drought has long been contested. Different categories of drought take into account meteorological and hydrological factors and also agricultural and socio-economic indicators (Wilhite and Glantz, 1985). Recent definitions have sought to acknowledge the importance of both the supply and demand of water resources as the root cause of drought (Agnew and Anderson, 1992: 91), and therefore necessarily encompass both biophysical and social processes. In the context of semi-arid grassland systems, drought can be defined as an abnormal reduction in water supplies for a particular land use, primarily pastoralism, and can occur either through climatic change or land-use change (Agnew and Anderson, 1992: 111). However, it is particularly difficult to distinguish between change and fluctuation, as rainfall variability is a key characteristic of these systems. Using this definition, it can be argued that the severity of the 2009 drought was caused in part by the short-term shock of successive failed rainy seasons (i.e. water supply) and the longer-term process of encroachment and key resource loss in the Amboseli system (i.e. water demand).

In terms of annual average rainfall figures, severe droughts occurred in the region in 1961, in 1972-76 and 1994-1995. A long term study by Campbell (1999) shows that these drought events acted as shocks accelerating processes of socio-cultural change in Kajiado, contributing to generational conflict over livelihood strategies, shifts towards alternative activities and land privatisation. Since then, there have been successive less severe droughts in 2001 and 2005-2006 (see Table 4.1 for a timeline of drought in Kajiado), all of which lowered the capacity of the livestock system to cope with the severity of the 2009 drought. According to experts in the Amboseli system, the frequency, duration and intensity of drought is increasing (Western, 2010), which in combination with socio-economic changes, is leaving the Maasai unable to completely recover from the preceding drought cycle (Jan de Leeuw[6], personal communication, 23/11/2011).

Table 4.1: A timeline of drought and disaster in Kajiado District

Period	Event(s)	Impact
1890-92	Major drought and cattle disease outbreaks	Approx. 90% livestock lost (Southgate and Hulme, 2000)
1909	Outbreak of East Coast Fever	Undocumented
1911-12	Migration of Maasai population from Laikipia to southern Maasai reserve	Large livestock losses (Southgate and Hulme, 2000)
1918	Drought and disease	Undocumented
1925-27	Severe drought	Famine and 15% cattle lost (Sindiga, 1984)
1929	Severe drought	Approx. 50,000 cattle lost (Southgate and Hulme, 2000)
1933-35	Severe drought	Famine, approx. 35% livestock lost (Southgate and Hulme, 2000)
1938-39	Drought	Undocumented
1943-46	Severe drought	Famine
1948-50	Failed rains, disease outbreak	Undocumented
1952-55	Droughts followed by floods	70-90% cattle mortality (UNEP and GoK, 2000)
1959	Severe drought	Undocumented
1960-61	Severe drought	Famine, 50-70% livestock lost (Talbot, 1972, Willis, 1999)
1963	Flooding	Undocumented

[6] This name has not been anonymised. Jan de Leeuw was the head of the 'People, Livestock and Environment' theme at the International Livestock Research Institute in Nairobi at this time.

Period	Event(s)	Impact
1973-74	Drought	35-40% livestock lost (Finch and Western, 1977)
1976	Severe drought	Famine, 50% livestock lost (Bekure et al., 1991)
1979-80	Drought	Food shortages
1983-84	Severe drought and ECF outbreak	50-70% livestock lost (Homewood and Lewis, 1987, Oba, 2001)
1986	Disease outbreak	Undocumented
1989	El Niño event	Undocumented
1991-92	Drought	Undocumented
1995-96	Severe drought	Famine
1998	El Niño event	Flooding
1999-2000	Drought	50% cattle lost (UNEP and GoK, 2006)
2005	Severe drought	30% livestock lost (Nkedianye et al., 2011)
2006	El Niño event	Undocumented
2009	Severe drought	85% livestock lost (Kenya Wildlife Service and Institute, 2010)
2010	El Niño event	Flooding

(Table 4.1 continued)

In 2009, it was explained that herders took their cows out of the Amboseli system, either to Mombasa on the coast or towards the capital city Nairobi in the west, in search of forage and water. This is the furthest they have had to move since settling in the Southern Reserve in 1912. Most participants had never herded beyond neighbouring group ranches, the furthest being Kajiado town during 1961. The different experiences the herders had on their journeys have led to very different attitudes and actions upon their return. For example, those who travelled towards Nairobi were granted emergency access to the grasslands of Nairobi National Park. However, those who travelled east into Tsavo National Park experienced the full force of the Kenya Wildlife Service, which in this case denied the Maasai their right to access protected areas in times of hardship.

Some *ilmurran* (plural) were exposed to alternative income opportunities, which has modified their current activities. For example, Parneres, a *murran* living close to Amboseli National Park's Meshanani gate in Olgulului Group Ranch, told me the story of his brother who had transported his family's herds by lorry to Mombasa on the coast. At the coast, he learned the potential for paid employment and returned there to seek work as an *askari* (security guard) at a hotel after the drought. Speaking with Parneres' brother at a later time, he explained that *askaris* like him working in Mombasa were able to supplement their income with trade in tourist trinkets. I was able to verify these stories while speaking with *ilmurran* from Kajiado when visiting Mombasa.

After the rains broke on 24 December 2009, the *ilmurran* began returning from their unprecedented travels with a range of experiences, some traumatic, some adventurous, which appear to have had a profound effect on them and their sense of security within their ecosystem. The story presented in Box 1 was told to me by one of the returning herders.

Box 1. Maitera's story

In January 2010, a local *murran*, Maitera, was helping me to rebuild the foundations of one of the tents that had been destroyed during a flash flood in my camp. Maitera is a *murran* from Eselenkei Group Ranch and is relatively small in stature and also in status. While we worked, Maitera explained how at the onset of drought in 2009 he was given the responsibility of taking his family's herds in search of grass and water. Maitera has not been to school like some of his brothers and cousins, but is regarded as an experienced and skilled herder in his family. He explained that when he left his family's *boma*, he had intended only to travel within his area, maybe south towards Amboseli in Olgulului Group Ranch, or perhaps into the Matupato ranches to the west of Eselenkei. These are usual grazing routes for his community in times of drought. Access to Olgulului is free, as it remains a communal group ranch. However, payment is required to graze on Matupato where the group ranch has been subdivided into private plots, which can raise rents for grazing. In order to access resources in both these areas, herders must draw heavily on family and social networks built up over many years. Six months later, Maitera returned home with his surviving cattle having travelled the full length of Kajiado District, up to Nairobi National Park and back, an approximate 140-mile round trip by road far outside own area. Maitera explained that no one had ever gone beyond Kajiado District for grass before.

As he spoke, I realised for the first time how significant these journeys were to those who were forced to move beyond their usual territories. He described the complexities of weighing up alternative routes, depending on customary social connections with unknown clan members, suffering the loss of many of his family's prized animals and using his own environmental skills to locate suitable grass and water resources. At one point in his journey, he reached a dead-end, unable to cross a river which forced him to retrace his steps for several days before choosing an alternative, equally unpredictable route. He explained the despair he felt and that this was a very difficult period of his journey. He feared he was going to fail his family by losing all his cattle. He also described the moment he realised that he had reached the outskirts of the capital city, Nairobi, and his impressions of the imposing skyline of the Central Business District. These experiences were completely new to him.

During his epic journey, Maitera demonstrated much skill in negotiating access to privately owned lands, tracking scarce resources and avoiding the risks of predation, cattle-rustling and disease. He feels that his experience has changed him, giving him a new source of personal resilience in coping with future droughts. Although his journey was unprecedented in its scale, he also believes he and his children will be forced to repeat it in future drought events, and that he is in a strong position to cope having succeeded once. He has also gained a new level of respect amongst his peers for returning with a good number of cattle.

Maitera's story is representative of many stories told to me by *limurran* in 2010-2011, although unlike Maitera the majority told to me were not as successful in preserving herd numbers. For many herders, the lived experience of the 2009 drought was a relatively large departure from the norm, which has provided the conditions for the reconfiguration of place identity within a broader concept of place. Through history, Maasai have shown great adaptability in modifying their livelihood strategies and identity to changing circumstances (Spear and Waller, 1993, Hughes, 2006a). However, dimensions of place identity such as environmental skills, self-efficacy, social connections and self-esteem (Fresque-Baxter and Armitage, 2012) may have been altered differentially for herders depending on their personal experiences, with potential consequences for the resilience of the Amboseli system. Some, like Maitera, returned with a proportion of their family's herd and experienced a lesser degree of trauma relative to those who pursued different strategies under different constraints and those who failed to maintain their herds.

Maitera's extraordinary journey may become common practice for the next generation of herders as climate and land use changes continue. However, by the time Maitera or his sons are forced to retrace this journey, they will encounter a different set of obstacles on their landscape. Not least of these will be the planned Konza Technology City and accompanying high speed rail link, "where Africa's silicon savannah begins" (Pell Frischmann, 2011), to be constructed in the Athi plains close to Kajiado town. Maitera and his contemporaries on Eselenkei Group Ranch have been relatively underexposed to socio-economic changes and have therefore maintained a relatively traditional, pastoralism-oriented worldview. However, the hardships of herding are already pushing many Maasai to abandon this way of life, privatising their communally owned lands in the hope of making a living from alternative activities such as small-scale farming and wildlife tourism. As one herder explains:

> *It is good to own land, not cows. Cows can die and prices change but land will always increase in price* (Lemuanik, *murran*, Mbirikani, 21/11/2011).

Lemuanik's views are representative of a proportion of *ilmurran* in Mbirikani and have been influenced by his own experiences on the Group Ranch such as increasing commercialisation, political corruption and proliferation of non-governmental organisation interventions on the group ranch. Analysis of my qualitative data suggests that this is a common view in Mbirikani, but that the ability of individuals to capitalise on the shift from livestock to land depends very much on their relative wealth. The cultural implications of this shifting land use are significant. While diversifying income is an established strategy for reducing risk, research suggests that the privatisation and fragmentation of rangeland is trapping pastoralists further into vulnerability as they lose access to key resources and social networks (Rutten, 1992, Mwangi, 2007, Galvin, 2008, Galaty, 2013). The 2009 drought may prove to be a tipping point in the Amboseli eco-cultural system as herders develop new ideas and modified worldviews, which affect for their land use and livelihood decisions.

In his longitudinal study of the southern Kajiado district, including Mbirikani Group Ranch, Campbell compared the responses of Maasai to severe droughts in 1972-1976 and in 1994-1995 (Campbell, 1999). He found that social coping strategies, including kin, clan and age-set networks, were eroded as each of these drought events progressed. Established coping mechanisms cited at the time of the first drought in 1972-1976 included movement of livestock within the Amboseli system, liquidation of assets and use of additional environmental resources. Additionally, he observed emotion-focussed strategies (Zamani et al., 2006) such as prayer to the rainmaker, as well as dependence on what Campbell describes as the moral economy, both customary and institutional support networks. After the 1994-1995 drought, Campbell found that the use of environmental resources was more frequent compared to the events of 1972-1976. New opportunities for coping were also observed including tourism and wildlife-related incomes, increased trade, horticultural production and migration in search of jobs. As exemplified by Maitera's story and the findings presented in this chapter, responses to the 2009 drought included new coping mechanisms again, demonstrating the adaptation of the system to shifting conditions.

4.5 'Maasailand' and place identity

Maasai pastoralists are an example of a society, which historically has depended on natural resources for their livelihoods and well-being. The Maasai culture is arguably a product of the specific environmental conditions they have faced over time. Evidence suggests that the people now identified as Maasai expanded from northern Kenya into the Rift Valley at least three hundred years ago, where they established their dominance by adapting their agro-pastoralist livelihood strategy to exploit the variable semi-arid conditions of the fertile Rift (Homewood, 2008). Thereafter, the Maasai proceeded to spread towards the Mara, Loita, Serengeti, Athi and Kaputei plains in southern Kenya and northern Tanzania (Sutton, 1993). During this expansion, the Maasai arranged themselves into territories known as sections (Jacobs, 1965). It was around two hundred years ago that a distinct cultural identity formed around pastoralism, founded on military defence of territory, regional dominance, age-organisation and self-reliance (Sutton, 1993).

The on-going management of increasingly unpredictable and variable environments by Maasai pastoralists over the past two hundred years has led to the co-evolution of a particular eco-cultural system (Pretty, 2011) characterised by the complex interrelationships between the Maasai and savannah landscape. It is this pastoralism adaptation that produced the socio-cultural institutions that created social networks of reciprocity and community, including age-sets and kin networks, as well as customary trading relationships with other groups which supported the pastoral economy (Spear and Waller, 1993). Therefore, the Maasai pastoralist ideology that emerged at this time was 'based as much upon ethnic claim to resources and their management as a claim to identity' (Spear, 1993: 13), allowing Maasai hegemony up until the clan wars, prolonged droughts and rinderpest outbreak of the late 1800s (Homewood, 2008, Lovatt-Smith, 2008). With their population and power base diminished, the Maasai were left susceptible to the incoming British and German empires. In 1911, after decades of progressive land alienation, the Maasai were persuaded by the colonial administration to move from their previous range into the newly established Southern Reserve, in which Kajiado District and the Amboseli system are now located (Letai and Lind, 2013). This process, and the Treaty upon which the deal was done, was contentious and the consequences for Maasai well-being in this administrative decision has been well documented (e.g. Hughes, 2006b).

The Amboseli National Reserve was established in 1948 to protect the area's diverse wildlife assemblage and there has been on-going conflict between Maasai and the reserve administrations over land and resources since (Lindsay, 1987, Campbell, 1993). The loss of access to the dry-season grazing of *Ol Tukai* swamps, situated within the Reserve, several years later symbolised this conflict for the Maasai (Western, 1982, Lovatt-Smith, 2008) and provoked memories of previous land losses. It is important to note that historically, wildlife has been integral to the Maasai culture and pastoralist way of life with co-existence between wild and domestic herbivores over long periods of time (Lamprey and Reid, 2004). Maasai spiritual and cultural beliefs have largely precluded the consumption of wild meat and have instilled a duty to protect *Ngai's* (God's) wild animals as well as his cattle (Lovatt-Smith, 2008). As such, wildlife has been a vital feature of the landscape of Maasailand for its inhabitants. However, Maasai and wildlife have been increasingly in competition as key resources in the landscape are lost. This long history of marginalisation throughout the colonial and post-independence eras has contributed to the current Maasai identity in this area, giving rise to a particular attachment to 'Maasailand' as a place and a strong desire to retain control over it.

Present day Maasailand remains relatively distinct as an area of semi-arid grassland across the border of Kenya and Tanzania (see Figure 4.3) and is widely recognised by the inhabitants, governments and also outsiders such as tourists and conservationists as synonymous with the Maasai culture and way of life. It can be argued that the inhabitants of Maasailand have an identity that is in part particularly associated with that place, an identity that is only reinforced by outsider perceptions of the Maasai and Maasailand (Hughes, 2006a). Although the Maasai are undergoing accelerating processes of change, the pastoral economy and socio-cultural institutions have persisted in the Amboseli system to some degree through successive political and economic shifts. This relative traditionalism is a matter of pride for parts of the community (Lovatt-Smith, 2008). Therefore, it can be argued that the close linkages and interdependencies between the Maasai and their environment have given rise to a strong sense of place identity, which is specifically associated with the landscape of Maasailand.

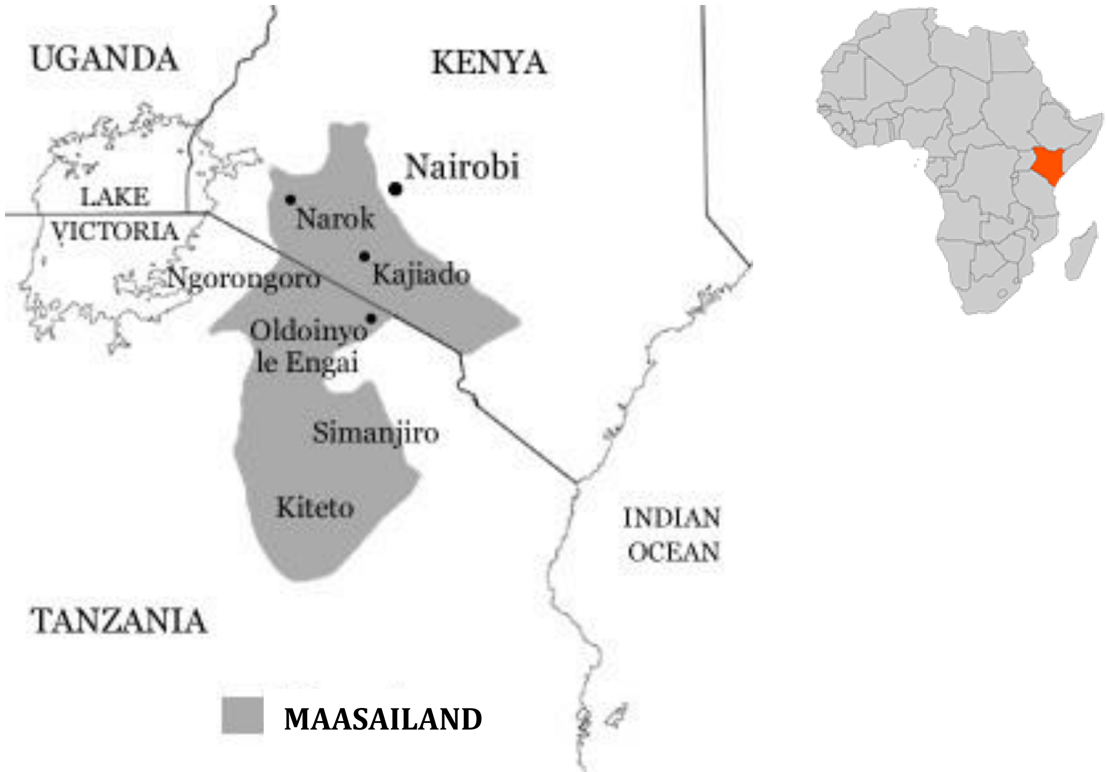


Figure 4.3: Present day Maasailand

4.6 Place, identity and the drought

Arriving in the Amboseli system in 2009, my experience of the drought was that people were living in a state of crisis, with decisions and actions having to be taken on an hour-by-hour basis in response to rapidly changing events. For example, as human-wildlife conflict increased with the decreasing prey base, herders would experience carnivore attacks in their homesteads and lose perhaps one or two valuable cows in one night. This loss would lead to the need to re-evaluate immediate plans and arrange to sell injured or dead animals, decide whether to replace them, reinforce the homestead before the next night, and so on. As the drought crisis deepened, people were more and more preoccupied with the daily business of survival. However, returning in 2011 I observed that the acute crisis was over and that people had had time to reflect on events, assess the impacts and devise longer-term strategies for recovering from these impacts. It was under these conditions I began to learn more about the real and perceived effects of the 2009 drought on the Amboseli communities.

During my fieldwork in 2011, many participants I spoke to referred to perceived changes in their relationship with the land, tangible changes in the landscape and disruptions to place-specific socio-cultural activities such as herding, all elements that are crucial to place identity (Cunsolo Willox et al., 2012). Here I explore the dimensions of place identity as identified in the literature (for example Fresque-Baxter and Armitage, 2012) and as they relate to the *Ilkisongo* section of Maasai who inhabit the Amboseli system.

4.6.1 Environmental skills and self-efficacy

Societies that depend on natural resources for their subsistence must command an intimate knowledge of the environment and have the ability to use a place to meet those needs (Prohansky et al., 1983). This ability depends on a community's perception of their environment and the environmental skill that develops through dwelling within it, which forms part of their culture (Ingold, 2000). Environmental skill can in turn affect how that place is defined and the self-understanding that comes with the competence to control a place (Prohansky et al., 1983). A demonstration of the interpretation and command of the environment in the Amboseli system is the naming of places. Throughout the group ranches, nearly all places are named after the vegetation that is found there, for example Oltepesi (*Acacia tortilis*), Oiti (*A. mellifera*), Elerai (*A. xanthophloea*), Osilale (*Commiphora spp.*), Eluai (*A. drepanolobum*) Orngosua (*Balanites aegyptica*), Oltukai (*Phoenix reclinata*) and Lenkiloriti (*A. nilotica*). The current name of a place therefore indicates the environmental conditions of that location and, most importantly, its suitability for grazing. In other Maasai sections where there is similar vegetation, such as the Laikipiak section in northern Kenya or the Purko section in the Maasai Mara to the west, the same place names are used. Through this utilitarian method of nomenclature, place names become a record of ecological knowledge and provide a sense of ownership over an otherwise dynamic environment. There are, of course, many aspects to the environmental skill and knowledge that enable the Maasai to subsist and thrive in their relatively harsh environments. Anderson (2000: 116) describes a 'sentient ecology' in his study of reindeer herders, the intangible understanding people have of their environments. The *Ilkisongo* Maasai demonstrate this quality in their mastery of the landscape e.g. in tracking lions across large areas and difficult terrain.

Related to environmental skill is self-efficacy, the perception of the ability to succeed in meeting subsistence needs and an associated sense of control over well-being (Twigger-Ross and Uzzell, 1996). During fieldwork in 2011, many participants referred to perceived changes in their relationship with the land, tangible changes in the landscape and disruptions to place-specific, socio-cultural activities such as herding, all elements that are crucial to place identity (Cunsolo Willox et al., 2012). For example, Murunga, a *murran* from Mbirikani Group Ranch, told me about his discovery of a human skeleton in the bush several miles from his *boma*. He estimated that the skeleton had been there for at least three months. The fact that this skeleton had remained unobserved in the landscape for such a long period of time seems to have disturbed him greatly and he reflected on this event on several different occasions. Murunga's reference to the fact this '*never would have happened before'* is a reference to a Maasai herders' intimate knowledge of his landscape and the features within it:

> *Because people aren't herding, things are being hidden in the bush… this never would have happened before* (Murunga, murran, Mbirikani, 25/10/2011).

For every journey I made by vehicle within the study area, even those far from established tracks, several *murran* commented later that they have seen where and when I have travelled. Similarly, a *murran* might comment during our conversation that he has seen my particular footprints in areas where I have walked. A herder depends on this ability to read the landscape on a daily basis and takes pride in these impressive observation and memory skills. Murunga is therefore lamenting the loss of this level of connection between herders and their landscape, brought about by the large-scale loss of livestock and cessation of daily herding activities. This state of mind appeared to be reflected in many of this herding age-set, depending on the degree of personal loss and trauma experienced during the drought. Familiarity, the daily experience of a place and being known in a place, is a key dimension of place identity (Breakwell, 1996). Losing this familiarity with the land and the redundancy of environmental skills and self-efficacy has caused Murunga to question his place identity.

4.6.2 Continuity and emotional attachment

For those Maasai who have lost their herds during the 2009 drought, the emotional and spiritual connection to the landscape as the place in which pastoralist needs are met has also been altered. David is a young, educated *murran* who explained to me the cultural significance of the livestock losses. He told me that it is not just the number of cattle lost by families that has affected them, but also the extinction of ancient livestock lineages, which date back through several generations of a family. He described how within a family's herds there is a group of core animals, which are passed down from father to his eldest son and are symbolic of that family's lineage. Therefore, the number of livestock lost may greatly decrease material wealth, but the particular loss of this core herd also has an impact on a family's cultural and emotional capital. This impact is demonstrated in the language David used to describe events:

> *During the drought, old stock, which have been passed down through generations, were lost. This affects which sons in a family will be passed stock from the old stock. It is very heart-breaking* (David, *murran*, Mbirikani 19/10/2011).

The irrevocable loss of these prized cattle may also influence people's decisions about restocking their herds versus turning to alternative incomes. David describes how now some people will buy cheap, Somali cattle for subsistence but currently do not 'have the heart' to begin to restore their herds for the longer term. David's description of emotional responses to livestock losses illustrate the implications of the loss of animals that are central to people's daily subsistence practices, annual cycles, and belief systems (Crate, 2008). However, David remains optimistic. He believes that Maasai "*will never leave pastoralism behind and those who are diversifying will return to the pastoralist way of life*". This sentiment was repeated even by the most 'capitalist' of participants I spoke with. Even those who are very much interested in generating cash income and investing in land acknowledged the important cultural link between Maasai and their cattle, suggesting that pastoralism will remain an integral part of livelihoods as long as conditions allow.

4.6.3 Distinctiveness, uniqueness, self-esteem and sense of belonging

Each place is distinct in itself and in giving rise to a distinct identity (Twigger-Ross and Uzzell, 1996). Association with specific places can build a sense of self-worth and belonging. The *Ilkisongo* Maasai maintain a traditional way of life relative to other sections, which have modernised under pressure from combined socio-economic and political drivers (Spear, 1993, Lovatt-Smith, 2008). Semi-nomadic pastoralism is the foundation of traditional Maasai culture and therefore closely tied to land tenure. The *Ilkisongo* largely maintain a communal group-ranch-management structure which gives them the fundamental right to freely access all resources within these areas and are also free to cross the Tanzania-Kenya border at will. Associated with this specific territory, there is a strong social coherence, group identity and sense of pride in belonging to the Maasai tribe generally and the *Ilkisongo* section specifically, which contributes to the sense of place associated with Maasailand. Furthermore, within the *Ilkisongo* section lie the sacred mountains of *Ol Donyo Lengai* ('Mountain of God'), upon which the Creator resides, and *Ol Donyo Oibor* ('the White Mountain'), which are both strong symbols of the *Ilkisongo's* spiritual connection, their land (Leboo, personal communication).

The wide scale loss of livestock and consequent visual impact on the landscape has led to a degree of disconnect between the Maasai and their place since the drought. Lankenua, a Maasai woman who assisted me in my research, would often reflect on this as we drove through the landscape. On one occasion as we passed close to the El Mau hills, she commented:

> *I wish you could have seen this place before the drought… you could see livestock all over, everyone bringing their cows to drink at El Mau… There was so much wildlife* (Lankenua, female, Mbirikani, 22/10/2011).

Lankenua was referring to a watering point close to the hills, which, together with a water hole at nearby Kigelia, are used by herders from the *inkutot* (localities) of Ol Donyo Wuas and Orngosua during the wet season. After the drought, any remaining livestock in these *inkutot* were herded close to the pipeline in Mbirikani Town, a permanent source of water, and were no longer to be seen moving across the landscape. During my time in the field in 2009 up to 2011, there were very few wild or domestic animals to be seen on the 12-mile journey from my camp at Ol Donyo Wuas to Mbirikani Town. Lankenua told me that previous to the drought, large herds of zebra, wildebeest and Thomson's gazelle were common sights around the water sources in their wet season dispersal areas, close to Ol Donyo Wuas and large herds of livestock would be taken to water there every other day, alongside the wildlife. She expressed sadness that this daily scene was no longer the norm, and said the lack of activity was a constant reminder that "*the livestock is gone*" (Lankenua). When I asked her when she thought we might see large herds at El Mau again, she could not say. I detect a similar sense of sadness in Lankenua's comments and in those of Murunga describing the human skeleton (see section 4.6.1).

4.6.4 Social connections

Over time, the Maasai, like many other pastoralist societies, have developed a set of highly adapted and resilient customary institutions which form the basis of their communities and relationships with each other and the environment (Evans-Pritchard, 1940, Homewood and Rodgers, 1991). The institutions of clan, age-set and kin relationships built through marriage are fundamental to existing in an unpredictable environment. These social connections are often diffuse over large areas but are exercised with strong local knowledge and identification with the land.

As described in Maitera's story (Box 1), herding strengthens social bonds and kin-networks in pastoralist communities, creating opportunities for sharing stories and experiences that maintain ties to the land. Interactions between pastoralists and rangelands embody their specific identities. Pastoralist societies typically construct their daily and annual activities and spiritual traditions around their cattle (Evans-Pritchard, 1940). The loss of the focal point of pastoralist identity has the potential to impact on cognitive and belief structures, leading to shifting worldviews and ultimately altered human-environment interactions (Crate, 2008). As such, increased frequency and severity of drought will render pastoralism a 'cultural phenomenon under threat' as social structures are eroded and people exit from herding (Adger et al., 2013: 113).

4.6.5 Security and commitment to place

As discussed above, the Maasai have been preoccupied with security throughout their history, regularly engaging in warfare with rival groups to retain control of their territories and the resources within (Sutton, 1993). The Maasai are essentially a para-military society structured around age-sets, a key stage of which is warrior-hood (*murran)*. The *ilmurran* act as the security force of the community protecting livestock and enforcing grazing rules in their locations. Even today, *ilmurran* will defend against intruders including cattle-rustlers and thieves in their territory (Sironka, personal communication). I heard about one such event during 2010 when a member of the neighbouring Kamba tribe stole the cashbox from a group ranch office.

In addition to physical security, socio-cultural, economic, psychological and emotional security in being able to carry out daily life without risk of harm are important to place identity (Fresque-Baxter and Armitage, 2012, Korpela, 1989). A sense of security and attachment to place is tied to future expectations and wanting to stay in a place and to protect a place (Stedman, 2002). The subdivision of land in sections of Maasailand is an interesting paradox. It has been argued that the fragmentation of heterogeneous resources into private plots is counter-intuitive to the sustainability of Maasai livelihoods (Galvin, 2008). However, one explanation of this shift in land use is the desire for safeguard land against external threats (Mwangi, 2007).

4.7 Subdivision – a case of place detachment?

The most striking finding on returning to the field in 2011 was a definite move towards the subdivision of the ranches in Eselenkei, Olgulului and Mbirikani Group Ranches. Arriving in Eselenkei after a year's absence, I was very surprised to hear that communal decisions had been taken to initiate a survey of the whole of Eselenkei Group Ranch for division into plots. In the case of Eselenkei in particular, this decision was unexpected as members had previously been resistant to the idea and sceptical about group ranches that had privatised their land. The *ilmurran* I worked with in Eselenkei during 2009-10 would frequently direct derisory jokes towards their neighbouring Maasai in Kaputei and Matupato who had subdivided their group ranches in the late 1970s and therefore had become '*less Maasai'* (Lemaron, *murran*, Eselenkei). For example, I have observed a situation where a *murran* showing less than perfect skills in tracking a lion on foot was described by his peers as '*a Kaputei'*, accompanied with a shake of the head and click of the tongue. This provoked a very angry response from the *murran* in question. The assumption here is that because the Kaputei section of Maasai has become sedentarised, they have lost their abilities to track wildlife, a key skill for any warrior. This is an opinion widely shared across Eselenkei Group Ranch.

I would argue that the changed atmosphere I witnessed in 2011 compared to 2009, alongside the stories of the lived experience of the drought that participants shared with me, are evidence that the inhabitants of Mbirikani and Eselenkei Group Ranches are experiencing a degree of trauma as the place where they live is altered, dislocating them from their environment. In this sense, these communities can be said to be experiencing psychological and cultural impacts as a result of the 2009 drought, with consequences for the long term resilience of the Amboseli eco-cultural system. The communal decision to subdivide communal land into privately-owned plots may be more of an emotional decision than a rational one (Mwangi, 2007), given previously negative attitudes towards subdivided areas. When questioned about why they supported subdivision, Eselenkei members said that they would wish to maintain the group ranch under communal management although private owners might combine their land for other uses such as wildlife conservation if they were allocated suitable plots. The desire to convert a communally managed Group Ranch to privately owned plots in order to maintain access to resources appears to be counter-intuitive.

Adger et al. (2011) claim that communities need processes that provide some control over their futures as part of a recognition of identity and place. These research findings suggest that in the wake of the 2009 drought in Amboseli, this desire for control over futures appears to be manifesting as a desire for land security through privatisation of Group Ranches where livestock losses have been heavy. The key to Maasai adaptability has been their dynamism and ability to innovate in response to change through time (Letai and Lind, 2013). However, key to this adaptability has been their social cohesion and strong, if fluid, identity related to the places and groups to which they belong. Subdivision in other areas of Maasailand has been shown to lead to an erosion of social capital and cultural resilience (Grandin, 1992, Galvin, 2008), as the need for such socio-cultural functions is diminished. In this sense, subdivision is likely to reduce the socio-cultural resilience of these group ranches which may in turn be a maladaptive response to environmental change in the long-term (Adger and Barnett, 2009). This is an example of climate change threatening culture and practices with implications for system resilience.

4.8 Outsider responses to the drought

"*Outsiders*", including tourists, conservationists, researchers and other non-Maasai stakeholders, can also form strong emotional attachments to Maasailand as a place. To conservationists and tourists, the Amboseli landscape and the National Park in particular are iconic, with powerful connotations of the idyll of an African savannah teaming with wildlife in the shadow of Mount Kilimanjaro (Adams and McShane, 1996, Norton, 1996). Often only temporary inhabitants or having never physically experienced the place, people can form strong attachments to both the perceived and real landscape even when absent or detached from it (Albrecht, 2010). The earliest writings of Maasailand, by explorer Joseph Thomson (1887), generated a particular image of the landscape as inhabited by large herds of wildlife and fearsome Maasai warriors, and these powerful stereotypes persist in the tourism and wildlife conservation industries today. Moreover, it has been argued that these stereotypes, have been internalised by the Maasai themselves (Hughes, 2006a).

During my time in the field in 2009-2010, I observed strong emotional reactions from tourists to the impacts of the drought, including the many carcasses of wildlife spread throughout Amboseli National Park. On visits to the tourist lodges in and around Amboseli, I witnessed tourists remonstrating with managers about the failure of their safari experience to live up to expectations. On encountering tourist cars in Mbirikani Group Ranch, I saw tourists expressing shock and distress at the scale of the herbivore die-off, and disgust at the associated smell that lingered permanently throughout the area. Similar reactions have also been exhibited on the following online forums and blogs. For example, one user of a travel forum writes:

> Its [sic] difficult to write about our evening game drive in Ambosell [sic]. Everywhere we see animals starving or dead. Where huge herds once roamed we see instead animals *desperately clinging to life* [emphasis added] trying to eat the almost non-existent grass. The stench from the rotting carcasses clings to us, as does memory of the look of confusion and despair on the faces of the animals *still clinging to life* [emphasis added] (nofootprint, 2009)

In an online forum run by Tripadvisor.co.uk, one user asked the following:

> Does anyone know the current conditions of the drought in Amboseli? I've read some articles and blogs about lots of dead animals and a very barren landscape. We are planning to be there in February but are concerned that the conditions may be a bit *traumatizing* [emphasis added] for our children (shell04pa, 2009)

To which one response was to declare Amboseli "the *ugliest* [emphasis added] national park I've ever laid eyes on. It's *disgusting* [emphasis added] and you can't believe people pay good money to come here." (aardvark01, 2009)

Another blogger describes his visit to Amboseli National Park:

> As I drove into Amboseli National Park from across the long dry lakebed, I was immediately taken aback by the large number of carcasses that were dotted everywhere. In some places it seemed as though a *bomb went off* [emphasis added] and destroyed every living creation within a large area. It seemed as though *a great battle* [emphasis added] took place with no one winning (Ward, 2009)

The wording of these blog posts are emotive, even sensationalist, in tone. However, they are consistent with the actions and opinions of tourists I observed in the field. The use of language such as "*traumatising*" and "*disgusting*" is highly emotive and these responses, as well as the anthropomorphist descriptions of wild animals, chime with the typical tourist image of wild Africa.

The Director of the Amboseli Elephant Research Project has been a researcher in the National Park since 1972. She is quoted in the Global Post newspaper in 2009 claiming that "The tourists *are appalled* [emphasis added]. They can't drive a hundred meters without coming across a dead animal." (McConnell, 2009). Similarly, the Director of the African Conservation Centre has also been carrying out research in Amboseli National Park for decades and in an article to Swara magazine reiterated the view that tourists were being emotionally affected by the impacts of the drought:

> By late September, tourists were *so upset* [emphasis added] by the sight and stench of death that the warden was fork-lifting carcasses out of sight (Western, 2010: 16)

In response to the loss of an estimated 71% of zebra and 83% of wildebeest from the Amboseli system between 2007 and 2010 (KWS and TAWIRI, 2010), the Kenya Wildlife Service and other partners decided to translocate over 7,000 zebras and wildebeest from private game conservancies in the north of Kenya to Amboseli National Park. In a press statement, the Kenya Wildlife Service veterinarian in charge of the translocation, described the severity of the drought for wildlife:

> Last year we lost most of the herbivores. It was a bad year for Amboseli and a bad year for Kenya… Amboseli is a tourist facility and if the tourists come and they don't see animals they are not happy (McConnell, 2010).

The article in the Global Post goes on to state that this in turn meant "a bad year for tourism… The drought also hit tourism as horrified visitors to Amboseli saw rotting corpses and whiting bones strewn across the parched landscape while the stench of decomposing animals filled the air" (McConnell, 2010).

While the prime argument for the translocation was to restore ecological balance to the Amboseli system, as a participant in a stakeholder workshop held in the Amboseli Serena Lodge on 9 December 2009, I witnessed several tourist operators expressing strong concern over the impact of wildlife losses and carcasses on tourism and lending their considerable support to the translocation plan on this basis. The written proceedings of the workshop minute that:

> The tourism group recognised that managing press reports would not help the situation and might even backfire when tourists are lured to an Amboseli that no longer exists (Kenya Wildlife Service *et al.*, 2009).

Maasai participants I spoke with about the wildlife translocations were unimpressed by the decision. They understood the need for tourists to see wild herds, but several Maasai men and women told me they thought this would not work and the animals would move elsewhere once released. Some Maasai expressed irritation, although not anger, that such effort should be made to help wildlife and tourists in the short term, rather than to help them restore their livestock herds. The implications of these outsider responses may be serious for the resilience of Amboseli as the already-vulnerable system is put under further pressure by the conservation and tourism lobbies.

The stereotypical African safari, as exemplified by the tourist experience in and around Amboseli National Park, has been described as the commodification of nature that is separated from culture (Norton, 1996). If the Maasai and Amboseli are a co-evolved eco-cultural system, there should be a tension between Amboseli the 'place', as a construction of the culturally specific meanings attached to it by the Maasai, and Amboseli the African wilderness and tourist destination. However, these results suggest that both the Maasai and "*outsiders*" have experienced psychological and emotional responses to the 2009 drought, which has altered their relationship with the Amboseli landscape. In his discussions of solastagia, Albrecht cites the writings of Aldo Leopold on 'the wilderness' as an early reference to the phenomenon as felt by the author in witnessing the destruction of the local environment (e.g. *A Sand County Almanac: And Sketches Here and There* published in 1949). Albrecht also describes the distress response felt by remote observers of rainforest destruction, for example, as solastalgic even where these individuals have never visited the place they feel strong attachments to (Albrecht, 2011). The outsider responses discussed in this section are an example of the emotional and psychological impact of the 2009 drought on those who held preconceived notions of Amboseli as a place of wildlife and wilderness.

4.9 Summary

The 2009 drought was an example of an acute environmental shock, which has had repercussions for the social, ecological and cultural resilience of the Amboseli system. The long-term effects of the shock are difficult to predict, some experts have described the drought as a 'tipping point' for the system (Western, 2010). The responses of participants to the drought demonstrate the impacts of the shock on the place identity of these communities. How persistent these impacts will be is hard to predict as pastoralist systems have long undergone cycles of 'boom and bust' (Devereux and Tibbo, 2013: 217). However, the psychological and emotional responses of the Maasai to the drought will have implications for the resilience and integrity of the Amboseli system, particularly if the event does indeed prove to be the tipping point for transformation of the communal rangeland system into privatised plots. These findings also add a case study to complement those from other contexts exploring the ways in which drought events impact on the well-being and identity of individuals and communities (Tschakert and Tutu, 2010, Cunsolo Willox et al., 2012).

Further to psychological impacts, it is clear that place-specific cultural aspects also mediate responses to shocks and stresses. The customary institutions which safeguard the social networks of pastoral groups like the Maasai are essential in maintaining the socio-cultural functions that are essential to the sustainability of pastoralist systems, such as kin, clan and age-sets. These socio-cultural functions also set the foundations for dimensions of place identity, such as a sense of belonging, emotional connection to place, self-esteem, environmental skill, self-efficacy, continuity, familiarity and security. It therefore follows that disruption in some of these dimensions due to drought will impact on place identity with implications for the resilience of the Amboseli eco-cultural system. More than social capital, these socio-cultural functions and their relationship to resilience have been largely overlooked in livelihood studies and environmental change research. This analysis demonstrates how place identity theory can be applied to improve understandings of the psychological and cultural impacts of environmental shocks and stresses and the resilience of eco-cultural systems, therefore addressing an identified gap in the literature. Understanding the role of socio-cultural functions in maintaining overall system resilience is essential in analysing processes of change in pastoralist systems and promoting their sustainability in the future.

As well as local, place-specific cultural aspects mediating responses to shocks and stresses, emotional responses to climate change on a global scale may be embedded in culture. The outsider responses described above are an example of how the perspectives of stakeholders from outside a specific place, who are often more economically and politically powerful, can shape interpretations of climate change impacts. These external perspectives can be particularly important where they interact with local responses to drought, via the tourism or conservation industries for example. As these stakeholders can hold considerable influencing power, there may also be implications at the climate-policy level.

CHAPTER 5. "LAND AS OURS, LAND AS MINE": LAND USE, LIVELIHOODS AND (MAL)ADAPTATION IN THE AMBOSELI SOCIAL-ECOLOGICAL SYSTEM

5.1 Introduction

Chapter 4 presented the socio-cultural and psychological responses of the Maasai to a particular extreme event, the 2009 drought. This chapter aims to situate these responses within the broader context of change within the Amboseli system. First, recent developments observed during the course of this study are described, including infrastructure development, shifts in livestock management and expansion of cultivation. A review of the historical and political context of the area has also been conducted and the results are presented here in order to contextualise the observed changes taking place in Amboseli.

This chapter argues that these broader processes of change are leading to institutional responses, both in terms of customary and more formal, political institutions, and the evidence is presented here. In analysing institutional responses, particular attention is given to the power dynamics affecting patterns of land use and livelihoods among the Maasai of the Amboseli system. In turn, change is occurring at different rates in different parts of the system, and these are driving shifts in worldviews in different parts of the system. This chapter explains that the tensions between institutions are reflective of the shift that is taking place in views about land and livestock in the livelihoods of the Maasai of Amboseli.

The last part of this chapter draws on concepts from the literature to question whether actions to adapt to climate change, in the context of broader change, are leading to potentially maladaptive outcomes. Drawing together the evidence of change processes in the Amboseli system, the likely causes of maladaptive action are then discussed.

5.2 Livelihood responses to change in Amboseli

Like all societies in semi-arid areas, Maasai have been coping with variability and adapting their livelihoods for centuries, making incremental changes to their activities to exploit local resources, interact with neighbouring tribes and engage with shifting political and economic processes, not least the advents of colonialism and then independence in Kenya (Spear and Waller, 1993). At times, sections or clans of Maasai, and other pastoralists in Kenya and the Horn of Africa, have undergone transformational shifts in their livelihood strategies, shifting to agro-pastoralism for a period spanning several generations, for example (Homewood, 2008). However, in the past century and increasingly in recent years, the pastoralists in East Africa have been undergoing accelerated processes of change in the face of multiple drivers (Galvin, 2009). As such, transformational shifts like those mentioned previously have been occurring throughout Maasailand, with the *Kisongo* area being a relative exception in their resistance to socio-cultural change. The 2009 drought, in combination with several other factors, may be forcing transformational adaptations in what is essentially still a semi-nomadic pastoralist system. What follows are observed livelihood responses to multiple drivers of change taking place in the Amboseli system since 2009.

5.2.1 New developments in Amboseli

In 2010, a new tarmac road was completed running from the Nairobi-Mombasa highway to the north of the study area, through Mbirikani Group Ranch to Amboseli National Park and the Tanzanian border at Loitokitok. This road, financed by the Chinese government, has provided a significant opportunity for livelihood diversification. Access to markets at Kimana, Loitokitok and Sultan Hamud has opened up for the inhabitants of the group ranches and the land adjacent to the road has been divided into plots for development. Those with capital have invested in these plots to establish businesses such as hotels, shops and rental properties for passing traders. An encampment of Chinese labourers has been located close to Mbirikani Town during road construction, providing a significant market for meat, charcoal and other products. More entrepreneurial individuals have overcome fears and suspicion of these "*outsiders*[7]" (a widely used term to describe non-Maasai actors) to exploit the opportunity they present, although these Chinese are generally disliked and mistrusted by the Maasai.

Another recent change in the area is the establishment of a gypsum mine on Mbirikani Group Ranch at Emukatan, close to the tarmac road. A Nairobi-based cement company has invested in the development of this natural resource and pays rent to the Group Ranch for its operations. It is difficult to establish whether this activity would have been permitted before the drought, but the negative response from the community (see Section 5.3.2) and suspicion of land grabbing would suggest that this development might not have been generally desirable under usual circumstances. The drought has been timely perhaps in providing a political advantage to those individuals with vested interests in developing them, as explained in Section 5.3.

5.2.2 Shifts in livestock management

As mobility and access to markets and services, such as banks and veterinary facilities, has improved with the road, new livestock breeds are becoming available on the market. Breed preferences diverge between individuals, with some focussing on new breeds characterised by good meat or dairy productivity and others choosing breeds with drought-resistant traits. The neighbouring Kaputei Group Ranch has been subdivided since the 1980s and the Maasai there (comprising the Kaputei section of the tribe) raise breeds (e.g. borana cattle) for commercial meat production that are bigger because of reduced mobility. The *Ilkisongo* Maasai of Mbirikani and Eselenkei generally are not keen on these breeds, being "*happy with beef and dairy in one breed, it is enough milk*" (Mejooli, *murran,* Mbirikani) and recognising it is important that their animals "*must be good in a drought*" (Ibid.), e.g. the traditional Maasai zebu cow. There are now Somali cattle breeds available at the local markets, which "*go long without water and are smaller so need less*

[7] Where participants have been quoted in this chapter, the text has been italicised. This is to distinguish more clearly between new results and quotations from the literature.

grass" (Legishon, *murran,* Eselenkei). These have become popular since 2011 when they flooded the market and became relatively cheap as Somali and northern Kenyan herders moved southwards during the drought in the Horn of Africa. At that time, these herds were brought to Tsavo West and East, to the east of Amboseli, to graze and the *Ilkisongo* Maasai "*will continue to buy them as long as they are available at that [low] price*" (Lemuanik, *murran,* Mbirikani).

Of significance here is the view of these cattle as cash reserves with no cultural value attached to them. The Somali cattle are not "*true Maasai cows*" (Legishon, *murran,* Eselenkei) so can be bought and sold as commodities to secure income and subsistence after the 2009 drought. As discussed in Chapter 4, participants do not see these cattle as forming the basis of a future core herd. This view of cattle as a commodity rather than a subsistence and cultural resource is being incentivised from above by increasing integration with the national livestock-based economy over the longer term. The Kenyan Government is increasingly turning its attention to the potential of arid and semi-arid lands to drive economic development (Elmi and Birch, 2013). During the 2009 drought, the Kenya Meat Commission implemented a policy to purchase weak cattle from drought-stricken herders at reasonable prices to support the local communities. As a result, a new abattoir has been built in Sultan Hamud, a local market for both Eselenkei and Mbirikani, and transportation has improved as wealthy entrepreneurs buy vehicles to rent to herders to access this facility. Coincidentally, domestic and regional demand for meat and hides is booming (Herrero et al., 2009, Catley et al., 2013), providing opportunities for additional income generation from livestock. As a net livestock importer (22% from neighbouring countries) and with Gross Domestic Product (GDP) from livestock production already estimated at 13% (the majority of which is from the milk trade) (IGAD, 2013), the Government of Kenya is aware of the potential of domestic livestock markets, as well as markets in the East African Community and in the Middle East as significant economic opportunities for development. Contingent on this economic and political context, it is likely that this pattern of commercialisation and market activity in the Amboseli system, which appears to have been accelerated post-drought, will continue in the long term.

In response to shifting conditions and the recent drought, some individuals are experimenting with different livestock-rearing strategies. One participant, Lolkerra explained that his strategy for drought-recovery was to buy and sell only goats and sheep because these are easier to maintain, herding labour is readily available within his *boma*, smallstock breed quickly, need less palatable forage and mobility, and are currently in-demand as a source of protein. Mixing the composition of livestock species is a common strategy adopted by pastoralists to cope with stress (Homewood, 2008), and this is certainly the case in the Mbirikani and Eselenkei group ranches. However, while others in his friendship group are investing in the Somali cattle, this individual is the only one taking this approach to herd only smallstock. While discussing Lolkerra's stocking decisions, his friends were gently mocking him for "*turning his back on cows*" but were also admiring of his foresight as this relatively innovative strategy is generating sufficient cash turnover to keep his brother and children at school. The background to this individual is that during the drought he lost many head of cattle but was particularly devastated by the loss of his prize bull, a significant investment and source of income as sire for rent. Rather than dying of starvation or thirst, the bull died of a broken back, stumbling in a ravine while seeking water. I was with the participant as he received this news in 2010 and witnessed his response to what he clearly felt was a tragic loss with severe repercussions for his family, shedding tears for his bull. This individual said he will buy cattle again in the future, but is convinced that keeping larger numbers of smallstock that can be readily converted to cash is the best strategy going forward.

5.2.3 Expansion of cultivation

Returning to the study area in 2011, I observed a clear change in the landscape with the spread of irrigation for horticultural cash crops in Mbirikani. Fenced plots of potato, onion and tomato crops had obstructed familiar roads to the extent that I became lost trying to reach my camping site. Post-drought, the need to diversify income opportunities and competition for water resources encouraged wide-scale illegal tapping of a water pipeline running from Kilimanjaro to Nairobi. One participant confirmed that "*new shambas (farms) are everywhere since the drought*" (Kapalei, junior elder, Eselenkei).

The pipeline was constructed in 1986 to bring Kilimanjaro's snowmelt water from Loitokitok to Athi River on the outskirts of Nairobi. The pipeline primarily supplies flower-farming operations at Athi River. At the time of construction, the pipeline "*made the Maasai very angry as they had no access to the water passing through their land*" (Kapalei, junior elder, Eselenkei). The pipeline is still viewed as "*a big waste of money*" and it "*would have been better to provide boreholes*" which herders could have used for watering livestock (Nampazo, junior elder, Mbirikani). The main pipeline runs through Mbirikani where some watering points have been provided at key locations along the pipeline route. There is a smaller branch of the pipeline running through Eselenkei. One *mzee* (elder) is regarded as unusually entrepreneurial in his area for using a leak in the pipe to irrigate banana trees. He was the only individual on Eselenkei who was exploiting the pipeline for cultivation at the time of research.

Since construction, there has been moderate illegal use of the water source provided by the pipeline on Mbirikani as individuals have tapped into it to irrigate their smallholder farms (*shambas)*. After the drought, this activity has expanded significantly as people turn to farming horticultural cash crops to generate income at the local markets. As new *shambas* have proliferated along the pipeline corridor, the sudden shift in land-use is causing problems, affecting tourism activities and increasing human-wildlife conflict, with several cases of people injured or killed by elephants accessing the new water source. During my fieldwork in 2011, conflict was arising also within the community due to established livestock routes being blocked by the new *shambas*.

Due to the extent of illegal tapping, the pipeline company turned off the water supply in October 2011. Mbirikani residents regarded this as a "*very serious*" action as people were in danger of losing their crops only the year after the drought took their livestock (Lemuanik, *murran,* Mbirikani). Participants felt that they had a right to the water and should be allowed to use the pipeline for irrigation since there were now "*no cows around to use it*" at the allocated watering points. Those benefiting from the irrigation thought the water company should allow people to use the pipeline for irrigation for the following 2-3 years so people can "*recover and make money*" after the drought (Ibid.). Others felt "*it is their right to use the water*" as the resource originates on their land (Legeny, junior elder, Mbirikani). A meeting was called for 25th October 2011 to negotiate with the water company, but the representatives did not come, leading to protest demonstrations in the community. It was explained to me that obtaining legal access to the pipeline requires a letter from the local chief to bring to the water company who will make a connection to the pipeline at the cost of 10,000 Kenyan Shillings (approximately £67), a significant cost where a day's manual labour (e.g. herding) earns 250 Kenyan Shillings, and therefore prohibitive to most individuals. In addition to this, there are monthly bills, which are costly and unpredictable as the company changes the rates without notice and there are no meters to estimate usage accurately. Those with legal or illegal access to the pipeline in 2011 were selling water in 20-litre drums to generate additional income. In my second period of fieldwork in 2013, I learned that this particular dispute was resolved, although tensions remained with Maasai wishing to maintain their new *shambas* beyond the drought.

Undoubtedly there is substantial income to be derived from the farming activity enabled by the pipeline, especially for potato crops. People who turned to farming in 2011 "*are now becoming rich*" (Murunga, *murran*, Mbirikani). However, as described above, entry costs are high and some have sold their cows to invest in these plots in the short term whereas others who have never had cattle or lost their herds in the drought are excluded from the opportunity altogether. Contradictory to the argument they made to the water company for short-term access, those using the pipeline told me they will keep their *shambas* in the future and that farming will not be just a temporary activity as they believe it is better to have a range of incomes. Now the cultivation of cash crops is seen as critical for subsistence as "*cows are now not enough*" (Ibid.). When asked if the spread of irrigation is a good thing, Mbirikani Group Ranch leaders said that they advise against it sometimes if "*it's bad for the livestock*", although I did not hear of a particular case where this had happened. They stated the rules that *shambas* are supposed to be placed far from the road and "*hidden*" so they are not visible to tourists using the road. In reality, these rules have not been observed, as the road itself has been re-routed around new plots.

While there is a long history of pastoralists, including Maasai, utilising crops during times of stress, the *Ilkisongo* have previously left the cultivation of these crops to neighbouring Chagga or Kamba agriculturalists, preferring to trade with them rather than farm themselves. Where Mbirikani and Olgulului Group Ranch members own subdivided plots close to Kilimanjaro, they have formed co-operatives with the local Chagga to run their *shambas*, splitting the crops on harvest. Adopting cultivation in the rangeland areas is therefore unusual and in Mbirikani is an opportunity enabled only by the presence of the pipeline.

There is on-going debate in policy circles about the potential of large-scale irrigation in adapting to climate change in semi-arid areas (Adams and Hughes, 1986, Johansson, 1991, Behnke and Kerven, 2013, Sandford, 2013). Local support for such a policy within Amboseli could be influenced by recent experience of profiting from the pipeline. With careful and sensitive implementation, such a policy could support the livestock-based production system of Amboseli while providing valuable resources for alternative livelihood activities and further economic integration. However, experience of implementing irrigation schemes in Eastern Africa has had negative impacts on pastoralist systems in terms of reduced mobility, land alienation, loss of productivity, unsustainable changes in rangeland ecology and altered pastoralist cultural practices and identity (see Sandford, 2013 for a recent review). Given this history and the experiences of rangeland enclosure and loss of key resources in Amboseli (Southgate and Hulme, 2000, Lovatt-Smith, 2008), any proposed irrigation schemes are likely to have negative impacts on parts of the community, although undoubtedly a few more powerful, wealthy Maasai would benefit.

The new-found wealth of individuals using the pipeline is also encouraging people to consider farming activities elsewhere. While some individuals have owned plots in Loitokitok and Kimana for several years, the feeling is that all members "*should be able to benefit from the fertile areas*" of the Group Ranch (Semeyian, female, Mbirikani). Such an arrangement was described as an "*equitable way to share resources*" as rich people with many cows will sell them and poorer people can benefit from renting their plots for grazing (Ibid.). This is a view reinforced by the experience of renting grazing land during the 2009 drought. At this time, the *Ilkisongo* were compelled to seek grazing in the neighbouring Kaputei area. As Kaputei is private land, having subdivided into plots in the 1980s, the *Ilkisongo* had to pay rent to owners for grazing. Conversely, the Kaputei were allowed free access to Eselenkei as this is communal land. While this rationale of land rents was accepted as fair by participants, the *Ilkisongo* Maasai in Eselenkei understandably want to benefit from similar circumstances in the future.

5.2.4 Subdivision of communal rangelands

Driven by the changes taking place since 2009, Eselenkei decided to begin the subdivision process in 2011, although it "*will take several years to complete*" (Kapalaei, junior elder, Eselenkei). When asked how they will graze their livestock after subdivision, participants explained they will continue to share grazing resources but people closer to the park or conservancy may agree to conserve their plots for tourism profit and plot owners will have the right to charge rent for their land. These decisions follow the example of neighbouring Olgulului Group Ranch, which subdivided some more fertile areas in 2011 including the Kitenden wildlife corridor south of Amboseli National Park. Subdivided plots are allocated by a numbered list of Group Ranch members. Participants perceived this as a fair process although there is "*no way to change if you don't like your plot*" (Lemuanik, *murran*, Mbirikani). One participant told me the story of an *mzee* (old man) in Olgulului who was assigned a plot of little apparent value. Initially this seemed like bad luck, until the *mzee* discovered a den of hyenas on his plot and rented out his "*hyena hill*" to a research group, therefore "*becoming rich*" (Santamo, *murran,* Olgulului).

In spite of the willingness to subdivide, there is a widespread fear in Eselenkei that people might sell their plots to "*outsiders*", or non-Maasai actors, as has happened elsewhere in the system. One Maasai with a plot near Kilimanjaro told how "*you find many new faces at Loitokitok now*" (Mejooli, junior elder, Mbirikani), explaining that non-Maasai people from Kenya and Tanzania are moving in to the town to seek livelihood opportunities. Loitokitok is a market town on the Tanzanian border to the south of Mbirikani. These comments demonstrate the contradictions felt by individuals and the community as a whole in striving to secure land rights, preserve their livestock-based production system and develop economic opportunities for improved living standards. Having experienced the incremental loss of land and key resources in Amboseli for decades, the *Ilkisongo* Maasai have a deep suspicion of any "*outsiders*" and a strong will to maintain control over what remains of their territory to prevent it being seized either by government actors of other élites. Paradoxically, these concerns appear to be driving the response to subdivide their land into private plots, providing opportunities for "*outsiders*" to enter the Mbirikani and Eselenkei Group Ranches as landowners, as has been the experience in neighbouring ranches (e.g. Kimana).

5.3 Institutional responses to change in the Amboseli system

While the livelihood shifts described above may be considered responses to a severe environmental shock combined with broader processes of change, there are important nuances to draw out of these stories. The power dynamics playing out in these livelihood responses is a significant factor in reducing or increasing the vulnerability of individuals and resilience of the system to future shocks. Critical here are both the structural features, such as the historical and political context of the system, and the agency of relevant actors, their motivations and relationships, and the balance of power between them.

Power can be defined and exercised in several ways. Power has been conceptualised as overt, covert or hidden (Lukes, 1974), or visible, invisible and hidden (Gaventa, 2006). Power is what makes the relationships between different people or institutions asymmetric and can be about exercising resources to achieve a desired outcome, negotiating institutions, norms and conventions, including the informal and formal rules or ways of doing things, or through the Foucauldian notion of the ability to shape other actors' attitudes or behaviours through discourse, embedded in socially constructed values and worldviews (Jones et al., 2012).

Acknowledging that actors are political, it is important to understand their interests, what motivates people's decisions and strategies, as well as how actors' values and beliefs affect what they consider to be in their interests (Jones et al., 2012). Institutions can be formal organisations, such as the Group Ranch Committee, or customs and patterns of behaviour, such as the Maasai age-sets or clans. Institutions can define who participates in decision-making. In addition to this, historical legacies and the policy context act as constraints or opportunities to decision-making. It is important to understand how the self-interest and the socio-cultural or political context affects people's actions and decisions, including in this case their livelihood strategies and land-tenure decisions.

As discussed in detail in Chapter 2, there are tensions within the term 'resilience' and studies conceptualising social-ecological systems through this lens often overlook normative aspects of these systems (Turner, 2013). Understanding the complex interactions of history, culture and ecology in particular places is key to building resilience and adapting to climate change, especially where social-ecological dynamics are non-linear and unpredictable, as in semi-arid lands like Amboseli. Power dynamics in social-ecological systems involve consideration of cross-scale interactions (Neumann, 2010), the role of actors (Blaikie and Brookfield, 1985), historical legacies in shaping observed patterns (Hecht and Cockburn, 1990, Peluso, 1992), the socio-economic factors affecting environmental impacts (Blaikie and Brookfield, 1985) and the social construction of natural resources by actors at each levels (Fairhead and Leach, 1996, Bryant and Bailey, 1997). Therefore, competing interests between people and institutions span scales are grounded in historical context and are mediated by age, wealth and other socio-economic factors. These issues are pertinent to adaptation in the Amboseli system and are discussed in greater detail in the following sections.

5.3.1 Historical and political context in Amboseli

Sedentarisation has been at the core of arid and semi-arid lands (ASAL) policy throughout both colonial and post-colonial eras in Kenya. The first ASAL policies emerged in the 1940s under the then African Land Development Board (ALDEV) to encourage agrarian change in pastoral areas. These policies were in response to concerns about environmental degradation and overgrazing. Implementation of these policies established grazing schemes in districts including Kajiado. This approach was continued under the subsequent Swynnerton Plan (1954-1959), under which communal grazing blocks with water sources, infrastructure and veterinary facilities were established. At independence in 1963, the ALDEV was replaced with the Range Management Division and the Group Representative Act of 1968 replaced grazing schemes with the group ranch system. This Act enabled legal freehold ownership over land by groups of pastoralists as well as access to funds for development.

The assumptions inherent in the Group Representative Act were that pastoralists were mismanaging and overstocking the rangelands and therefore causing the environmental degradation of these areas. The policy framework reflected state bias against pastoralism and the dominant international and national narratives that have pervaded up to the present day (Keya, 1991, Galaty, 2002, Elmi and Birch, 2013, Galaty, 2013). Globally, pastoralist groups have been and are still viewed as backward and irrational and there persists a widespread opinion that rangelands would be better replaced with more productive land uses (Monbiot, 2003, Catley et al., 2013). A recent content analysis of 100 Kenyan newspaper articles published between 2000-12 found pastoralists to be negatively depicted and blamed for problems ranging from banditry, violence, poaching, and general lawlessness (IIED, 2013).

Although approximately 80% of Kenya's land cover is designated as ASAL (see Figure 5.1), the historical policy context of underinvestment and marginalisation has left these areas with weak governance and institutional capacity, inadequate social and economic services and a greater degree of poverty compared to the farming regions of Kenya, which are also the tribal homelands of the ruling classes in Kenya (Pavanello and Levine, 2011, Elmi and Birch, 2013). As a result of sedentarisation policies (Rutten, 1992, Ng'ethe, 1992, Adano and Witsenburg, 2008), the rangelands have become ecologically degraded with decreased capacity to support large numbers of livestock as populations increase. The number of livestock per capita is declining leaving families more vulnerable to drought, traditional coping mechanisms are being undermined by fragmentation of the range and conflict is increasing in these areas as alienation and disempowerment grow (Homewood, 2008, Galvin, 2009, Little, 2013). Key resources have been lost and mobility increasingly curtailed by the institution of administrative boundaries, protected areas and encroachment of farming lands due to population pressure (Keya, 1991, Southgate and Hulme, 2000). Neoliberalism in independent Kenya and the market-driven promotion of tourism and agricultural development prefers individual ownership and does not support communal land tenure (Metcalfe and Kepe, 2008). Based on this difficult history, the fear of land grabs and an on-going struggle for land rights underlie pastoralist livelihood strategies and decision-making processes (Cousins, 2010).

Figure 5.1: Kenya's arid and semi-arid lands (source: Elmi and Birch, 2013)

However, there are shifts in narratives and policy taking place in Kenya. In the late 1970s the potential contribution of the ASALs was recognised in national policy for the first time and more integrated policies to exploit the human and economic resources of the rangelands were implemented (Keya, 1991). At this time, it was acknowledged in some quarters that semi-nomadic pastoralism was the most sustainable use of the rangelands. More recently the new African Union Policy Framework for Pastoralism (2011) offers the opportunity to integrate pastoralist economies into national and regional policies. In Kenya, the dedicated Ministry for Northern Kenya and Other Arid Lands was established in 2008 and made significant strides in shifting the policy gaze to support sustainable development in the ASALs (Elmi and Birch, 2013). Unfortunately, in 2013 the Ministry was disbanded under the new government. The new Constitution adopted in 2010 has been widely accepted after initial problems with definitions and the policy regarding communally owned land. Throughout East Africa and the Horn, the ASALs are seen by governments as increasingly central to overcoming the challenges of climate-compatible development and 'green' economic growth (see for example Jones and Carabine, 2013).

Nonetheless, exacerbated by the historical legacy of state control over the ASALs, mistrust over land security reached a peak in the period 2009-2010. In Kenya, the draft Constitution coincided with the 2009 drought and build up to the contentious 2013 general election. Participants described their worries about the draft Constitution as another attempt to seize and control pastoral lands, expressing fear of a change of government to alternative tribal centres of power and on-going land seizures for conservation and tourism. Participants felt that the reduction in livestock numbers in the Amboseli system only reinforced the perception that pastoral lands are "*empty*" (Mbiraru, *murran,* Eselenkei) and "*unproductive*" and therefore "*up for grabs*" (Kapalei, junior elder, Eselenkei). Inhabitants of Eselenkei and Mbirikani Group Ranches felt the collapse of the livestock production system during the drought could be used as evidence that pastoralists cannot manage their lands sustainably. As a result, they have strived to bring the land into use via other forms of production such as small-scale irrigation, securing areas through agreements with tourist operators and subdividing valuable areas into private plots before outsiders seize them. Of course, the need to find alternative sources of income after the drought has necessitated different livelihood strategies at the individual and household levels, but the particular approaches taken by the group ranches collectively (i.e. subdivision and land leases) are symptomatic of the fear of land seizures and the will to maintain control over their land. However, underlying these approaches at the sub-group ranch level, there are tensions playing out between groups, institutions and individuals, which have implications for the changing patterns of land use and livelihoods described in this chapter. These will be discussed in the next section.

5.3.2 Power and agency in Amboseli

By their own estimation, the *Ilkisongo* are a relatively traditional section of Maasai, adhering to customary institutions, norms and values. At the core of customary institutions are the age-sets and clans, which are crucial in decision-making processes. In addition to these, governance traditionally lies with the community elders, age-set leaders, chiefs and spiritual leaders (the *laibon*). These individuals emerge over time and are chosen for their leadership qualities by consensus within their peer groups.

According to participants and previous studies carried out in Eselenkei and Mbirikani Group Ranches (e.g. Rutten, 1992, Southgate & Hulme, 2000, Lovatt Smith, 2008), the introduction of the Group Ranch system has led to shifts in the balance of power and decision-making within Maasai society. Increasingly, customary institutions are being superseded by new political and governance structures such as the Group Ranch Committees, local MPs and the patronage and social networks associated with wealthy and powerful individuals. The decision-making power that has lain previously with the elders and customary leaders of the community has been subverted by the introduction of politically powerful individuals elected by majority (rather than consensus) irrespective of their age. In some studies of pastoralist societies, it has been argued that current leadership structures resemble the indirect rule of colonial times where central government co-opted traditional governance systems (Mwangi, 2007, Metcalfe and Kepe, 2008). It is clear that the group ranch system has placed the centre of political power and governance out with the community.

Registered members elect group Ranch Committees, comprising Chairman, Secretary and Treasurer. According to one participant, the process used to be that the dominant or majority clan would hold the Group Ranch Chair but this is not so today. The reason given was the roles of politicians as patrons to the Group Ranch leaders. Several participants explained that it is outside individuals who "*decides which committee gets in, not the wananchi* [literal translation: ordinary people]" (Sironka, *murran,* Eselenkei), with a sense of resignation that "*this has been the way for a long time*" and there are "*many examples of this*" (Sabore, junior elder, Eselenkei). Similar instances of patronage and party politics influencing local decisions about resource use have been documented in neighbouring Kimana and Olgulului Group Ranches (see for example Southgate and Hulme, 2000).

Several participants cited the gypsum-mining agreement on Mbirikani Group Ranch as an example of outside interests circumventing local concerns, which led to "*big political problems*" on Mbirikani in 2011 (Ntimama, *murran,* Mbirikani). According to reports, the Chairman changed the designation of the Group Ranch from 'agricultural' to 'industrial' without consultation in order to make the deal with the cement company. Members of Mbirikani were "*very unhappy*" (Simel, *murran,* Mbirikani) about the factory proposal as it required the resettlement of several families without adequate compensation. Apparently, the Chairman was able to sign such a deal without the support of the Group Ranch members because "*he is strong from above"* (Koyati, junior elder, Olgulului)*;* implying patronage gave the Chairman the power to make this decision. Subsequent disputes over the deal led to a high court ruling in October 2011 to prevent the development. Mbirikani members believed this dispute would lead finally to a change of leadership, calling for Group Ranch elections in December 2011. One participant claimed "*there should be a change of leadership very soon*" (Masigonde, *murran,* Mbirikani) while another claimed that and the contenders running for Chair are "*already rich so they will not steal in this way*" (Ntimama, *murran,* Mbirikani).

However, on returning to the field in 2013, I saw that the cement factory had been constructed and was in operation. The Group Ranch Committee were still in their posts and the families in Emukatan, the site of the gypsum mine, had been moved to new locations with some financial compensation. When asked in 2013 how the cement agreement had gone through, one participant replied "*you know, in Maasai there is always clan*" (Ole Koinet, junior elder, 13/11/2011).

It was explained by another that "*a powerful chairman has his clan*" (Santamo, *murran*, Olguluglui) and a Chairman who is sufficiently strong both within his clan at the local level and with those at higher levels of power can make decisions without consensus. I was told that the *Iliasir* clan are known for having many strong politicians because they "speak well" and can mobilise their members as "*this is where power comes from*" (Sironka, *murran*, Eselenkei).

Such power used to “*lie only with elders*” (Santamo, *murran,* Olgulului). In the past, Group Ranches were largely separated along three clan lines. The *Ilmolean* were originally from Kuku and Rombo Group Ranches to the east of Amboseli National Park, the *Iliatayok* from Olgulugui Group Ranch and the *Iliasir* from Mbirikani and Eselenkei. Today the clans are mixed throughout these locations “*but clans will stick together*” in political issues (Surum, junior elder, Olgulului).

Another example of shifting power structures that was given to me was an agreement made in 2009 between a tourist operator and the Mbirikani Group Ranch Committee. The Committee, under the same Chairman, agreed to set aside a large area of land as a conservancy. While the agreement has been signed and investment made, members have not agreed to the relocation of *bomas* from the designated area and the loss of grazing rights in what is a key resource for hundreds of herders throughout the area. Mbirikani members explained their desire to privatise and subdivide the conservancy area between all members “*before it is seized*” (Lolkerra, *murran,* Mbirikani). If the area is subdivided equitably, participants agreed they would still lease the conservancy land to the tourist operator but would receive the conservation fees directly and not via the Group Ranch Committee. When asked why they supported subdivision more generally, participants from Eselenkei explained they wanted to protect against vested interests as “*In Olgulului, (where) they make 24 million Kenyan Shillings a year from the (Amboseli) park, but you never see a new borehole*” (Mbiraru, *murran*, Eselenkei). The meaning of this quotation is that the participant believes when resources are under the control of the Group Ranch Committee, they are less likely to see the benefits than if they were under the private control of individuals. This marks a substantial shift away from the model of communal management and customary norms that have persisted in Amboseli thus far.

A shift in the balance of power has also led to tensions between age-sets and elders as well as between customary and political institutions. In Eselenkei Group Ranch, it was explained that the push for subdivision since the drought comes “*mainly from younger group ranch members*” (Ole Koinet, junior elder, Eselenkei) wishing to break autonomous links between fathers and sons and to respond to what they see as failing and costly communal decision-making processes.

The decision-making process about the subdivision of Eselenkei led to tensions particularly between the *ilmurran* (warrior age-set) and elders. It was explained that the *ilmurran* are not registered as Group Ranch members, rather they sit under their fathers' membership. Women are also excluded unless they are widows. Therefore the *ilmurran* would not be entitled to an individual plot under subdivision. Consequently, a dispute arose between the *ilmurran* who were pushing for registration rights before subdivision and the already-registered *ilkidotu* (junior elders) who were trying to prevent this so their plots would be larger. The *murran* chief, a customary age-set leader, was advocating on behalf of the *ilmurran* that the registration rules be changed such that long-term resident *ilmurran* would be granted rights. In this case, the *ilmurran* won the dispute and now they and their sons can be registered as members.

It was explained to me that "*the murran chiefs are strong in some decisions but not in others*" (Sironka, *murran,* Eselenkei). They have influence in age-related matters but not in more general decision-making processes. Clan and age-sets are important networks and sometimes one takes precedent over the other. One participant explained that clan "*is more important than age, clan is like family*" (Nampazo, junior elder, Mbirikani). Another explained that "*if you go to another (Maasai) section, you will find your clan and he must help you, just as you must help him*" (Leboo, junior elder, Eselenkei). Clearly, the dynamics of decision-making within and between these customary institutions, intersecting with newer political power structures, is complex. However, in Eselenkei participants still feel that customary institutions persist and "y*ou must bring your fears to the table and have them addressed until a consensus is reached. This is how decisions are made*" (Sankei, junior elder*,* Eselenkei).

Shifts in power including patron-client relationships and power networks have been shown to impact on adaptive capacity (Nelson and Finan, 2009) and can lead to unequal vulnerabilities within communities (Adger, 2003). In this case, there is power asymmetry according to age-set, clan and gender and these are the tensions that underlie the changing patterns of land use and livelihoods brought about after the drought. At the group-ranch level, apparently collective decisions are taken to subdivide areas, allow illegal tapping of the pipeline or leasing mining rights for the cement factory. However, there are significant power struggles occurring between genders, clans, generations and customary versus political institutions at sub-group ranch levels. A more nuanced view of the social and political dynamics taking place within the group ranches helps to understand and explain the seemingly counter-productive shift in land use and livelihood taking place at larger scales.

5.4 Shifting worldviews

The majority of diversification and burgeoning economic activity described in Section 5.2 is taking place on Mbirikani Group Ranch. By comparison, Eselenkei has fewer alternative livelihood opportunities. Selenkay wildlife conservancy was established in 1997 and is leased by the community to a tourist operator. This lease generates income and employment opportunities, but the conservancy is a small-scale operation compared to that of Mbirikani. Other conservation and research projects in the area have little presence in Eselenkei compared to Mbirikani, Olgulului or Kimana Group Ranches. The members of Eselenkei are also disadvantaged by a lack of structural opportunities such as the tarmac road, pipeline and proximity to the wet areas of Loitokitok at Kilimanjaro. A factor in this economic disparity between the two areas is the politicised nature of the Mbirikani community relative to Eselenkei. Some clear differences have emerged from the data regarding these two communities. To illustrate the different worldviews I observed between Eselenkei and Mbirikani, a profile of a member of each Group Ranch is provided in the box below.

Box 2. A profile of two murrans

Lembui, Eselenkei Group Ranch

Lembui is a *murran* from Eselenkei Group Ranch. He has recently married his second wife and has three children. Lembui did not go to school rather he has been a skilled herder for his family throughout his life. He has killed two lions and is a proud, well-respected *murran* in his community. Lembui wears traditional Maasai clothing (*shuka)*, he has scar marks on his face and extended earlobes. While scar marks are common, extended earlobes are rarely practiced for children who attend school. Lembui has invested in a mobile phone, like most people with sufficient cash, and a bicycle. Apart from that, he invests his spare capital in livestock. He will send one of his daughters to school and the other two children will remain at home to help with herding. Lembui has found casual labour with the conservancy as a reliable and skilled tracker. He does not speak Kiswahili but is learning quickly in the hope he can gain employment as a tour guide.

Lemashon, Mbirikani Group Ranch

Lemashon is a *murran* from Mbirikani Group Ranch. He is unusual in that he has not married and has no children. When asked why he has made this decision, he says he wants to make money before he marries. Lemashon went to primary school and is fluent in Kiswahili and English. He is politically active and respected in his community, although he holds no official position. He works at the tourist lodge on Mbirikani and also owns plots of land in Loitokitok, which he leases to Chagga farmers. He has also bought a plot next to the tarmac road where he is building a property for renting out rooms. He has built a house at his home with a tin roof, rather than a thorn *boma*. Lemashon owns a mobile phone and a motorbike and also has substantial herds of livestock which family members herd for him. Lemashon has only ever worn a *shuka* for ceremonial purposes when he became a *murran*. He does not have extended earlobes although he does have scar marks. He has killed a lion and has a lion name. He says if he has children they will all be educated at the private academy in Kimana, not at the government-funded primary school, which he thinks is not good. Lemashon likes to keep up with the news and always asks me to bring the newspapers from Nairobi for him to read.

Lembui and Lemashon are contemporaries and friends. However, they are very different in their worldviews and in their opinions about each other's approaches to being Maasai pastoralists. At the same time, there are interesting disjunctions within the worldviews of each of these individuals. While Lemashon is considered a "*modern*" and "*educated"* Maasai, he has participated in *olamayio* (the *ilmurran* lion hunting ritual) and is one of the few to secure a lion name as the "*first spear*" to kill a lion. This is a name he uses in certain contexts (e.g. ceremonies) and with certain individuals. Lembui is very conventional in his views and practices. While he despairs at the changes taking place in Maasailand, still he recognises the value of educating himself and his children to be prepared better for them.

While these are only two individuals out of many on these Group Ranches, their profiles have been described here as broadly representative of the observed differences between *ilmurran* in these two areas. Furthermore, these differences are recognised by the community members themselves and participants often referred to their perceptions of the respective areas in explaining practices or decision-making. For example, participants from Mbirikani have described Eselenkei people as "*not learned, they are only interested in cows*" (Sankale, *murran,* Mbirikani) and are "*somehow innocent"* (Oloishona, junior elder, Mbirikani) in comparison to the more entrepreneurial Mbirikani members. According to Mbirikani participants, Eselenkei herders "*buy many cows*" (Naengop, *murran,* Mbirikani) and "*corruption is low in Eselenkei because their land is not worth anything except for the conservancy*" (Masigonde, *murran,* Mbirikani). On the other hand, participants from Eselenkei have described their Mbirikani counterparts as "*too modern*" (Reson, female, Eselenkei). In their view, they do not need to diversify their livelihoods as they are doing, it is "*a big lie*", "*they have just seen that people have become rich and want to do the same*" (Meticiki, *murran,* Eselenkei).

One Eselenkei participant stated his opinion that "*they (Mbirikani inhabitants) should invest in cows; I don't know why they are moving away from livestock*" (Sabore, junior elder, Eselenkei). The importance of education to these respective communities differs. While Mbirikani members see Eselenkei members as "*not learned*" (Legeny, junior elder, Mbirikani), Eselenkei members expressed the view that "*leaders should not be learned, they should be herders*" (Lemaron, *murran,* Eselenkei) so that they understand the concerns of the community. They attribute the political problems in Mbirikani to their educated and "*tricky*" Group Ranch Committee (Ibid.).

Participants in Eselenkei described with regret that "*life is changing*" () for herders. *Ilmurran* used to "*move from boma to boma, making friends and helping with herding and fencing. Now people are not friendly anymore*" (Legishon, *murran,* Eselenkei). According to participants from both Group Ranches, "*Eselenkei is the only place you will still find this happening*" (Komeyicin, junior elder, Mbirikani). The influence of Christianity and education were cited as preventing these traditional *murran* practices. In Mbirikani, I was told that "*people don't want to herd anymore, it's a tough life, they want to go to school and get jobs. They don't want to walk in the bush day after day*" (Naipanoi, female, Mbirikani).

Attending several ceremonies throughout the study area, I witnessed individuals having self-induced seizures during dancing. I was told that this is an ecstatic state and occurs because the dancers "*feel very strongly*" and "*remember the manyatta and what it means to them*" (Ole Koinet, junior elder, Eselenkei). During initiation, all young Maasai attend the *manyatta,* a ceremonial *boma,* in their area where they eat meat, dance and hunt, forging the strong social bonds of their age-set that are vital for the future. At each of six ceremonies I attended, one or two individuals experienced these seizures and all of them were from Eselenkei, with shared experiences of the *manyatta*. It was explained to me by members of both Group Ranches that the *manyatta* in Eselenkei is a "*stronger*" spiritual experience based on traditional cultural practices and beliefs, whereas in Mbirikani the focus is more on fun, competition and camaraderie for the young men.

A notable difference emerging between these two groups of Maasai pastoralists is their respective attitudes towards land and livestock. In Mbirikani, participants claimed "*it is good to own land not cows, selling land to buy cows has happened in Kimana, allowing other tribes to move in*" (Loyian, *murran,* Mbirikani). This opinion is reinforced by the fact that "*cows are easily lost*" during droughts (Tonkei, *murran,* Mbirikani). They believe *"you can keep cows once you have your land"* (Ngoje, *murran,* Mbirikani), "*cows can die and prices fluctuate but land always increases in value*" (Kurary, *murran,* Mbirikani). Mbirikani members explained that "*people want to send children to private academies now so need more money*" to maintain these lifestyles (Terenua, female, Mbirikani). Eselenkei members are still committed to livestock as the central livelihood resource and many are rebuilding their herds after the 2009 drought.

Rather than being definitive statements of the differences between Eselenkei and Mbirikani Group Ranches, this analysis is aimed at describing some of the tensions that are emerging in the communities of Amboseli, particularly disjunctions between customary and political institutions and more traditional and commercial approaches to coping with stress and adapting to change. The shift of emphasis from livestock assets to land assets is associated with the realisation that livestock is no longer reliable as "*the Maasai bank*" (Lolkerra, *murran,* Mbirikani). In Maasailand, land has been seen as territory rather than a resource to be appropriated by individuals (Campbell, 1993). Now multiple external stressors are transforming this worldview from "*land as ours*" to "*land as mine*", a process first observed in an early study of the Maasai of Kajiado District (Campbell, 1993). The shock of the drought has accelerated the shift with a renewed focus on ownership of plots for farming or business. Combined with the longer term cultural shift associated with socio-economic changes, it is likely that the "*land as mine*" worldview associated more strongly with Mbirikani will become dominant as the Maasai adapt to change. If more customary pastoralist strategies, based on social networks, communal decision-making and mobility comprise valuable adaptive capacity, the implications of a shift towards more individual strategies may be significant in the long term.

5.5 (Mal)adapting to climate change in Amboseli

As has been described in Chapter 2 and elsewhere in this thesis, semi-nomadic pastoralism is a livelihood strategy that has adapted to climate variability and uncertainty of resource availability. Semi-arid systems, including the Amboseli system, have continued to cope to some degree with increasing variability in climate. However, the extent to which they have the capacity to adapt to climate change in combination with non-climate related stressors is not clear. Coping with climate variability and shocks such as the drought infers reactive, short-term responses for survival or subsistence where options are limited (Tanner and Horn-Phathanothai, 2014). Adapting to climate change should involve longer-term livelihood security and well-being.

A considerable risk involved in adapting to climate change is that of maladaptation. This can be defined as “action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups” (Barnett and O'Neill, 2010: 211). As described in Chapter 2, there is little evidence of the causes of maladaptation, although it is generally accepted that maladaptive outcomes can occur from action to adapt to change (IPCC, 2014a). Where responses to climate shocks and stresses are reactive, unplanned and focus on the short-term, the risk of maladaptation is considered to be greater (World Bank, 2010). Furthermore, where system dynamics and complexity are not well understood, erroneous decisions may be made that lead to unintended maladaptive outcomes (Satterthwaite et al., 2009, Pittock, 2011). Shifts in belief systems about climate change caused by sudden shocks may also cause shifts in behaviour that are maladaptive (Niemeyer et al., 2005).

Barnett and O’Neill (2010) have described maladaptive outcomes as those that disproportionately burden the most vulnerable, set paths that limit future choices, have high opportunity costs, increase greenhouse gas emissions or reduce incentives to adapt. In the following section, this framework has been applied to the Amboseli system to demonstrate how a combination of shifting livelihood strategies, beliefs about climate change and wider political and social changes may be leading to maladaptive outcomes as inhabitants act to adapt to short-term shocks, like the 2009 drought, and longer-term stresses.

If Mbirikani or Eselenkei Group Ranches are subdivided, it will be the more marginalised households who will become more vulnerable to future climate change as these poorest members will be more likely to sell their plots and be dispossessed of land. Erosion of customary norms will remove social safety nets for these individuals. Moreover, the commercialisation of livestock production taking place will disadvantage marginalised households with less access to markets and sources of social and economic capital.

Committing livelihoods and institutions to pathways that are difficult to change in the future can only reduce the resilience of the system to change. Subdivision, commercialisation of livestock production and loss of decision-making power will limit the future choices of individuals and the system as a whole.

There are substantial social and environmental opportunity costs associated with a move away from customary rangeland management to fragmented land uses. These include, as we have seen in this and previous chapters, the erosion of cultural norms and institutions, and impacts on the structure and function of rangeland ecosystems.

At a larger scale, managing the Amboseli rangelands in unsustainable ways may reduce the capacity for carbon storage in soil and aboveground vegetation carbon storage. Furthermore on a wider scale, commercialisation of livestock production and increased livestock numbers has the potential to increase greenhouse-gas emissions from agriculture (i.e. methane).

Creating a change in social norms away from sustainable rangeland management and privatisation of communal resources creates disincentives to adapt to climate change in the longer term. Individuals under pressure will be more likely to sell their assets in reaction to shocks and will not invest in the quality of the grasslands as they do today through managed rotational grazing and other customary rules.

In common with other semi-arid systems, there are many drivers of change taking place in Amboseli, including population growth, wider opportunities for education, political shifts, integration into markets, technological innovations and the growth of urban centres. These factors are affecting the power dynamics, incentive structures and worldviews of people living within the system. In turn, they have further implications for how individuals and communities interact with the ecological components of their system via land use, livelihoods and development.

5.6 Causes of maladaptation

While it is possible to assess certain outcomes as being maladaptive, it is recognised in the literature that it is very difficult to distinguish causes of such outcomes (IPCC, 2014). This chapter argues that power dynamics in the Amboseli system, interacting with broader drivers of change, are altering Maasai worldviews regarding land and livestock assets, cultural and political institutions and ways of living in complex and often contradictory ways. Although Maasai pastoralists have proven adept in adapting to changing conditions in the past, the rapid onset of multiple stressors within this system may lead to potentially maladaptive outcomes in terms of coping with current and future climate change and variability and extreme events such as the 2009 drought. Maladaptive outcomes will have serious implications for the vulnerabilities of inhabitants and the resilience of the system as a whole.

The dilemma facing the inhabitants of the Amboseli system is how to cope with changing conditions produced by external forces while maintaining a predominantly pastoralist way of life, which is valued by all participants to some degree. For some, the need to secure a pastoralist production system while providing alternatives that do not undermine the resilience of pastoralist livelihoods is recognised. In striving to achieve this security, underlying power dynamics are altering patterns of land use and livelihoods, which while necessary to cope with changing conditions are potentially maladaptive and inequitable in their particular configurations. The tensions and disjunctions between individuals and groups discussed in this chapter are examples of the kinds of social and political dynamics taking place in Amboseli and which are affecting interactions with the environment via livestock, land use and development strategies. These dynamics are occurring at several scales from the group-ranch level, to sub-group ranch institutions and the individual or household level. Furthermore, while incremental shifts in livelihood activities have been a feature of Maasai societies for centuries, the adaptations taking place in 2009-2013 in the Amboseli system suggest more transformative changes in the socio-cultural fabric of Maasai society and the environment in which they live, exacerbated by the extreme drought event. These dynamics and changing patterns of land use and livelihoods may have serious implications for the adaptive capacity and resilience of a system facing the challenges of current and future climate change.

It should also be recognised that although the action of subdividing the group ranches may be maladaptive on the whole, there are likely to be winners and losers of such an outcome. One kind of maladaptive outcome is a result of action to adapt to climate change that disproportionately burdens the most vulnerable (Barnett and O'Neill, 2010). Inevitably in this situation the least vulnerable can disproportionately benefit from deliberate maladaptive action, or manipulation (Thomsen et al., 2012). This is where the causes of possible maladaptation intersect with the power dynamics described in this chapter. Based on their knowledge of subdivision in other parts of Maasailand, many participants are aware that subdivision will lead to short-term gains but will likely be detrimental in the long-term. Nonetheless, the nature of the recent shock (the 2009 drought) has increased the incentive for short-term recovery, explaining the seemingly paradoxical decision to subdivide. Those in positions of power with access to resources may be able to influence such decision-making, aware that there will be profit to be made from subdivision in the longer term as people begin to sell their plots.

There is growing emphasis in academic and policy circles on alternative approaches to managing the rangelands. Ironically, these are based on locally held and hybrid knowledge systems, communal land management and drought-management strategies. It is now widely recognised that semi-nomadic pastoralism is the most sustainable use of the ASALs with significant opportunities for appropriate economic development (Elmi and Birch, 2013). Interviewing a government agricultural scientist, she told me that "*anything you can do (with your research) to show that communal management and traditional pastoralism are the best strategy for the Group Ranches will be very good*" (Agricultural scientist, Kenya Agricultural Research Institute). What this research does suggest is that the shifts taking place in Amboseli are rooted in the legacy of historical political structures and narratives about pastoralism and affected by the power dynamics that have arisen as a result of external drivers of change. If these shifts are indeed transformative in nature, leading to new political, cultural and ecological structures and functions, they may well be maladaptive.

5.7 Summary

The Maasai have shown over centuries that they have the capacity to cope with their difficult environment and respond to changing conditions. The multiple stressors acting on the Amboseli system, not least climate change, and shocks such as the 2009 drought have the potential to overwhelm these coping mechanisms without proactive adaptation. However, as this Chapter has illustrated, there are risks of maladaptation as the Maasai react to change. Adaptation will only be sustainable if locally led; public policy and the private sector have important roles to play in creating the incentives for more inclusive and appropriate development pathways, which support a livestock-based economy. If this can be achieved, the current narratives of risk and resilience, disaster and poverty in pastoralist communities can be succeeded by one of diversity and opportunity.

CHAPTER 6. MODELLING DECISION-MAKING IN THE AMBOSELI SYSTEM

6.1 Introduction

In employing an interdisciplinary approach, this research has used modelling as an integrating tool throughout the analytical process. Using iterative and participatory research methods, the modelling approach has attempted to combine actor-based and systems-based enquiry to explore participants' experiences of livelihoods, land-use change and climate change, with a particular focus around responses to the 2009 drought.

This chapter discusses the approach taken to develop a theory of decision-making and the behavioural rules that underpin it, including discussion of the thematic coding and analysis of qualitative data presented in Chapters 4 and 5 and development of conceptual framework for decision-making in the Amboseli system. This analysis was used to inform the architecture of agents in this system are described, including overarching goals for (i) subsistence, (ii) coping with stress, and (iii) maintaining socio-cultural functions, and the attributes that influence particular sets of decisions.

This chapter also reflects on the model-building process and the challenges inherent in distilling, abstracting and modelling behavioural rules from rich qualitative data, as well as a discussion of the value of modelling as a process relative to model outcomes. This contributes to current debates in the literature about the interface between qualitative, participatory field research to develop a deeper understanding of the social and ecological dynamics of the system and attempts to generalise beyond individual case studies. Different pathways of decision-making in the Amboseli system are presented, drawn from the findings of the qualitative analysis and modelling process, leading to a revised conceptual framework of the system.

6.2 Development of theory

As detailed in Chapters 4 and 5, social and cultural shifts have emerged as important themes in the qualitative data. Therefore, these themes have formed the basis of the theory of decision-making in the system. It is well documented that many semi-arid pastoralist systems, including the Amboseli system, are undergoing a process of change driven by socio-economic, political and environmental factors such as population growth, globalisation, changes in land use and land tenure, shifting policy context, market access, technological innovations and climate change (Catley et al., 2013). Analyses of pastoralist societies over the last decade or so have been focussed primarily on the socio-economic impacts of these factors in terms of assets, cash flows, livelihood incomes and natural resource availability. However, using the mixed methods described in Chapter 3, this research has revealed shifts over different historical timescales in the socio-cultural fabric of the communities of the study area, which came out strongly in the coding of qualitative data and have implications for the patterns of pastoralist livelihoods and system resilience in Amboseli. For example as described in Chapter 4, when questioned soon after the drought participants described how "*people don't want to herd anymore*". Young people "*don't want to walk in the bush day after day*", rather they "*want to go to school and get jobs*". Herding is considered "*a tough life*" compared to alternative employment opportunities, particularly in light of the lived experience of the 2009 drought. While both socio-economic and more qualitative methodological approaches may show similar broad patterns in livelihood strategies and activities across a system, the apparent drivers underlying the decisions towards livelihood trajectories are likely to differ.

Another finding that has emerged from the qualitative data, and which is discussed in greater detail in Chapter 5, is the normative differences between groups of Maasai in the Amboseli system, for example the two communities within the study area. Although the inhabitants of Mbirikani and Eselenkei group ranches share a broadly similar environment and pursue common livestock-based livelihoods, their differential socio-political experiences and exposure to resources and commercial opportunities has led to differences in their broad worldviews. For example, views on education and the relative importance of land and livestock as assets differ between the younger generations of these two group ranches. As described in Chapter 4, further complexity is added to these longer-term processes of socio-cultural change by apparent sharp shifts in relationships with the landscape and livestock as a result of the lived experience of the 2009 drought. For example, some herders were exposed to alternative income opportunities as they were forced to travel outside their areas, modifying their current and planned livelihood strategies (see Chapters 4 and 5 for detailed discussion).

In order to devise rules for modelling the decision-making processes of these communities, an understanding of the livelihood activities and strategies was developed. In common with many pastoralist communities throughout East Africa and beyond, the Maasai of the Amboseli system face a broad series of choices ranging from more traditional, mobile pastoralism to mobile pastoralism combined with other household activities (e.g. paid employment, farming small plots, starting small businesses), to increasing commercial and non-livestock based economic activities. Now it has been well documented that Maasai, and other pastoralist groups, have periodically moved between these broad livelihoods strategies in response to environmental and political perturbations, while maintaining livestock at the core productive unit of their economies (Spear and Waller, 1993).

As explained above, underlying the patterns of livelihood activities in Amboseli are particular worldviews and norms. Differences in worldview were identified while working through material gathered during periods of fieldwork, with initial descriptive codes such as “cows”, “herd”, “livestock”, “land” and “plots” applied, including the example statements above. Coding was carried out through several iterations and refined into more analytical codes such as “worldview”, “traditional perspective” and “commercial perspective”, which also included the above statements. In this way, and consistent with a grounded theoretical approach, a theory has emerged from the data that some Maasai favour more “traditional” livelihood strategies, investing in their herds as a means of coping with variable and uncertain conditions, while others tend to invest spare capital in diversifying their livelihoods with plots, employment and commercial activities. These worldviews are affected by differential economic and political conditions and individual experiences of perturbations such as the 2009 drought.

These findings relating to the socio-cultural norms and values of the system have focussed the theory guiding the design and development of an ABM. In addition, external factors, notably the 2009 drought, impact on livelihood decision-making processes, interacting with these underlying norms to modify and constrain the options available to particular individuals.

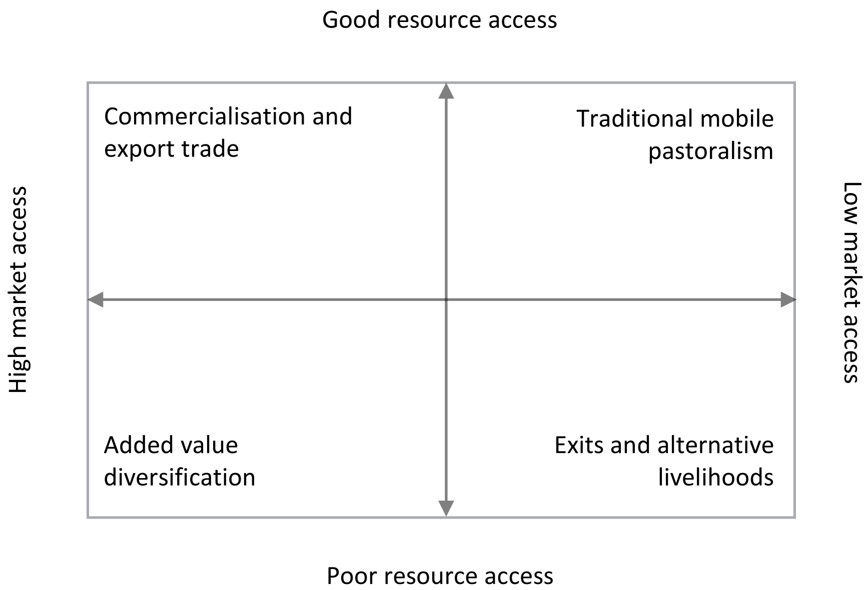


Figure 6.1: Four scenarios for the future of pastoralism (Catley et al., 2013: 15)

The conceptual framework shown in Figure 6.1 was developed by Catley et al. (2013) from the findings of a 2007 workshop involving stakeholders including researchers, policy-makers, development practitioners and pastoralist community leaders (UNOCHA-PCI, 2007, Catley et al., 2013). Derived from decades of empirical research, the framework shows four livelihood strategies observed in African pastoralist communities across East Africa and the Horn of Africa. The meeting concluded that these four livelihood strategies are driven primarily by two factors, access to resources and access to markets, while recognising that these drivers are in turn influenced by a range of factors on several scales (see Chapter 2 for a review of the dynamics affecting semi-arid systems).

Taking this framework as a starting point and based on the preliminary findings of this PhD research, the conceptual framework has been adapted for the Amboseli system (see Figure 6.2). The agency of pastoralists to make decisions about their livelihood strategies has been added to the middle of the diagram and is central to the use of this framework in developing an ABM. Also indicated here is the importance of context in influencing decision-making spaces across these quadrants. For example, a key focus of this research is the impacts of an external shock (the 2009 drought) on the system and the decisions of those operating within it.

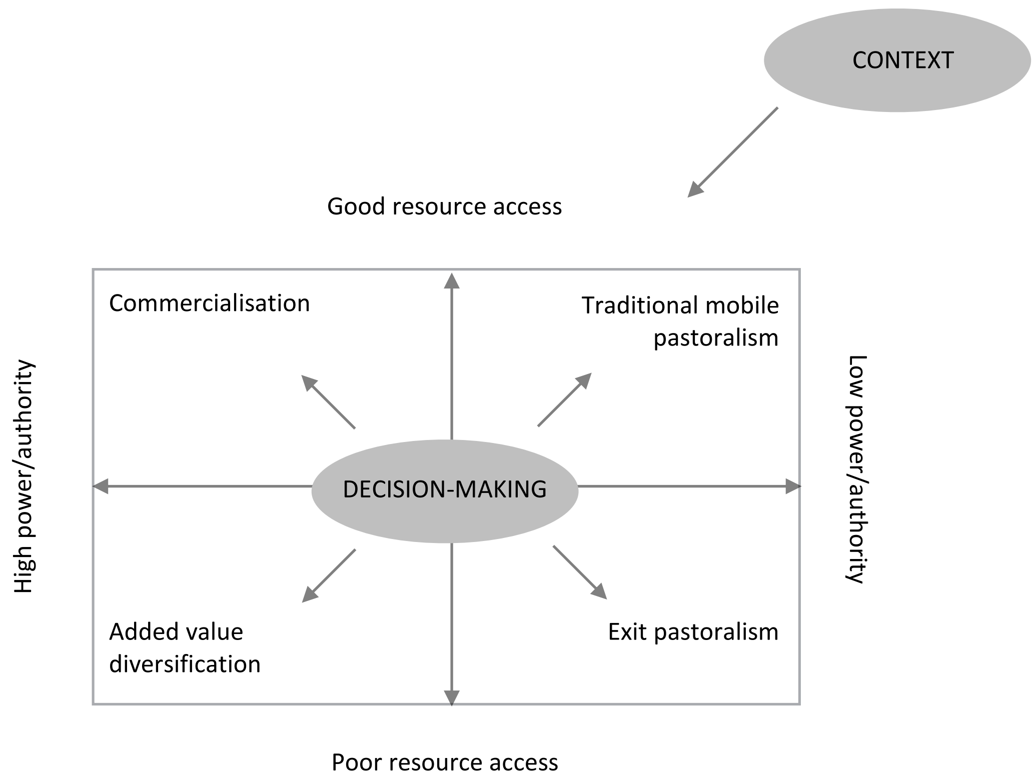


Figure 6.2: Conceptual Framework for decision-making in the Amboseli system (Adapted from Catley et al., 2013)

The importance of access to resources in making livelihood decisions is retained in the horizontal (x) axis of the diagram. In this interpretation of the framework, resources refer to the forage and water required for maintaining herds, or to the financial / institutional capital or physical resources, including markets, that are required to diversify livelihood activities and cope with changes in context. Perceived or actual access to resources will depend on individual production objectives (e.g. livestock versus land assets) and the entry points available for diversifying livelihood activities, both of which may change over time and in response to contextual factors.

Access to markets has been replaced along the vertical (*y*) axis by level of authority and power, which may represent political authority held by group ranch leaders or non-governmental organisation employees for example, or those who enjoy the patronage of these individuals. This factor may also represent customary authority, such as that held by *murran* chiefs, clan leaders and spiritual leaders (the *laibon*) as well as those with access to these sources of authority and power. Social capital, such as kin, clan and age-set networks, is also a source of power for each individual. These two alternative sources of power and authority, political and customary, also overlap and interact across the Amboseli system whereby each individual holds a complex and often contradictory level of social capital comprising both political and customary networks, which ultimately affects their decision-making spaces.

As discussed in Chapter 5, the level of authority and power exercised by an individual affects and is affected by their access to resources as well as the nature of their chosen livelihood strategies. For example, two of the wealthier and more politically connected individuals of Mbirikani Group Ranch were able to gain access to privately owned grazing resources during the drought. On the scale of the study area, access to markets is mediated more by the ability to transport livestock, the availability of spare labour and the ability to secure a good price for livestock, rather than the physical presence of a market in the area. All of these factors have been interpreted here as functions of authority and power. In contrast to the original conceptual framework developed at UNOCHA-PCI[8], subsuming access to markets within access to resources and replacing it with level of authority and power essentially emphasises the importance of normative, socio-cultural dynamics

[8] UNOCHA-PCI is the United Nations Office for the Coordination of Humanitarian Affairs – Pastoralist Communication Initiative.

as well as economic drivers affecting livelihood activities within the Amboseli system.

6.3 Agent architecture

Based on the theory developed out of the qualitative analyses, primary agents for the design of an ABM for the Amboseli system were identified at the herder level and share common attributes such as ethnicity (Maasai) and primary livelihood activity (pastoralism). In this design, herder agents each own a herd and have a set of overarching goals, which were derived from the primary and secondary data as described earlier in this chapter. These goals are as follows, in order of the importance attributed to them:

1. Meet subsistence needs e.g. through pastoralism, agro-pastoralism or a mix of pastoralism with other livelihood activities;

2. Cope with stress and shocks e.g. maintain herd mobility, manage herd composition, herd-splitting, increase herd size; and

3. Maintain socio-cultural functions e.g. *osotua* (a practice by which Maasai will gift stock to each other when in need, in a relationship that is reciprocal over time), knowledge or information transfer through social networks, social capital between members of the same age-set, clan and kin groups.

While all herders share these common goals, the agents are differentiated in their motivations and options by criteria, which include clan, relative wealth, opportunities for alternative strategies and worldview. These criteria relate to their ability to access resources and sources of authority and power, as shown in Table 6.1.

Table 6.1: Agent Attributes and Decision-making

DECISION-MAKING / ATTRIBUTES	Exit pastoralism	Traditional mobile pastoralism	Added value diversification	Commercialisation
Access to resources				
Resource access	Poor	Good	Poor	Good
Herd size	< Average	Average	> Average	100-1000s
Land ownership	None or < Average	Average	> Average	Plots for planting horticultural crops
Income sources	Unpaid dependents or hired herder to another herder. No/minimal income.	Minor, periodic income from unskilled work or rents (e.g. wildlife revenues).	Significant, secure employment.	Livestock trading, business interests, more than 1 individual in *boma* has employment.
Assets	Few/none	Bicycle, mobile phone	Vehicle, run a business	Property/land rental, vehicle hire
Authority and power				
Level of authority and power	None – low	Medium - high	Low - medium	High
Nature of authority and power	None – low	Customary	Mixed customary & political	Political
Entry points for diversification	None	Few e.g. limited conservation, tourism	Some e.g. conservation, research projects, tourism, tarmac road, market, illegal irrigation from pipeline, access to swamps	Many e.g. non-local markets, land purchases/rents
Social capital	None, marginalised	High	Political (e.g. kin or age-mate connections)	Traditional or political leader / government or NGO employee / patronage of MP and group ranch committee
Beliefs	Livestock	Livestock	Land	Land
Education	None	None or limited	Primary or secondary level	Primary or secondary level
Strategy	**diversify by necessity**	**diversify to manage risk**	**diversify to manage risk & for wealth accumulation**	**diversify for wealth accumulation & power**

To capture the role of different worldviews identified in the analysis (see Chapter 5), a Beliefs-Desires-Intentions (BDI) approach to agent architecture was developed (Rao and Georgeff, 1995, Sakelleriou et al., 2008). This approach allows for agent behaviours to be mediated by their particular worldview or belief sets, which are derived from the environment, from their learned experiences and through their interactions with each other.

6.3.1 Subsistence

Two types of agents are indicated by the data analysis, one type with a "traditional" worldview and the other with a "commercial" worldview. According to the three overarching goals, all herder agents would execute the intention *to subsist* daily (on a daily time-step), which includes more specific intentions *to find grass*[9], *to graze* and *to monitor condition* of their herd. The intention *to subsist* is common to both *traditional* and *commercial* agents (see Figure 6.3 for ABM process).

6.3.2 Coping with stress

In the design of an ABM of the Amboseli system, the second overarching goal is implemented as an intention *to cope with stress*. As identified from discussions with research participants, in each day of the long rains (March to June) and short rains (November – December), every agent *checks rain* and carries out an intention to *assess location*.

One way to implement this assessment of location is to have agents score their current patches against the patches of ten random herders according to a set of identified criteria, including the relative condition of the 11 patches, the number of cattle in and neighbouring each of the patches, a preference to stay in their current locations and a preference to move to their home locations in the wet season months (Boone et al., 2011a). Upon receiving the score, an agent will either remain in the current location or move towards a new one.

---

[9] Where I have put phrases in italics in this section, they refer to behaviours that are represented in the model design.

Decisions about coping with environmental stress depend on agent beliefs about rainfall. If it does not rain for a consecutive number of days in the long rains, indicated in Figure 6.3 with (-), the agent begins to *cope with stress* until it does rain for a consecutive number of days. After this onset of rains, they will continue *to subsist* until the next intention is triggered. If it has not rained for a consecutive number of days during the short rains, the agent will begin to *anticipate stress*, preparing for the eventuality of a failure of the next long rains. According to participants, failure of short rains is not necessarily a cause for serious concern, unless it is to be succeeded by a failure in the next long rains.

These are rules, which were derived from the first rounds of qualitative data. Strategies for coping with stress are differentiated by agent's worldviews. For example, more *traditional* agents will follow a set of intentions based on customary coping mechanisms including *split herd*, *reduce herd*, *osotua* and *mix species*. If these strategies for coping with stress fail, beliefs should be modified and something else attempted. Agents that have pre-determined or adapted *commercial* beliefs will be more likely *to sell cows* earlier and *to diversify* their activities *to cope with stress*.

If it does rain for a consecutive number of days in the short rains, indicated on Figure 6.3 with (+), this is considered good conditions and a *traditional* agent will choose to *increase herd* while times are easier, working under the belief that if the next long rains do fail, they will be able to absorb the stress and lose some livestock, and if they do not fail, the agent will become wealthier in terms of livestock holdings. A *commercial* agent on the other hand, may increase their herds during this time or alternatively *diversify* to bring in other sources of income.

6.3.3 Maintaining socio-cultural functions

The goal *to maintain socio-cultural functions* is more complex and includes intentions such as maintaining social networks which are crucial in maintaining mobility, surviving shocks and stresses and gathering information about natural resources, cattle prices and so on (Homewood and Rodgers, 1991). For example, *osotua* is represented in the ABM as part of the coping with stress intention set. Many aspects of Maasai culture are adapted to support pastoralist livelihoods, which is one reason why Maasai are relatively resistant to change (Spear, 1993). However, differentiation driven by shifting worldviews and experiences may erode customary coping mechanisms based on social networks, leading to the loss and/or replacement of this source of resilience in the system.

As displayed in Table 6.1, diversification strategies that may look the same can be driven by different motivations, related to beliefs, which are difficult to capture in the model. This equifinality is not uncommon in modelling approaches. Some individuals are forced to exit pastoralism and diversify by necessity after losing their herds. Those practicing traditional mobile pastoralism tend to be driven by more traditional belief sets and customary social norms. These individuals, including Lembui from Eselenkei (see Chapter 5), are more likely to diversify their livelihood activities to manage risk in times of stress. Others, including Lemashon from Mbirikani (see Chapter 5), diversify livelihood activities as a means of managing risk but also to build economic capital. These individuals tend to be more commercial in their outlook with different aspirations and views of the world compared to the former. The few individuals who can diversify into commercialised livestock production will tend to be driven by a desire to accumulate wealth, and in the case of the two individuals from Mbirikani who maintained their herds during the drought (see Chapter 4), to build the ability to influence others, particularly those with power and authority.

The intention to *diversify* in itself should lead to a complex set of decisions around the four broad spaces of the conceptual framework in a full implementation of the ABM. Understanding these processes was a key aim of repeated field visits and is discussed in more detail in the next section of this chapter.

6.3.4 Reflections on the ABM

While qualitative data analysis can be highly empirical, ABM offers a means of distilling more general patterns and processes that can have relevance in a general range of settings whilst operating within the parameters of the particular case study. As demonstrated in my research methodology (Chapter 3), using sequential descriptive and analytical coding to develop theory and abstract rules for the ABM has proven a useful way of interrogating the social-ecological dynamics and decision-making processes that are grounded in the qualitative data. I found it was the process of designing the agent architecture, building the model structure and developing individual rules and pieces of code to represent these dynamics, which has proven to be of interest and value in understanding the Amboseli system, rather than the results of a fully functioning ABM. As such, I implemented the rules discussed above in an ABM, using the NetLogo platform (see Chapter 3 for further details), but I did not go on to implement a fully-functioning ABM with all rules interacting to interface with a simulated environment[10] and generating outputs. My approach therefore was more experimental, interrogating qualitative rules and identifying limits to their implementation through the process of coding and simulation, which also resonated with the limits to decision-making processes described by participants in real-world situations. After my second field visit, it was this model-building process carried out in participation with research participants that captured my interest. The ABM as a process has acted as a further layer of analysis helping to interpret the data in different ways, iteratively and in both directions from qualitative data to decision-making rules and vice versa. In the next section, I will describe the ways in which the model-building process has elucidated my understanding of the social-ecological dynamics of the Amboseli system.

[10] I had originally intended to couple a fully-functioning ABM to the aDGVM (see Chapter 3)

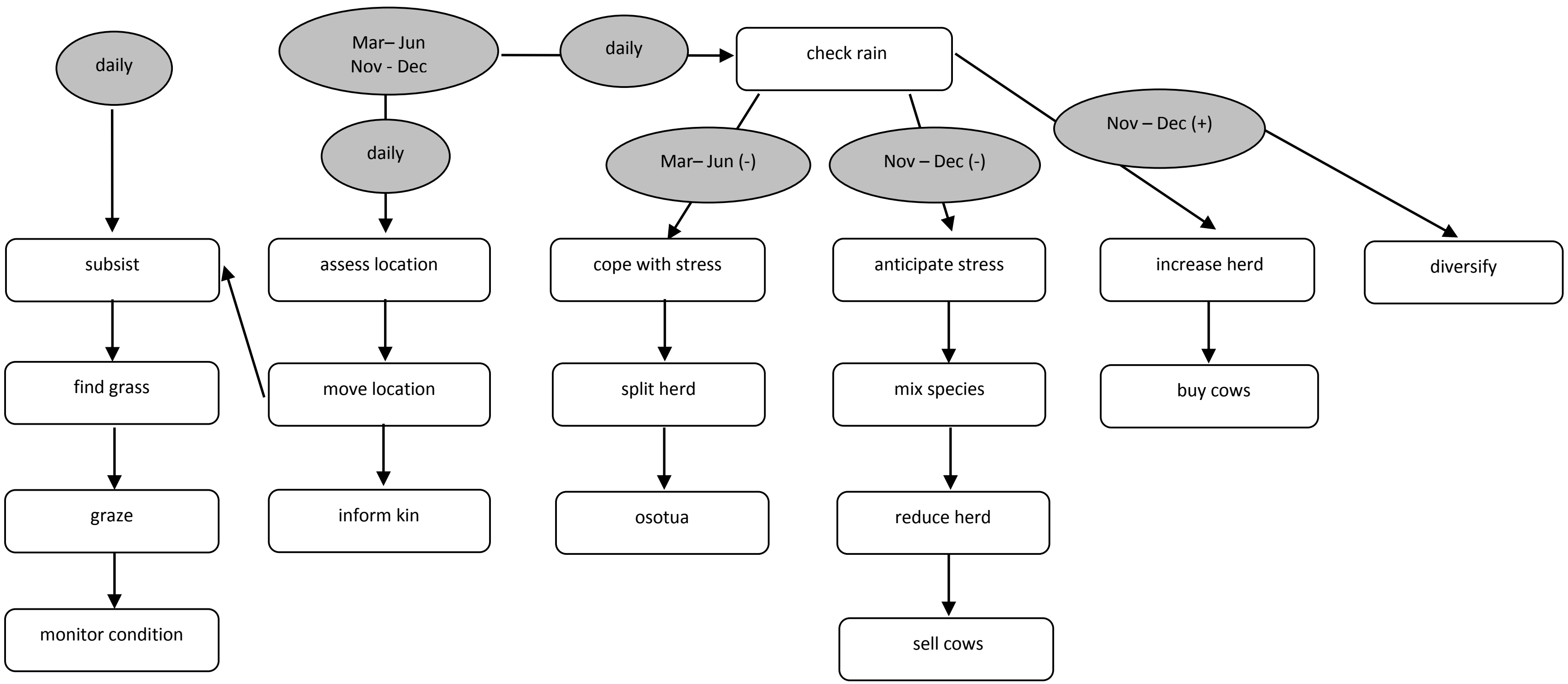


Figure 6.3: ABM process diagram showing agent behaviours as they relate to the three goals. Grey shading indicates timing of procedures, (-) indicates no rain and (+) indicates rain.

6.4 The model-building process

In designing the methodology for this research, qualitative methods were selected as a means of capturing the experiences of livelihoods, environmental change and land-use change in the Amboseli social-ecological system. As described in Chapter 3, this approach was adjusted during the course of fieldwork to have a greater focus on the informal discussion and participant observation methods. Developing an ABM to explore these experiences over different scales and under different scenarios offered a means of focussing in on key processes and their implications for the system, while still considering the agency of actors to respond to change (a key strength of ABM). Using qualitative data to inform behavioural rules for agents maximised the potential to capture a more *emic* representation of the system, especially when participants were also involved in the building and interpretation of the ABM.

Repeated periods of fieldwork have allowed the theory of decision-making in the Amboseli system and model parameters and assumptions to be tested and refined with the original research participants (see Chapter 3 for details of field visits). In 2010, the immediate aftermath of the drought was experienced, and the qualitative data captured at this time is interpreted in the conceptual framework shown in Figure 6.2. A return visit to the field was carried out in 2013. The main objective for this last fieldwork period was to test elements of the conceptual framework and model theory described above and the model parameters and assumptions outlined in Table 6.1.

An example of how the final round of fieldwork altered the design of the model is the adjustment of erroneous assumptions about seasonal decisions. When asked what they would do if it does not rain in the short rainy season (November-December), participants said they would carry on as normal rather than take actions in anticipation of a drought, which had been the assumption in the first version of the model. Instead, a more realistic representation offered by participants is that agents will start to anticipate stress if the short rains fail and the subsequent long rains (March-June) are delayed. Returning two years after the drought, it appeared that while people had adopted different livelihood strategies as a result of the drought, they did not consider drought *risk* explicitly in their short-term decisions. As one participant explained it, "*if you told me there was going to be a drought tomorrow I would not believe you. There will be bad droughts again but only God knows what will happen in the future*".

A further limitation that arose in using qualitative methods to inform ABM development is that numerical thresholds and values often have to be applied, which can add rigidity beyond the evidence presented in that data (Yang and Gilbert, 2008). What became evident in talking to participants was that decision-making processes are heuristic and qualitative. There are no set thresholds or criteria for particular decisions (Goldstein and Gigerenzer, 2002), rather daily or seasonal assessments based on the best available information and individual circumstances, including worldview, access to resources and level of authority and power. For example, when asked about decisions of when to increase their herds, some participants said they generally prefer to buy stock just before the rains arrive when prices are low and forage not widely available, but this has to be weighed against the likelihood of a good rainy season to support extra stock and rising market prices after the rains arrive. In this sense, there is no set time or formula for decisions to go to market, even for one individual, and factors such as transportation costs, market prices and available labour also form part of the decision-making heuristic. For this reason, actual set figures and numbers should be avoided in a full implementation of the ABM. Instead, ranges should be used to capture the spaces within which decisions are made relative to other factors, rather than linking decisions to specific variables like market prices. The example of agents assessing their patch against alternative patches by scoring several criteria is one attempt to overcome such limitations. However, a limitation with this approach of taking a range of values and implying some stochastic implementation in this way is that interactions between the ranges may be missed i.e. one response may make another response more or less likely, but without specifying the exact nature of that relationship.

While simplification is "the most essential characteristic of modelling" (Grimm & Railsback, 2013: 196) and agent-based modelling in particular provides the capability to identify and explore key dynamics in a complex system, it was at this point I decided that the in the case of the Amboseli system modelling this complexity of decision-making in its entirety would not best meet the research aim. However, it was through the process of distilling behavioural rules through iterative periods of reflection, interrogation and testing with participants that I was led to the more interesting element of the research presented in Chapters 4-6. It is this process of simplification of complex dynamics that is one of the key strengths of agent-based modelling and there is great potential for these approaches to further elucidate social and ecological patterns at the system level (see Chapter 8 for a discussion of further research).

There is growing recognition in the literature of the importance of model process (as well as model outcomes) in understanding social-ecological systems. Acknowledging a "healthy tension between bottom-up/qualitative/place-based approaches and top-down/quantitative/generalizable approaches", Twyman *et al.* (2011: 1) review a series of approaches to addressing vulnerability to climate change along this spectrum. They conclude that the process of building "throw-away models" (Sandker et al., 2010: 4) can offer much to research enquiry in this area with a focus on process rather than outcomes. Cautioning that a focus on modelling the mechanistic elements of a system "obscures the diversity of performative social behavio[u]rs and normative cultural positions of actors within the model[l]ed system", Crane (2010: 1) acknowledges also the role of modelling in involving stakeholders in adaptation and policy-oriented research processes as well as providing a means by which to combine different perspectives and types of empirical knowledge. The findings of this research support this assessment. In Amboseli, the modelling process has allowed for repeated and focussed interaction with research participants, beyond that offered by socio-economic surveys, and has undoubtedly captured processes of interest in explaining observed patterns in land use and livelihoods, for example the role of cultural preferences and norms. Focussing around the 2009 drought has provided the opportunity also for participants to reflect in some depth and over time on their own responses to this shock in terms of their livelihood strategies, identifying some of the tensions and disjunctures in decision-making brought to the fore by this event.

6.5 Pathways of decision-making in Amboseli

It became clear during the course of the research that while the broad livelihood strategies indicated in Figure 6.2 have held up in the case of the Amboseli system, the pathways of decision-making are by no means linear or constant in time and space. Each research participant responded to the 2009 drought event in a unique and individual way. For example, many participants who initially fell within the *added value diversification* quadrant of Figure 6.2 were able to use their financial capital to rebuild their herds. However, they chose slightly different approaches. In the majority of cases, participants invested in cheaper, smaller Somali cattle breeds flooding the market due to the 2010-11 drought in the Horn of Africa (see Chapter 5 for more on this). The aim here was to fatten and sell these Somali cattle quickly to raise the cash to buy more traditional Maasai cattle breeds, although several participants realising the income potential of alternative breeds are planning to alter the composition of their herds to exploit these new opportunities. Other individuals chose novel strategies. For example, Lolkerra saw an opportunity and decided to eschew the popular Somali cattle favoured by the majority of his peers to buy a flock of sheep in 2011. As opposed to goats, which are browsers and the more conventional small-stock choice for Maasai in Amboseli, sheep only thrive where high quality forage is available. Sheep can reach a high price on the local market where they are preferred by the adjacent Kamba agriculturists. In 2011-12, the absence of grazing herbivores (particularly wildebeest and gazelle) in the Amboseli system provided the abundance of forage Lolkerra needed to raise his flock of sheep. While I witnessed his peers mocking Lolkerra’s unconventional choice, they also clearly admire his entrepreneurialism in exploiting this opportunity, which is bringing him significant financial benefits in the short term.

Sustained success of this kind likely will lead to prestige and greater power and influence for Lolkerra within his community.

As these examples demonstrate, it is difficult to pinpoint definitive agent typologies for decision-making in the design of the ABM. The characteristics outlined in Table 6.1 clearly hold a range of assumptions, and while these typologies have been useful in conceptualising the stories and experiences of individuals, the disparity and complexity hidden within this table have emerged as the most interesting findings in repeated field visits. It is these different livelihood strategies that constitute the resilience of the Amboseli social-ecological system to the shock of the 2009 drought. The differences between Lolkerra's approach to increasing his livestock holdings with sheep, his peers' strategy in buying Somali cattle and others who prefer to maintain herds with traditional Zebu cattle cannot be captured meaningfully in the ABM. However, it is these details and the ways in which they interact with the external context and socio-cultural fabric of the Maasai themselves, which need to be considered in understanding the resilience of the Amboseli system.

Just as each individual has pursued different pathways across the decision-making space of conceptual framework, repeated visits to the study area revealed that many research participants had changed direction over this period of time in response to changing circumstances. Some participants have gained new opportunities after the drought. For example, individuals have been forced to *exit pastoralism* and leave the system for a year to seek wage-based employment at the coast in Mombasa, for example, and have then returned intending to buy livestock to commence *traditional mobile pastoralism* but have instead found employment with tourist operators (as *added value diversification* for their households) as a result of their exposure to this industry while away. Others have been less fortunate in their experiences, being forced to *exit pastoralism* and begin labouring for other households herding livestock before marrying into another network to begin herding family herds again. While on the face of it, this latter trajectory may look like an arrow tracing from *traditional mobile pastoralism*, into *exit pastoralism* and back into *traditional mobile pastoralism* on Figure 6.2, the nature of the *traditional mobile pastoralism* practiced over this period has changed significantly from the perspective of the individual.

It was during the iterative process of designing, coding and testing the decision-making rules for the ABM that the complexity of decision-making and livelihood trajectories was revealed. In repeatedly trying to pin down the rules governing livelihood decisions with research participants, the differences between and contradictions within individuals in the Amboseli system emerged. The process of working through the elements of Table 6.1 with participants was critically informative for my own understandings of the system and generated much useful and thoughtful discussion, which may have been missed using different methodological approaches. Although broad patterns of livelihood activities and the factors affecting decision-making about these generally held up to scrutiny, it became clear that constraining individuals within the criteria of Table 6.1 processes of decision-making described above was complex and the results of doing so of less interest than identifying these tensions. The conflicts and disjunctions discussed in detail in Chapter 5 cannot be easily reconciled with the agent architectures outlined in Table 6.1. In reality, and particularly in the relatively extreme context of the 2009 drought, participants placed themselves within several boxes of Table 6.1 and charted their livelihood decision-making across the quadrants of the conceptual framework (Figure 6.2) as non-linear, complex arrows, as depicted in Figure 6.4 below.

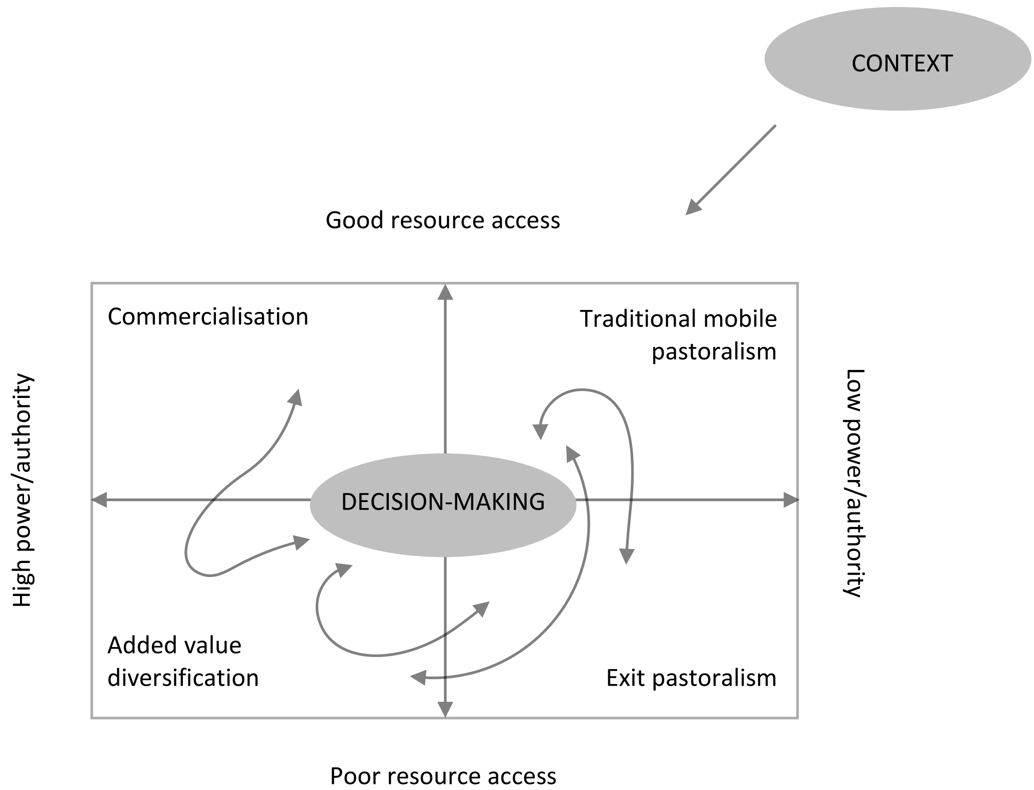


Figure 6.4: Revised conceptual framework of decision-making in the Amboseli system after 2013 field visit. Arrows represent individual pathways of decision-making, as influenced by context, resource access and power/authority. These decisions determine livelihood strategies under any given set of circumstances.

During fieldwork, I spoke with participants who had followed each of the trajectories shown in Figure 6.4 over a period of time. For example, Kutata had very little resilience at the household level to cope with the drought, lost all his livestock and had to exit pastoralism altogether. His family has now started labouring for cash, have moved to family members' *bomas* or have migrated to Mombasa or Nairobi to seek employment to begin the slow process of building up cash to establish a new herd. While some members of the household may not return from urban centre, it is expected that this household will re-enter traditional mobile pastoralism when possible. This kind of story was relatively common among participants, as most households in the system had sufficient social and economic resources to improve their circumstances over the relatively short period of time of this study. How these individuals will persist in the future is less certain, hence the dynamic nature of this revised conceptual framing.

Individuals who had been practicing traditional mobile pastoralism but had not lost all their cattle or had been able to save cash assets to cope with an event such as the drought have moved into added value diversification. Rather than investing spare capital in new livestock, these individuals have invested in seed for plots, or in a motorbike for transport rental, or in other kinds of business, often in partnership with friends or family. Some of these individuals may return to traditional mobile pastoralism when the market conditions are right to rebuild herds, or they may continue with added value diversification to build resilience in anticipation of future drought shocks. This pathway was less common in the communities of the Amboseli system, largely due to the relatively high level of social capital remaining in the system. However, there were a substantial number of participants sufficiently marginalised from customary networks, power structures and access to alternative incomes that experienced an exit from pastoralism.

Those very few individuals who had the power and capital to rent private land for grazing, for example, or access external sources of capital, were in a position to sell stock for high market prices after the drought and invest in land or equipment to commercialise their livestock production. These individuals have been assisted in this livelihood shift by the provision of abattoirs in nearby market towns, such as Sultan Hamud, and construction of the tarmac road between Emali and Loitokitok, a major market town in the region.

6.6 Summary

What is clear from this analysis is that the 2009 drought was a shock that disturbed the *status quo* in the livelihood strategies of Amboseli from those depicted in Figure 6.2 to the situation described above and in Figure 6.3. Whether the shifts can be absorbed without altering the fundamental structure and function of the system as a whole, Amboseli may have been resilient to the 2009 drought. However, if the cumulative impact of these shifts are more transformative in nature, such as wide-scale subdivision, or are maladaptive, the inhabitants of the system risk reducing their capacity to cope with future extreme events and climate change. Therefore, these shifts could in turn lead to further marginalisation and trap the Maasai of Amboseli into poverty.

CHAPTER 7. RANGELANDS IN A CHANGING CLIMATE: CATTLE AND CARBON

7.1 Introduction

Chapter 6 introduced the approach to using modelling as an integrating tool in investigating the resilience of the Amboseli system to land-use change and climate change. Specifically, the role of agent-based modelling approaches as a process for interrogating drivers of land use and livelihoods decisions was explored.

This chapter describes in detail how the grazing sub-model introduced in Chapter 3 (section 3.4.5) was developed, including explanation of selected parameters. Next, a series of 2^3 factorial simulation experiments are described. These are designed to test the effects of (i) climate change with and without communal grazing, (ii) climate change with enclosure of rangeland, and (iii) climate change with subdivision of communal rangeland. The model parameters used in each experiment are described.

The results of each experiment are discussed in turn, including an analysis of the effects of climate change and land tenure on vegetation structure and function both in terms of qualitative findings and statistical results. These results are then synthesised and interpreted in a discussion of the potential of the Amboseli system and rangelands generally in sequestering carbon for climate change mitigation and social-ecological resilience. The role of modelling in integrating these findings is also discussed.

7.2 Simulating grazing in the aDGVM

As described in Chapter 3, Dynamic Global Vegetation Models (DGVMs) are particularly useful in exploring the responses of ecosystems to disturbance and global change at different scales. The design of DGVMs lends them to couple well with General Circulation Models (GCMs), the primary family of models used by climate scientists to explore climate change, thus are useful in exploring climate-vegetation dynamics (Cramer et al., 2001b, Rounsevell et al., 2014). The adaptive DGVM was designed specifically to represent the mix of tree and grass vegetation that is characteristic of savannah ecosystems because alternatives DGVMs (including the widely-used HYBRID, IBIS, LPJ, SDGVM, TRIFFID and VECODE) do not adequately represent these habitats (Scheiter and Higgins, 2009). The aDGVM was chosen for this research into vegetation-climate dynamics in the Amboseli savannah system due to these properties.

A sub-model was built to simulate grazing in the aDGVM[11]. This grazing model was adapted from the elephant-impact model developed by Scheiter and Higgins (2012), and adapted to simulate the effects of grazing by both cattle and goats within a given area. The results of simulations with the aDGVM and grazing sub-model can allow interpretation of impacts of different scenarios on vegetation structure (proportions of tree and grass biomass) and function (carbon allocation).

The aDGVM simulates two both grasses (using C_4 photosynthetic pathway) and trees (using C_3 photosynthetic pathway), and assumes that both are regulated by the same biophysical processes, including photosynthesis, allocation, phenology, biomass and allometry (Scheiter and Higgins, 2010a). These are determined by the soil (GSDTG, 2000) and climate input data (New et al., 2002).

In the aDGVM, each grass and tree individual consists of eight different biomass pools, which are divided into living and dead biomass pools. The living biomass pools are root biomass, stem biomass and leaf biomass. The dead biomass pools are standing dead stem and leaf biomass and, stem and leaf litter and dead root biomass (Scheiter and Higgins, 2008b).

Adapted from the parameters of the elephant-impact model, the grazing sub-model is designed to calculate the amount of grass and tree biomass a livestock

[11] The aDGVM and grazing sub-model are programmed in C++ and have been implemented in this study on the Dev-C++ Bloodshed platform on a Windows operating system.

population removes from a stand (defined as being 1 hectare) of savannah vegetation. Livestock visit a stand at a fixed frequency of times per year and consume biomass according to the following equation (Scheiter and Higgins, 2010b).

While the grazing sub-model is not spatially explicit, there is a habitat-selectivity function (c) built in that distributes the livestock population according to perceived habitat quality (Scheiter and Higgins, 2012). When $c = 1$, cows and goats are evenly distributed across their area, while values greater than one indicate that livestock concentrate in a fraction $1/c$ of the total area. In these experiments, the habitat selectivity factor is a parameter that is altered. However, within each experiment the value is the same for both cows and goats. This is not necessarily directly representative of real-world grazing systems, where goats and cows are grazed under different regimes, but this approach is judged to be sufficient given the broad nature of this modelling exercise.

$$C_v = c\,(N_c + N_g)\,(C_{cow} + C_{goat})\ /\ A \qquad (1)$$

Here, C_v is biomass consumed per livestock visit in kilograms per hectare (kg ha^{-1}). N_c is the number of cows and N_g is the number of goats. C_{cow} is the biomass required per cow per day (kg day^{-1}) and C_{goat} is the biomass required per goat per day (kg day^{-1}). A is the area of the vegetation (ha).

Grazing by cattle (C_{cow}) is simulated by removal of grass biomass from the aboveground standing grass biomass pools in kilograms per day per hectare (kg day^{-1} ha^{-1}) as follows:

$$C_{cow} = p_g C_v \qquad (2)$$

This reflects the preference of cattle, which are selective grazers, for nutritious forage. Cattle are not able to digest coarse or woody vegetation therefore do not consume from material from trees. It is assumed there is a maximum leaf removal of grasses while grazing and that a proportion of the standing aboveground grass biomass is not accessible to grazing ($1 - r_{pg}$).

Goats are mixed feeders and achieve their daily biomass requirement through both grazing (C_g) and browsing (C_t), as follows:

$$C_{goat} = C_g + C_t \tag{3}$$

$$C_g = p_g C_v \tag{4}$$

$$C_t = p_t C_v \tag{5}$$

Goat grazing is simulated by removal of aboveground standing grass biomass, both living and dead. Again, it is assumed there is a maximum leaf removal of grasses (1 – r_{pg}).

Goat browsing is simulated by removal of living leaf biomass (B_{ll}) and dead hanging leaf biomass (B_{lh}) of a tree, as follows:

$$C_{ll} = \min\,(r_{pt}\,B_{ll}, B_{max}) \tag{6}$$

$$C_{lh} = \min\,(r_{pt}\,B_{lh}, B_{max}) \tag{7}$$

The absolute amount of biomass removed per tree does not exceed some maximum B_{max}. Goats also remove twigs and small branches while they consume tree leaf biomass, which is simulated by removing some biomass from the stem biomass (C_s). The actual amount removed is assumed to be proportional (r_{st}) to the amount of leaf biomass removed and cannot exceed the total stem biomass of the browsed tree, such that:

$$C_s = \min\,(r_{st}\,(C_{ll} + C_{lh}), B_s) \tag{8}$$

There is also a diet-partitioning factor to account for the proportion of grass and tree biomass in the diet of goats (Scheiter and Higgins, 2012), as follows:

$$p_g(\Theta_g) = 1 / 1 + \exp\,(\alpha - \Theta_g / \beta) \tag{9}$$

$$p_g(\Theta_g) = 1 - p_g\,(\Theta_g) \tag{10}$$

The percentage soil moisture content (Θ_g) is used to calculate the percentage of grass (p_g) and tree (p_t) biomass in goat diet (*ibid.*). The diet-partitioning factor currently assumes a preference for grass up to a certain threshold for soil moisture content (α), after which the goats include more and more trees in their diet (β). This rule does not apply to cattle (which are grazers). It is important to note that the grazing sub-model does not take account of livestock behaviour or population dynamics. Table 7.1 below includes the parameters developed for the grazing sub-model.

Table 7.1: Summary of all parameters and variables used in the grazing sub-model

Parameter	Description	Type	Value	Unit
v	Livestock visitation frequency	parameter	-	per year
c	Habitat selectivity factor	parameter	-	unitless
N_c	Number of cows	parameter	-	animals
N_g	Number of goats	parameter	-	animals
C_{cow}	Biomass consumption (cows)	constant	10	kg/day/ha
C_{goat}	Biomass consumption (goats)	constant	2	kg/day/ha
r_{pg}	Maximum leaf removal of grass	constant	90	%
α	Diet partitioning factor (goats only)	parameter	0.5	unitless
β	Diet partitioning factor (goats only)	constant	0.1	unitless
g	Grazing rate of other herbivores	parameter	-	kg/day/ha
A	Area	parameter	-	ha
Θ	Soil moisture content	variable	-	%
C_g	Proportion of grasses in diet (goats only)	variable	-	%
C_t	Proportion of trees in diet (goats only)	variable	-	%
r_{pt}	Maximum leaf removal of trees	parameter	90	%
B_{max}	Maximum leaf removal of trees	constant	4.3	kg
B_{ll}	Living tree biomass	variable	-	kg
B_{lh}	Dead hanging tree biomass	variable	-	kg
B_s	Tree stem biomass	variable	-	kg
C_{ll}	Removal from living leaves	variable	-	kg
C_{lh}	Removal from dead leaves	variable	-	kg
C_s	Removal from stem	variable	-	kg
r_{st}	Factor for stem biomass removal	constant	3	unitless

Carbon balance and allocation is implemented in the aDGVM using the Yasso soil-carbon model (Liski et al., 2005) for soil-carbon pools and the allocation concepts of Tilman (1988) and Friedlingstein *et al.* (1999) for carbon allocation in living biomass pools. In this way, the aDGVM can calculate the fluxes of carbon within a simulation run, allowing calculation of net primary productivity and net ecosystem exchange outputs that are of interest in the experiments described below.

The sensitivity of the parameters used in the grazing sub-model has been tested in experiments used by the elephant impact and sub-model as described in Scheiter and Higgins (2012). Similarly, the ability of the aDGVM to predict current and future vegetation patterns has been extensively evaluated as described in Scheiter and Higgins (2009). The aDGVM has been shown to model vegetation cover and structure in Africa better than the available alternative models can (Scheiter and Higgins, 2009).

The grazing sub-model can be implemented with the aDGVM as a compiler option, and can be used simultaneously with a climate-change-scenario compiler option, which simulates ambient (2010) climate or a medium greenhouse gas emissions scenario representing projected 2100 climate, compared to the period 1961-1990. This is the A1B scenario from the Max Planck Institute for Meteorology (Hamburg) ECHAM5 IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2007). The A1 scenario family assumes very high economic growth, global population peaking mid-century and then declining, and energy needs being met by a balance of fossil fuels and alternative technologies (*ibid.*). A1B (a subset of the A1 family) lies near the high end of the spectrum for future greenhouse gas emissions, particularly through mid-century (*ibid.*). I have used A1B as the climate change scenario here on the basis that it represents the more likely trajectory for emissions in Africa. Lying at the higher end of the emissions spectrum in the IPCC *Fourth Assessment Report* (2007), A1B is also more aligned with the Representative Concentration Pathways (RCP) scenarios used in the more recent IPCC's *Fifth Assessment Report* (2013), where it sits approximately mid-way between the low- and high- emissions RCP scenarios (see Figure 7.1).

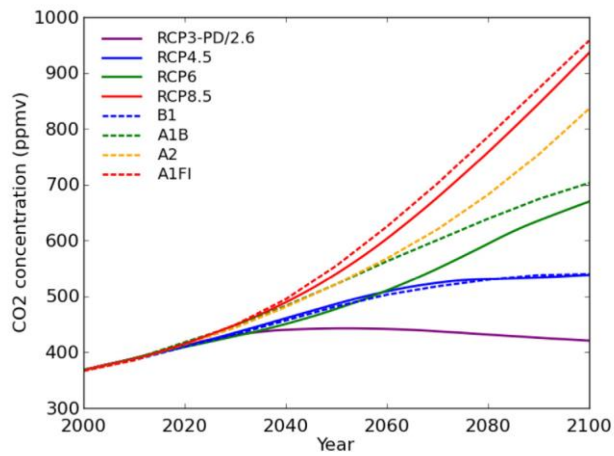


Figure 7.1. Comparison of carbon dioxide concentrations (in parts per million by volume) for the 21st century from RCPs and SRES scenarios. RCP 6 is closest to A1B (source: Jubb et al., 2013).

The aDGVM with grazing sub-model can be run with different climate and land-tenure scenarios, depending on the parameters of these climate change and grazing options. The next section will describe the simulation experiments carried out using these models.

7.3 Simulation experiments

For this analysis, I used a 2^3 factorial experimental design to explore the effects of climate change and land-tenure scenarios on vegetation structure and function of the Amboseli system. The three experiments designed for this study are described below.

7.3.1 Experiment 1 – Climate change with grazing / no grazing

This experiment was designed to compare runs with and without the grazing sub-model under both climate conditions. Treating climate and grazing as factors, simulations were carried out as follows (see Table 7.3 for parameterisation):

- ambient climate and no grazing

- 2100 climate and no grazing
- ambient climate with grazing (communal group ranch)
- 2100 climate with grazing (communal group ranch)

7.3.2 Experiment 2 – Climate change with enclosure

This experiment was designed to address the question of how enclosure of key areas of the communal group ranches might impact on vegetation structure and function. The aim here was to simulate a scenario to represent some of the shifting land uses in Mbirikani, for example, including conversion of land for gypsum mining, conservancy or farms for cultivation, such as those along the pipeline (see Chapter 5). The following simulations were carried out:

- ambient climate and 100% communal group ranch (no enclosure)
- 2100 climate and 100% communal group ranch (no enclosure)
- ambient climate with 85% communal group ranch (enclosure)
- 2100 climate with 85% communal group ranch (enclosure)

7.3.3 Experiment 3 – Climate change with subdivision

This experiment was designed to address the question of how subdivision of the communal group ranches might impact on vegetation structure and function. To achieve this, the parameters were adjusted to represent a plot based on studies and already subdivided areas, e.g. Kaputei, (see Table 7.3 for parameterisation).

- ambient climate and communal group ranch
- 2100 climate and communal group ranch
- ambient climate with subdivided plots
- 2100 climate with subdivided plot

In order to obtain more reliable estimates of the effects of climate change, subdivision and enclosure, a two-phase spin-up process was used. The first spin-up phase (years 1 – 150) did not include any grazing and the second spin-up phase (years 151 – 350) introduced grazing. The analyses use the mean values of response variables for the 150-year period that follows both spin-up phases (years 351 – 500).

For the purposes of these experiments, Mbirikani Group Ranch was used as an example system. This is because enclosure has occurred in this area, so indicative parameters can be derived, and data on livestock numbers and potential plot sizes under subdivision are available. By this I mean that the parameters set were based on data for Mbirikani, such as area (125,000 ha), number of cattle, size of potential plots, and so on. The input parameters selected for these simulation runs were based on the literature where appropriate (see Table 7.2)

Table 7.2: aDGVM input parameters with grazing sub-model (italics indicate key variables for Experiment 1-3

	Parameter	Value	Notes
1.	Initial tree population	20	Figure based on sensitivity analysis and estimated tree cover of Mbirikani GR
2.	Number of years to run simulation (yrs)	500	Includes two-phase spin up (see above)
3.	Longitude of study site (Lon)	37.31	Longitude of Mbirikani GR
4.	Latitude of study site (Lat)	02.11	Latitude of Mbirikani GR
5.	Run with/without fire	0	Fire is not a common feature of the Amboseli system, 0=no fire
6.	Initial value for rSeed	0.5	rSeed is a random number generator used in the aDGVM
7.	*Climate change scenario*	*0 or 3*	*0=ambient (2010) and 3=SRES A1B (IPCC, 2007)*
8.	*Name of output directory*	*MGR_1-8*	-
9.	*Visitation frequency*	2/14	Based on communal grazing on biannual rotation or sedentary plots (Boone and Coughenour, 2001)
10.	*Habitat selectivity factor*	*1/1.18*	*Representing 100% and 85% communal GR available for grazing respectively*
11.	Max. consumption per tree (goats only)	0.9	Trees in Mbirikani are generally very small, goats will eat 90% of available biomass (Field, 1979)
12.	*Number of cows*	*44,000 / 18*	*Estimated number of cows in Mbirikani (Ntiati, 2002) and in plots respectively (Boone and Coughenour, 2001)*
13.	*Number of goats*	*17,000 / 8*	*Estimated number of goats in Mbirikani (Ntiati, 2002) and in plots respectively (Boone & Coughenour, 2001)*
14.	Diet partitioning factor (goats only)	0.5	Goats prefer grass and tree biomass equally (50:50) if available (Field, 1979)
15.	Daily biomass requirement cows (kg)	10	(King, 1983)
16.	Daily biomass requirement goats (kg)	2	(King, 1983)
17.	Grazing rate of other herbivores	0	This parameter can represent grazing wildlife species, but is not implemented in these experiments
18.	*Area (ha)*	*125,000 / 27*	*Area of Mbirikani GR (Southgate and Hulme, 2000) and area of plot calculated by number of registered members (Ntiati, 2002)*

Table 7.3: Parameters of each simulation run in each 2^3 factorial experiment

EXPT.	Test Directory	A. CLIMATE CHANGE	Clim_Scen	B. PLOTS	Area*	Visitation frequency	Number of cows	Number of goats	C. ENCLOSURE	Habitat selectivity
1	MGR_1	Ambient	0	No	125,000	2	44,000	17,000	No	1
	MGR_2	2100	3	No	125,000	2	44,000	17,000	No	1
	MGR_3	Ambient	0	No	125,000	-	0	0	No	-
	MGR_4	2100	3	No	125,000	-	0	0	No	-
2	MGR_1	Ambient	0	No	125,000	2	44,000	17,000	No	1
	MGR_2	2100	3	No	125,000	2	44,000	17,000	No	1
	MGR_5	Ambient	0	No	125,000	2	44,000	17,000	85% left	1.18
	MGR_6	2100	3	No	125,000	2	44,000	17,000	85% left	1.18
3	MGR_1	Ambient	0	No	125,000	2	44,000	17,000	No	1
	MGR_2	2100	3	No	125,000	2	44,000	17,000	No	1
	MGR_7	Ambient	0	Yes	27	14	18	8	No	1
	MGR_8	2100	3	Yes	27	14	18	8	No	1

7.4 Analysis

After running the simulation experiments, output data on six variables were selected for analysis and collected for each day of 500 years. These variables were grass biomass (kg/m^2), grass net primary productivity (kg C/m^2), tree biomass (kg/m^2), tree net primary productivity (kg C/m^2), tree population (number) and net ecosystem exchange (kg C/m^2). The model outputs for the two spin-up phases (see above) were discarded and data for years 351-500 exported to R for analysis.

Carrying out statistical analysis on very large sample sizes is problematic as significant effects can easily be found. To overcome this constraint, where n=219,000 per experiment, data was aggregated into yearly, rather than daily, data giving a sample size of 600 per experiment. The boxplots of response variables by climate and land-tenure effects are presented for each experiment in Figures 7.2-7.4.

First, the distributions of each response variable were checked for normality using Q-Q plots (see Appendix 2 for results) for each experiment. In all cases, the data were not normally distributed. While some variables improved with log transformation (see Appendix 2 for Q-Q plots of transformed data), they still could not be considered normally distributed. Therefore, analysis of variance (ANOVA) was not a possible significance test, due to violation of the normality assumption. Square root and Box-Cox transformations were also attempted but did not normalise the data.

Instead, Generalised Linear Models (GLMs) were fitted to each response variable. GLMs are common parametric models employed by plant ecologists to model responses to environmental data. Gamma and Gaussian GLM families were fitted and the best model selected using diagnostic plots (see Appendix 2 for diagnostics of each response variable in each experiment) and the Akaike Information Criteria (AIC) (Yee and Mitchell, 1991, Franklin, 1995). Some of the response variables fitted the Gamma or Gaussian GLMs better than others (i.e. grass biomass, grass net primary productivity).

7.5 Results

The following sections assess the effects of climate and land tenure on these variables, both qualitatively from trends observable in the boxplots shown in Figures 7.2 to 7.4, from descriptive statistics (see Tables 7.4-7.9) and statistically from fitting GLMs to their distributions (see Appendix 2).

7.5.1 Experiment 1 – effects of climate and communal grazing compared to no grazing

Statistically, climate has a significant effect on all response variables ($P<0.0005$). Under scenario A1B, tree population, tree biomass and tree net primary productivity are all qualitatively and statistically significantly greater than at ambient conditions. Conversely, grass biomass and grass net primary productivity are both significantly lower with 2100 conditions compared to ambient conditions, with carbon being released from the grass and soil carbon pools into the atmosphere. Net ecosystem exchange is significantly greater under 2100 conditions, with the increase in tree primary productivity accounting for the net uptake of carbon by vegetation.

Table 7.4: Descriptive statistics for Experiment 1 response variables by climate

Response variable	Climate	Median value	Interquartile range
Grass biomass (kg/m^2)	Ambient	0.257	0.110
	2100	0.180	0.514
Grass net primary productivity ($kg\ C/m^2$)	Ambient	0.0003	1.19×10^{-4}
	2100	0.0002	0.82×10^{-4}
Tree biomass (kg/m^2)	Ambient	7.18	0.17
	2100	30.14	15.96
Tree net primary productivity ($kg\ C/m^2$)	Ambient	0.001	0.003
	2100	0.005	0.002
Tree population (number)	Ambient	1001	129
	2100	4030	674
Net ecosystem exchange ($kg\ C/m^2$)	Ambient	0.001	0.0003
	2100	0.004	0.0020

Table 7.5: Descriptive statistics for Experiment 1 response variables by land tenure

Response variable	Tenure	Median value	Interquartile range
Grass biomass (kg/m^2)	No grazing	0.208	0.095
	Communal grazing	0.215	0.088
Grass net primary productivity (kg C/m^2)	No grazing	0.0002	0.0001
	Communal grazing	0.0002	0.0001
Tree biomass (kg/m^2)	No grazing	11.3	22.7
	Communal grazing	10.3	23.1
Tree net primary productivity (kg C/m^2)	No grazing	0.002	0.005
	Communal grazing	0.001	0.005
Tree population (number)	No grazing	2029	3057
	Communal grazing	1939	3002
Net ecosystem exchange (kg C/m^2)	No grazing	0.0013	0.0034
	Communal grazing	0.0011	0.0033

Statistically, communal grazing does not appear to have a significant effect on any of the response variables compared to no grazing. In the case of tree population, the interaction between climate and grazing also has a significant effect ($P<0.05$). Qualitatively, there is a slight increase in the effect of communal grazing on average grass biomass (median=0.215 kg/m^2 compared to 0.208 kg/m^2). Grass net primary productivity appears constant under both no grazing and grazing conditions (median=0.002 kg/m^2 for both). This result is consistent with the increased grass productivity observed in savannahs when sustainably managed for grazing (Oba et al., 2000, McNaughton, 1979). Woody vegetation displays qualitatively lower median values under the effect of grazing, with tree biomass (median=10.3 kg/m^2 compared to 11.3 kg/m^2), tree net primary productivity (median=0.001 kg C/m^2 compared to 0.002 kg C/m^2) and tree population (median=1939 compared to 2029) marginally suppressed compared to no grazing. Net ecosystem exchange shows a slightly decreased median value with the effect of grazing (median=0.0011 kg C/m^2 compared to 0.0013 kg C/m^2), suggesting marginally less uptake of carbon by vegetation.

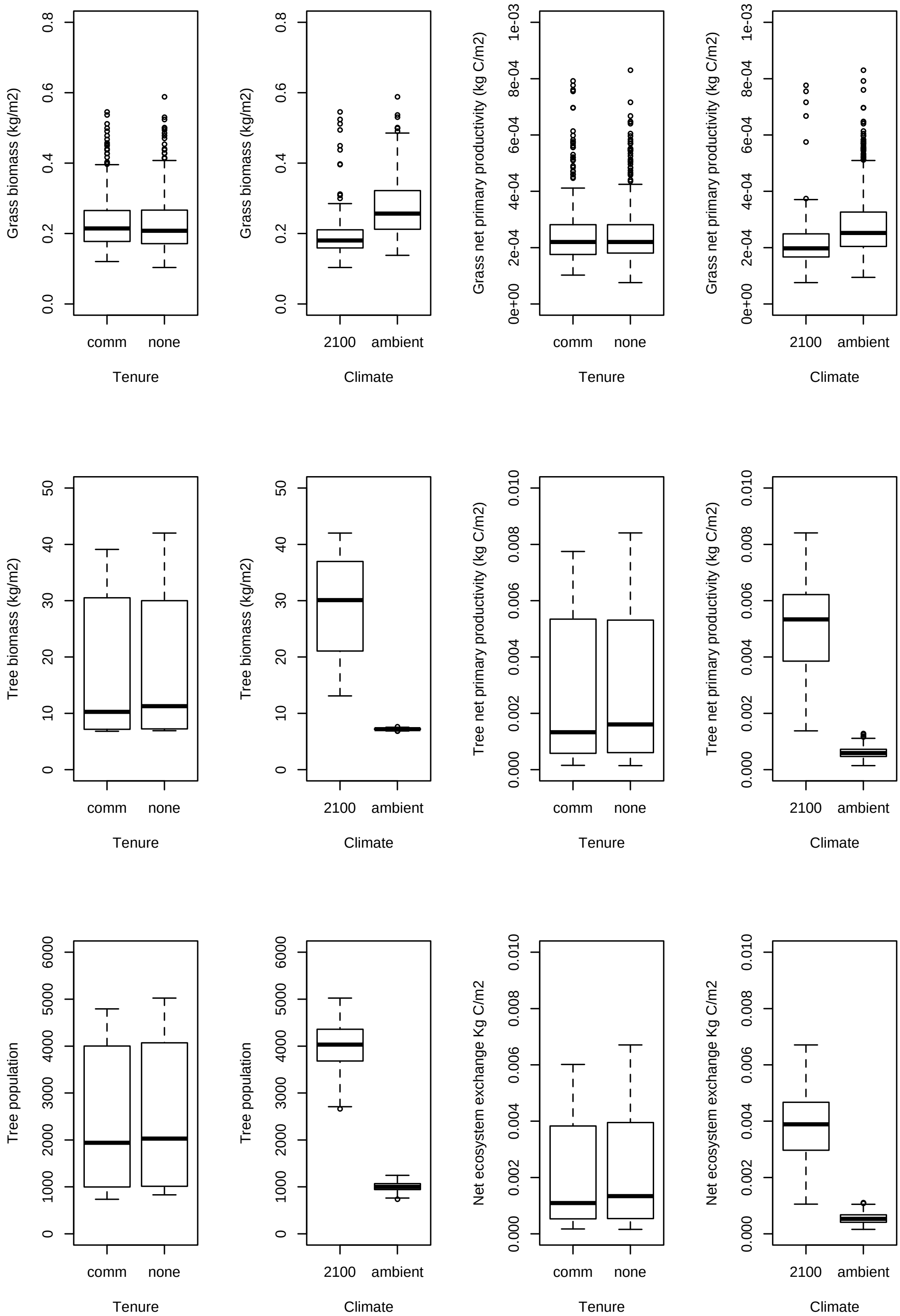


Figure 7.2: Outputs of Experiment 1 – effects of communal grazing and no grazing with climate change on six response variables ('comm' is communal grazing, 'none' is no grazing, '2100' is with climate change and 'ambient' is without climate change)

7.5.2 Experiment 2 – effects of climate and communal grazing with and without enclosure

As shown in Experiment 1, climate has a statistically significant effect on all response variables ($P<0.0005$). Under scenario A1B, tree population, tree biomass and tree net primary productivity are all qualitatively and statistically significantly greater than at ambient conditions. Conversely, grass biomass and grass net primary productivity are both significantly lower with 2100 conditions compared to ambient conditions, with carbon being released from the grass and soil-carbon pools into the atmosphere. Net ecosystem exchange is significantly greater under 2100 conditions, with the increase in tree primary productivity accounting for the net uptake of carbon by vegetation.

Table 7.6: Descriptive statistics for Experiment 2 response variables by climate

Response variable	Climate	Median value	Interquartile range
Grass biomass (kg/m^2)	Ambient	0.252	0.106
	2100	0.180	0.055
Grass net primary productivity (kg C/m^2)	Ambient	0.0002	8.42×10^{-5}
	2100	0.0002	0.13×10^{-5}
Tree biomass (kg/m^2)	Ambient	7.24	0.21
	2100	31.04	15.32
Tree net primary productivity (kg C/m^2)	Ambient	0.000	0.000
	2100	0.002	0.002
Tree population (number)	Ambient	1003	120
	2100	4029	743
Net ecosystem exchange (kg C/m^2)	Ambient	0.0005	0.000
	2100	0.0039	0.002

Table 7.7: Descriptive statistics for Experiment 2 response variables by land tenure

Response variable	Tenure	Median value	Interquartile range
Grass biomass (kg/m^2)	Enclosure (85%)	0.207	0.088
	Communal grazing	0.215	0.088
Grass net primary productivity (kg C/m^2)	Enclosure (85%)	0.0002	0.0001
	Communal grazing	0.0002	0.0001
Tree biomass (kg/m^2)	Enclosure (85%)	10.62	15.32
	Communal grazing	10.26	23.14
Tree net primary productivity (kg C/m^2)	Enclosure (85%)	0.002	0.005
	Communal grazing	0.001	0.005
Tree population (number)	Enclosure (85%)	1937	3058
	Communal grazing	1939	3002
Net ecosystem exchange (kg C/m^2)	Enclosure (85%)	0.0014	0.0034
	Communal grazing	0.0011	0.0033

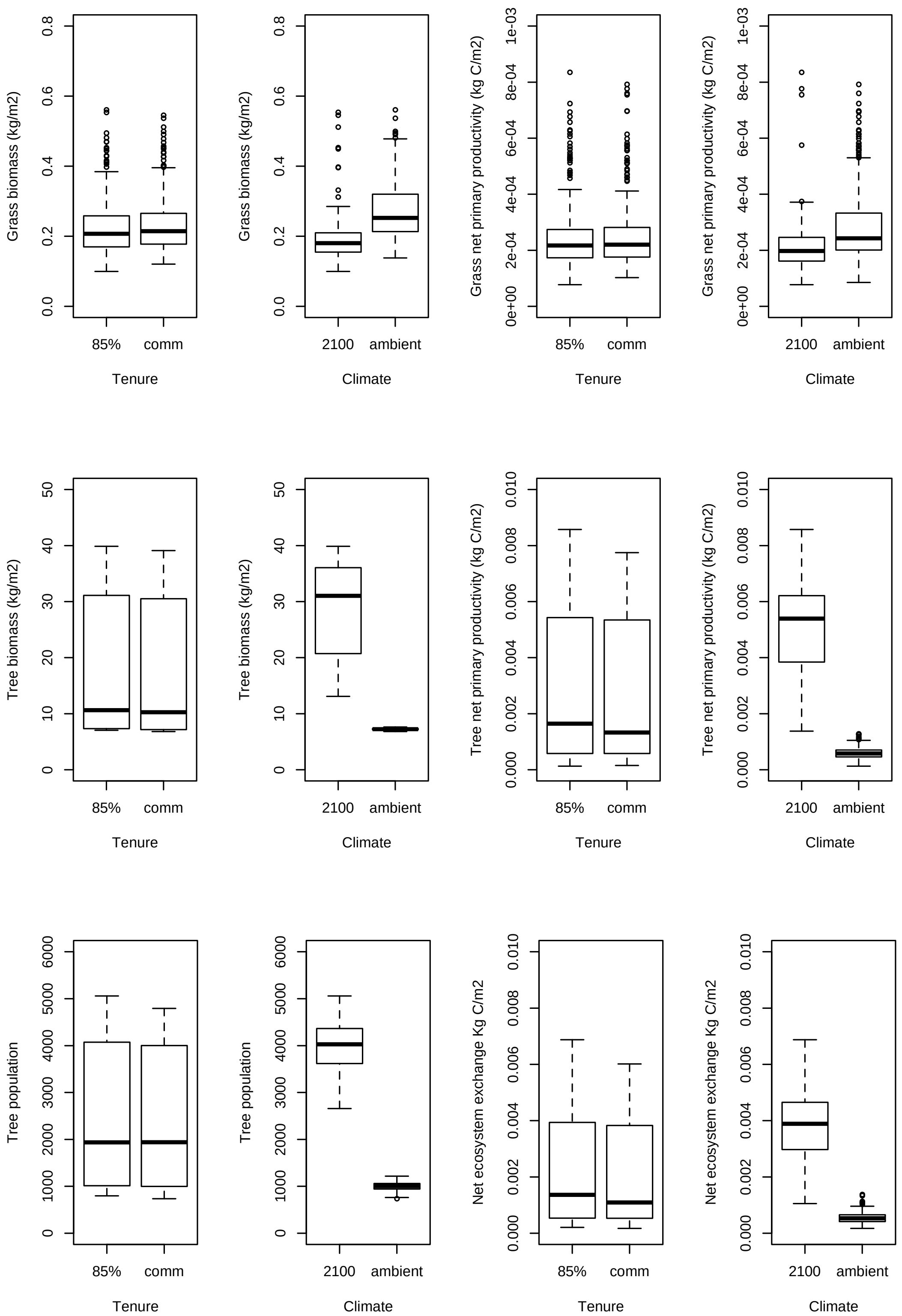


Figure 7.3: Outputs of Experiment 2 – effects of communal land tenure and enclosure with climate change on six response variables ('comm' is communal grazing, '85%' is enclosure, '2100' is with climate change and 'ambient' is without climate change)

Statistically, enclosure of 15% of communal grazing land does not appear to have a significant effect on any of the response variables, with the exceptions of grass biomass ($P<0.05$) and tree population ($P<0.1$). In both these cases, the interaction between climate and enclosure does not have a significant effect. With only 85% of grazing land available, grass biomass is significantly reduced (median=0.207 kg/m^2 compared to 0.215 kg/m^2). However, this effect on grass biomass does not appear to have a similar qualitative effect on grass net primary productivity (median=-0.0002 under both tenure conditions). With enclosure, tree population is statistically significantly affected, albeit only be two trees (median=1937 compared to 1939). There does appear to be a qualitative effect on tree biomass (median=10.62 kg/m^2 compared to 10.36 kg/m^2) and tree net primary productivity (median=0.002 kg C/m^2 compared to 0.001 kg C/m^2), with marginal increases in both variables.

Qualitatively, net ecosystem exchange shows a slightly increased median value with the effect of enclosure (median=0.0014 kg C/m^2 compared to 0.0011 kg C/m^2), suggesting marginally higher uptake of carbon by vegetation.

7.5.3 Experiment 3 – effects of climate and communal grazing compared to subdivided plots

As with the previous two experiments, climate has a statistically significant effect on all response variables ($P<0005$). Under scenario A1B, tree population, tree biomass and tree net primary productivity are all qualitatively and statistically significantly greater than at ambient conditions. Conversely, grass biomass and grass net primary productivity are both significantly lower with 2100 conditions compared to ambient conditions, with carbon being released from the grass and soil carbon pools into the atmosphere. Net ecosystem exchange is significantly greater under 2100 conditions, with the increase in tree primary productivity accounting for the net uptake of carbon by vegetation.

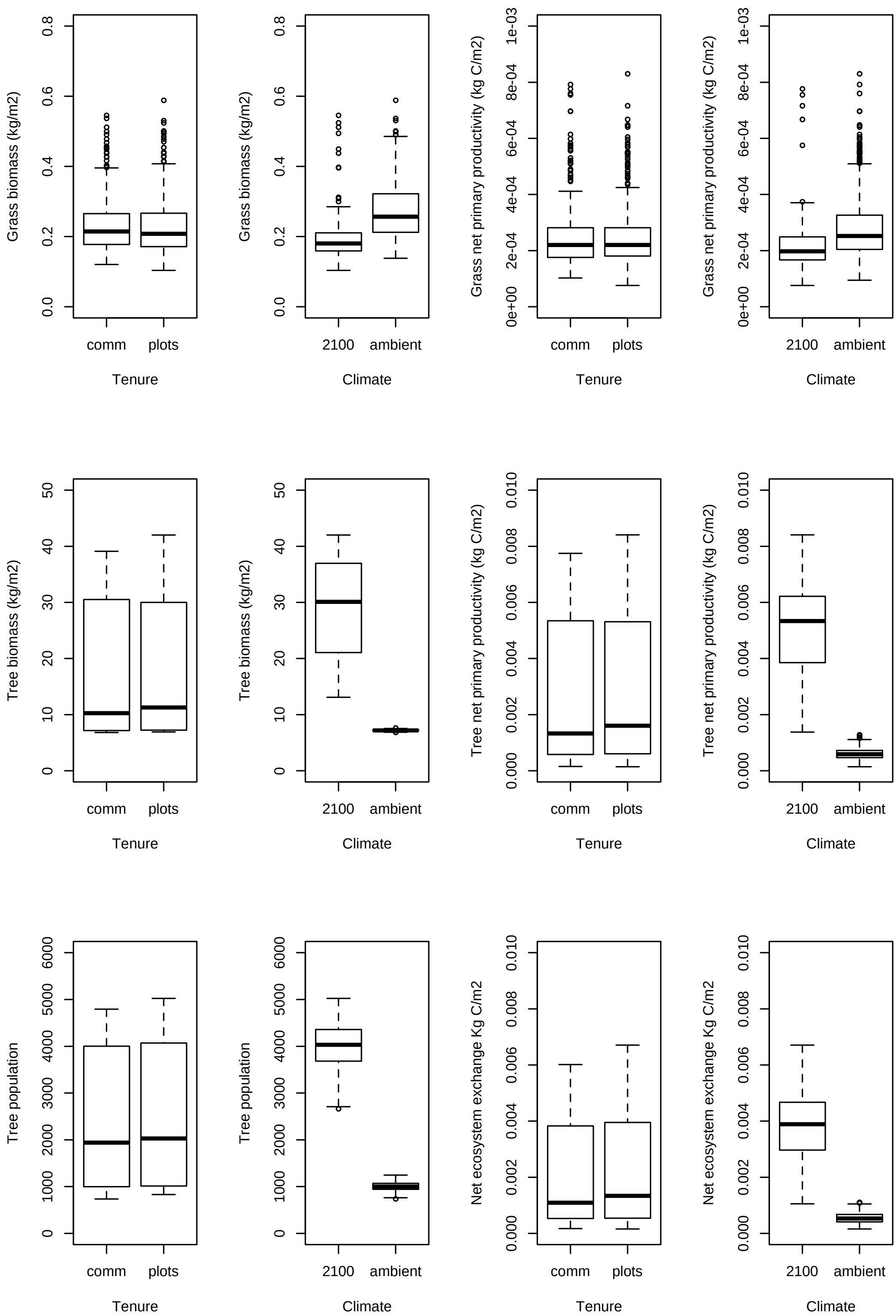


Figure 7.4: Outputs of Experiment 3 – effects of communal land tenure and private plots with climate change on six response variables ('comm' is communal grazing, 'plots' is a subdivided plot, '2100' is with climate change and 'ambient' is without climate change)

Table 7.8: Descriptive statistics for Experiment 3 response variables by climate

Response variable	Climate	Median value	Interquartile range
Grass biomass (kg/m^2)	Ambient	0.257	0.110
	2100	0.180	0.514
Grass net primary productivity (kg C/m^2)	Ambient	0.0002	1.19 x 10^{-4}
	2100	0.0002	0.82 x 10^{-4}
Tree biomass (kg/m^2)	Ambient	7.18	0.17
	2100	30.09	15.85
Tree net primary productivity (kg C/m^2)	Ambient	0.000	0.000
	2100	0.002	0.002
Tree population (number)	Ambient	1001	129
	2100	4030	674
Net ecosystem exchange (kg C/m^2)	Ambient	0.0005	0.0003
	2100	0.0039	0.0017

Table 7.9: Descriptive statistics for Experiment 3 response variables by land tenure

Response variable	Tenure	Median value	Interquartile range
Grass biomass (kg/m^2)	Plots	0.208	0.095
	Communal grazing	0.215	0.088
Grass net primary productivity (kg C/m^2)	Plots	0.0002	0.0001
	Communal grazing	0.0002	0.0001
Tree biomass (kg/m^2)	Plots	11.3	22.7
	Communal grazing	10.3	23.1
Tree net primary productivity (kg C/m^2)	Plots	0.002	0.005
	Communal grazing	0.001	0.005
Tree population (number)	Plots	2029	3057
	Communal grazing	1939	3002
Net ecosystem exchange (kg C/m^2)	Plots	0.0013	0.0034
	Communal grazing	0.0011	0.0033

Statistically, subdividing communal grazing land into private plots does not have a significant effect on any of the response variables, with the exception of tree population ($P<0.01$). However, the interaction between climate and land tenure does not have a significant effect on tree population. With plots, tree population is significantly decreased (median=1937 compared to 2029). There does appear to be a corresponding qualitative effect on tree biomass (median=11.27 kg/m^2 compared to 10.26 kg/m^2) and tree net primary productivity (median=0.002 kg C/m^2 compared to 0.001 kg C/m^2), with marginal increases in both variables with plots.

Grass biomass is qualitatively affected by subdivision, with marginally depressed biomass with plots (median=0.208 kg/m^2 compared to 0.215 kg/m^2). However, grass net primary productivity remains constant (median=0.0002 kg C/m^2 in both land tenure scenarios). Qualitatively, net ecosystem exchange shows a slightly increased median value with the effect of subdivision (median=0.0013 kg C/m^2 compared to 0.0011 kg C/m^2), suggesting marginally higher uptake of carbon by vegetation.

7.6 Discussion

In general, the results of all three experiments suggest a reduction in grass biomass and net primary productivity and increase in tree biomass and net primary productivity with the effects of land tenure and climate change. In all three experiments, the effects of grazing and land tenure are negligible relative to the significant effects of climate change.

7.6.1 Effect of land tenure on vegetation structure and function

The results show only marginal effects of grazing on the structure and function of vegetation in the system. In interpreting these results, it is important to note that the parameterisation of communal grazing in the grazing sub-model represent the average conditions of the Amboseli system in terms of livestock numbers and visitation frequency. The management of rangelands for communal grazing in this way is considered the most sustainable use of semi-arid grasslands (FAO, 2009). Therefore, we would not expect to see significant negative effects of communal grazing on the system. Limitations of the grazing sub-model include the selection of single populations of cattle and goats as input parameters and the lack of livestock behaviour or population dynamics. The number of livestock in the Amboseli system is extremely difficult to estimate due to the challenges of counting mobile populations over large areas. Few livestock, or even human population, censuses have been made at local scales[12] and the number of livestock fluctuates hugely between seasons and between years. The numbers of cattle and goats used in input parameters 12 and 13 here have been selected through review of the limited

[12] Ntiati, 2002 documents the last, most-cited census of group ranch members carried out for the group ranches of Kajiado District in 2001

census and informal data available, but clearly represent a snapshot of possible livestock numbers on Mbirikani Group Ranch. Several alternative numbers of livestock were tested within the limits of estimates in the literature. In general, the aDGVM with grazing sub-model was not highly sensitive to the numbers of cattle or goats within these limits, although some effect was detected.

The model shows reinforcement of the general pattern of decreased grass biomass and increased tree biomass with enclosure of 15% of the rangeland. These results suggest that limiting the mobility of livestock has an effect on vegetation structure and function. In this simulation, 85% of the rangeland has been open to grazing. However, the remaining 15% does not represent a different land use, such as the gypsum mine, tarmac road or agriculture, rather represents natural savannah vegetation. Thus, this simulation of enclosure does not accurately simulate land-use change, which may present more significant overall effects on vegetation structure and function.

The simulation of plots in Experiment 3 shows very similar results to the comparison of communal grazing and no grazing in Experiment 1. This is an interesting example of the limitations of the model to capture complex dynamics. The aDGVM is not spatially explicit and each hectare stand is modelled separately with no interaction between them. The model therefore does not capture seed dispersal or the transport of nutrients and water between stands, which is clearly a major simplification of savannah dynamics. For this reason, reducing the overall area of vegetation simulated (via input parameter 18) along with reducing the number of livestock to represent average plot holdings, can be expected to give similar results to a larger area with a greater number of livestock (like the Experiment 1 results).

7.6.2 Effect of climate change on vegetation structure and function

The results for all three experiments show that climate change, as represented by the simulation of SRES A1B at 2100, has a significant effect in decreasing the biomass and net primary productivity of the grass population. This effect is consistent with the literature, which suggests the fertilisation effect of increased atmospheric carbon dioxide concentrations (Scholes and Archer, 1997, Bond and Midgley, 2000, Bond and Midgley, 2012). This effect is caused by the increased competitive advantage of C_3 trees over C_4 grasses, due to the physiological ability of the former to take up additional atmospheric carbon dioxide for photosynthesis relative to the latter (Polley, 1997, Navas, 1998, Campbell and Stafford Smith, 2000).

This effect is further reinforced by the results for the tree response variables, which suggest that climate change is likely to have a significant effect on the encroachment of woody vegetation in the Amboseli system. While this may increase net ecosystem exchange of carbon (see Figures 7.1-7.3), which will in turn likely have a positive effect on carbon sequestration and the mitigation of climate change at a regional scale, the impacts may be severe at the local level. For example, the frequency and distribution of fire may increase with increasing fuel load (Bond and Midgley, 2012, Scheiter and Higgins, 2009) and forage will become less palatable for cattle as the proportion of annual grasses increases relative perennial species (O'Connor, 1994), and carbon- and nitrogen-based toxins become more prevalent for herbivores (Cavagnaro et al., 2011). These are complex dynamics that are not picked up by the grass super-individuals modelled in the aDGVM.

These results show the effects of climate change to be significantly serious in terms of reducing grass biomass and net primary productivity and increasing tree population, biomass and net primary productivity. Considering the projected trends for moderate temperature rise, increased rainfall trends and reduced drying trend are relatively mild in comparison to Southern Africa, for example, (IPCC, 2014a), these effects are still predicted by the aDGVM to have an impact on savannah structure and function and therefore pastoral livelihoods. Reflecting on the findings of Chapter 4, it is interesting to consider the implications of changes in the structure of savannah vegetation for place identity. An increase in tree biomass and tree cover would fundamentally alter the landscape, and possibly the relationships with those who inhabit them.

7.7 Cattle and carbon

Land-use change is both a cause and a consequence of climate change. Land-use change is also a major driver of observed ecosystem change (MEA, 2005) and in the conversion of savannah, grassland and pastures to agriculture is the second largest land-use change in the tropics after deforestation (Hosonuma et al., 2012). As well as altering the concentrations of greenhouse gases in the atmosphere, land-use change can alter surface-level dynamics such as wind profiles, energy balances and evapotranspiration, and can contribute to the albedo effect of surface cover or clouds. These dynamics are well accounted for in the aDGVM. However, land-use change has been assessed as a small driver of climate change globally, but a very important dynamic locally (Brovkin et al., 2013). The results presented here are likely to be underestimating the local impacts of land tenure, particularly as the input data used is global and alternative land uses, primarily agriculture, have not been simulated here.

The carbon sequestration potential of the Amboseli system is highlighted by the results of these experiments. Climate-change mitigation through Reduction of Emissions through Deforestation and forest Degradation (REDD) and similar schemes has been implemented with varying success in forest ecosystems (IIED, 2009). The potential of grassland systems for carbon sequestration has also been recognised (FAO, 2009). Already carbon finance schemes are gaining traction in the Amboseli system. One scheme managed by Jadora with Soils for the Future aims to value the sustainable management of the entire system under communal grazing for carbon sequestration (Jadora LLC, 2012). The Mbirikani Carbon Project, managed by the African Wildlife Foundation, has assessed the potential for forest resources on the inaccessible lava fields and cloud forests of the Chyulu Hills and is seeking certification from the Voluntary Carbon Standard for a voluntary carbon market (AWF, 2011). I observed some enthusiasm amongst the Mbirikani community for these alternative sources of income. Although the commercial aspect of these schemes appeals to the Group Ranch Committee in Mbirikani there are likely to be issues with the implementation. For instance, the carbon sequestration in grasslands depends on sustainable grazing management, and in the case of semi-arid areas this requires herd mobility and communal land tenure. As such, there is potential for tension between this aim and the desire to subdivide into private plots. Also, it should be noted that the reliability of these schemes is highly dependent on climate-finance streams and the performance of the schemes in sequestering carbon in the longer term, and revenue sharing between Group Ranch members is likely to be an on-going issue, as exemplified in Chapter 5. In general, rangelands offer particular challenges to community-based payments for ecosystems services schemes such as these, which also apply to Amboseli. There are limitations in setting boundaries, in land tenure arrangements and in local capacity for managing these schemes (Dougill et al., 2012). Lessons learned from carbon sequestration schemes in forest systems indicate the need for strong institutions, clear land tenure arrangements, community control over land management decision-making and upfront flexible payment schemes (Ibid.).

7.8 Summary

The key message from this chapter, is that models are abstract, based on mechanistic understandings of processes and, in cases as complex as the aDGVM, contain many other sub-models with their own inherent assumptions. DGVMs are typically based on global data and have had great value in indicating dynamics of interest and importance at global scales. In this case, the effects of climate change on vegetation structure and function are clear and add evidence to the findings of the previous chapters regarding the implications of climate change for system resilience. Additionally, the effects of land tenure are hinted at with qualitative observations, if not supported with statistically significant results. However, as the discussion above demonstrates, capturing complexity and local specificities are significant challenges in any such models. Devising scenarios for testing the effect of land tenure here was constrained by the architecture of the model and the important complexity behind land-use strategies as described in Chapters 4-6 is difficult to reflect. With time and effort, models can be improved almost infinitely and one must “Remember that all models are wrong: the practical question is how wrong do they have to be to not be useful” (Box and Draper, 1987: 74)

When management and policy decisions are based solely on mechanistic models, without consideration of power dynamics, place-specific context, traditional knowledge and other social and cultural factors, unexpected and desirable outcomes can arise. As discussed in Chapter 6, rangeland management and pastoral livelihoods have suffered more than most in this respect. I have taken the integration of the results and lessons learned in designing these simulation experiments in the spirit of Joshua Epstein (2008: 4) “Models can surprise us, make us curious, and lead to new questions.” In the next chapter, I will address what these new questions might be.

CHAPTER 8. CONCLUSIONS

8.1 Introduction

The aim of this research was to investigate the dynamics of land-use change and climate change of the Amboseli system in southern Kenya, and the implications of these drivers of change for the social-ecological resilience of the system. Semi-arid systems such as Amboseli are highly vulnerable to the impacts of climate change and are also undergoing rapid processes of change, including fragmentation of rangelands. At the same time, these systems support an estimated 1 billion people worldwide (FAO, 2009) and have relatively unrecognised economic potential to contribute to sustainable development in countries like Kenya.

In addressing this research aim, I have employed a mixed methodology, using a qualitative approach to understand the responses of the Mbirikani and Eselenkei Group Ranch communities to the 2009 drought. I have also used modelling, including agent-based modelling and vegetation modelling approaches, to integrate these qualitative findings with explorations of longer-term processes of land-use change and climate change.

In this chapter, I will discuss the empirical findings of this research with respect to each of the research objectives in turn, before reflecting on the theoretical and policy implications of this work. Finally, recommendations for building on this research and suggested further work are presented.

8.2 Empirical findings

As described in Chapter 3, three research objectives were addressed to achieve the research aim. In this section, the empirical findings that support these objectives will be discussed in turn.

8.2.1 Responses to the 2009 drought as a particularly extreme weather event and the implications of these responses for the adaptive capacity of pastoralists in the Amboseli social-ecological system

It is clear from Chapter 4, that the responses of different individuals and communities to the 2009 drought were mediated by their particular place identities, cultural norms and lived experience of the drought. Almost all participants from both Mbirikani and Eselenkei Group Ranches lost the majority, if not all, of their livestock during 2009-2010. Living in these communities during this time, I experienced the sense of crisis in making decisions about how to cope with a shock that exceeded those experienced by the current generation of herders and many of their fathers. Many individuals, as exemplified by the story of the herder Maitera in section 4.4.1 of this thesis, underwent extraordinary journeys to maintain their families' herds, travelling far beyond their usual dry season routes.

Returning to the field in 2011 for my PhD research, I sensed a different mood. In the aftermath of the drought and its devastating impacts on livestock, the landscape and livelihoods, the same individuals referred to above appeared to be experiencing a sense of personal and collective trauma. Returning again in early 2013, evidence of how the lived experience of the drought had influenced the land-use and livelihoods decisions of research participants was clear. My findings from across these periods of time show the particular experiences of these individuals have had an impact on their relationship with their 'place', with their landscapes, with their herds and with the future of their way of life as pastoralists.

In the specific context of the Amboseli system, my findings demonstrate that the extreme 2009 drought has affected the Maasai's sense of place identity by impacting on elements of place identity. These elements are: environmental skills and self-efficacy; continuity and emotional attachment; distinctiveness, uniqueness, self-esteem and sense of belonging; social connections; and, security and commitment to place (Fresque-Baxter and Armitage, 2012). My findings go on to show that these impacts are influencing the collective decision to subdivide the communal Group Ranches into privately owned plots, a likely maladaptive response in terms of resilience to climate change. My findings also show how the responses of outside actors (namely conservationists, researchers and tourists) to the 2009 drought and its devastating impacts on wildlife populations and the tourism industry, are playing into the complexity of factors affecting land-use decisions in the Amboseli system.

Broadly speaking, my findings are in line with a burgeoning body of research recognising the psychological and cultural impacts of climate change and the importance of these for adaptive capacity and building resilience in specific contexts (Albrecht, 2006, Doherty and Clayton, 2011, Stain et al., 2011, Cunsolo Willox et al., 2012). The engagement of this work with these concepts is discussed further in section 8.3.

8.2.2 The multiple stressors acting on the Amboseli system, including wider processes of land-use change and climate change

In Chapter 5, I have described the multiple stressors acting on the Amboseli system and how these stressors are influencing patterns of land use and livelihoods. These multiple stressors include climate change, climate variability, land-use change, environmental degradation, poverty and inequality, and cultural factors, the specific combinations of which have been recognised as critical drivers of change in specific regions by the IPCC in their recent report on vulnerabilities, impacts and adaptation (2014a).

My findings outline how these drivers of change interplay with the historical and political context of Amboseli and with the dynamics of power and agency within and outside the system to influence land-use and livelihood patterns as the worldviews of the Maasai shift. Chapter 5 describes how the pressures resulting from the shock of the 2009 drought have thrown customary and political institutions into disharmony, with related shifts from the view of livestock as the unit of production, to land as the primary livelihood resource resulting in specific land-use decisions. The juxtaposition of Mbirikani and Eselenkei Group Ranches presents an example of the nexus of these shifts. Also, shifting worldviews are shown to be linked to adaptation responses.

The livelihood and land-use responses explored in Chapter 5 are potentially maladaptive outcomes for the social-ecological resilience of the Amboseli system. As discussed in the chapter, the decision-making processes taking place, including those to subdivide the communal group ranches, are likely to disproportionately burden the most vulnerable, set pathways that limit future choices, have high opportunity costs, increase greenhouse-gas emissions and reduce incentives to adapt to climate change.

8.2.3 The socio-economic, cultural and ecological factors driving land-use decisions, the interactions of these with climate change and implications for the social-ecological resilience of the Amboseli system.

Chapter 6 describes the development of a theory of decision-making based on the findings presented in Chapters 4 and 5, as they pertain to livelihood strategies and land use. Drawing on the qualitative data collected during fieldwork, the theory describes four types of decisions for pastoralists: to exit pastoralism; to practice traditional mobile pastoralism; to include added value diversification; and, commercialisation. This theory identifies access to power and access to resources as the key factors determining the direction of these decisions. Reflecting the dynamism in pastoralist systems (see section 8.3.2 below for more on this), all of these decisions involve a degree of diversification of livelihood strategies in response to the environmental, political and economic context, which shifts over time. This diversification may be driven by a necessity or to manage risk, depending on access to resources and power or authority in any given context. Alternatively, diversification may be driven by the desire to accumulate wealth and / or power, again in response to context. These decision-making processes are shown to be non-linear and complex, with particular individuals shifting in and out of livelihood strategies over time.

Given the important role of context in this theory, climate and other stressors are drivers of decisions about livelihoods and therefore land use. Feedbacks also exist over time, with decisions about land-use altering the context and decision-making space, constraining or enabling future livelihood strategies.

Chapter 7 presents the results of a series of simulation experiments designed to explore different land-tenure and climate-change scenarios in the Amboseli system. These results reinforce my findings about the interactions between land-use change and climate change. Under these simulations, climate change up to 2100 will have a significant effect on the structure and function of vegetation in Amboseli. Results show that grass biomass and net primary production is significantly reduced in 2100 compared to ambient climate, and tree biomass, population and net primary production is increased. These results suggest a significant alteration in the ratio of grass and trees in the Amboseli savannah. Net ecosystem exchange shows an increased flux of carbon, with increased sequestration in vegetation. The land-use change simulations were constrained by the design of the aDGVM itself, as discussed in Chapter 7. Nonetheless, results of these simulation experiments indicate that current communal grazing will not have a significant effect on vegetation structure and function in the future. However, the results also indicate that alterations in this management regime, by enclosure of parts of the rangeland or subdivision into plots for example, have the potential to impact significantly on the vegetation of Amboseli, exacerbated by the interaction effect of climate change.

My findings are consistent with the hypothesis that land-use change is both a cause and a consequence of climate change, and interactions between the two are important dynamics for the resilience of rangeland systems. Alteration in the structure of vegetation may lead to further landscape detachment and place identity issues in the future, particularly if these shifts are sudden. This effect in turn may impact on the social-ecological resilience of the system. Findings presented in Chapter 4 provide support for this conclusion. The combination of the two stressors of climate change and land-use change with wider processes of change, as discussed in Chapter 5, also acts on resilience. The findings of these experiments also support the idea that semi-arid grasslands like Amboseli can provide solutions to climate change adaptation and mitigation through carbon sequestration, as well as providing co-benefits in terms of livelihood security and resilience building, if managed sustainably.

8.3 Theoretical implications

This research is an interdisciplinary enquiry into the factors affecting the social-ecological resilience of a semi-arid system. The methods employed reflect this interdisciplinarity, combining innovative modelling approaches with qualitative field research. As such, the research and its findings have contributed to knowledge in four main areas: the implications of climate change for non-material aspects of well-being, or cultural factors; current understandings of pastoralism and semi-arid systems; critical engagement with resilience thinking as a framework for social-ecological enquiry; and, approaches to agent-based modelling.

8.3.1 Culture and climate change

This strand of analysis began with a general feeling of collective trauma in the Amboseli system upon my return to carry out PhD research in 2011. At first, this trauma and the transitions it appeared to be driving were not a particular focus of this research, rather the theory of psychological and cultural factors affecting livelihood and land-use decisions emerged from the data during analysis. Engaging with the theory and literature around place identity, solastalgia and environmental trauma, it was exciting to discover this case study example of these ideas playing out as a result of an extreme weather event and in the context of climate change and resilience. As literature around cultural impacts of climate change emerged in 2013, with a paper in *Nature Climate Change* for example (Adger et al., 2013), and the IPCC's recognition of the non-material aspects of well-being and importance of cultural factors for adaptive capacity, the relevance of these findings in building the evidence base for these concepts became clear.

8.3.3.1 Cultural impacts of climate change

While the impacts of climate change for socio-economic and the material aspects of well-being have been explored for a range of systems, the cultural impacts of climate change are a relatively new area of enquiry. The psychological aspects of environmental shocks have been described in some communities (see for examples Albrecht, 2006, Stain et al., 2011), but links to climate change have been only hypothesised and rarely demonstrated (exceptions are Doherty and Clayton, 2011, Cunsolo Willox et al., 2012). With this research, I have built on this broader work to provide an example of how an extreme weather event has impacted on the beliefs, customary institutions and worldviews of the Maasai of Amboseli and how these impacts on non-material aspects of well-being are important in shaping responses to climate variability and climate change.

8.3.3.2 Cultural aspects of adaptation

There is a growing recognition in academic and policy circles that culture, including social norms, values and behavioural rules, are of great important for adaptive capacity in specific places (Adger et al., 2013, IPCC, 2014a). These cultural factors can act as enabling factors but also as barriers to successful local adaptation (Nielsen and Reenberg, 2010) and need to be well understood to build resilience. The IPCC report on vulnerabilities, impacts and adaptation acknowledges the urgent need to further develop the evidence base for cultural dynamics affecting coping mechanisms and adaptive capacity in order to better understand how climate vulnerability and adaptation are experienced (IPCC, 2014a). The findings of this research constitute a valuable case study contributing to this evidence base.

8.3.2 Understandings of pastoralism and livestock-based production systems

Pastoralist systems have been the subject of several powerful yet erroneous paradigms in the past several decades. These have typified arid and semi-arid lands as both ecologically and economically unproductive, inefficient and underdeveloped (IIED, 2013, Easedale and Domptail, 2014). Partly as a result of such paradigms and their legacies, arid and semi-arid lands are politically and economically marginalised areas with relatively high levels of poverty and vulnerability, as well as exposure to climate-related risks.

In reality, pastoralists have been successfully adapting to climate variability for centuries (see Chapters 4 and 5 for a history of Maasai livelihoods and development policies in semi-arid lands). However, as described above and in previous chapters, semi-arid systems are currently undergoing rapid processes of change including population growth, education, livelihood diversification and land-use change which are posing unprecedented challenges. Recently, the conceptualisation of pastoralism in marginal semi-arid lands as dynamic sites of innovation and development opportunity marks the most recent paradigm shift (Catley et al., 2013). This shift in the social sciences is mirrored in the natural sciences as understandings of the ecological functioning of semi-arid systems is advanced also (Reynolds et al., 2007). The next phase of arid and semi-arid lands research should focus on gaining better understandings of the social-ecological dynamics of these systems over time, at different scales and in different contexts (Easedale and Domptail, 2014). This research is a small contribution to this effort in the case study of the Amboseli system.

Different forms of mobility are emerging in pastoralist systems in response to land-use change (Moritz, 2010). To take the example of Mbirikani Group Ranch, enclosure of key resources and shifts in land use from communal rangeland to plots, tarmac road, gypsum mining, carbon offset schemes and wildlife conservancies is leading to alternative modes of resource exploitation and innovation (Scoones and Adwera, 2009). The accumulation of capital as a livelihood strategy is one response to these changes, giving pastoralists the means to transport herds by vehicle, rent grazing land or hire additional labour during hard times (Catley and Aklilu, 2013), a strategy employed by several of the wealthier participants in this research. However, incremental enclosure for private interests only adds to the uncertainty facing pastoralists living in semi-arid lands and gives rise to new combinations of winners and losers, depending on access to power or authority (see Chapter 7). As demonstrated by Maitera's story negotiating access across Kajiado and beyond, navigating unknown obstacles is giving rise to new forms of adaptive capacity (Chapter 4).

The kinds of dynamic change taking place in Amboseli are not necessarily negative or unsustainable. For example, cultivation of plots encloses the best quality grazing areas, which used to be reserved for dry season grazing in times of stress. Without these areas, pastoralists are more vulnerable to climate-related risks (Coppock, 1994). On the other hand, agro-pastoralism has always been a means of coping with environmental variability and remains an important adaptation strategy in semi-arid areas. In fact, it is this dynamism and flexibility that is at the core of adaptation to climate change. However, these findings show that when pressures are inequitable and unplanned, maladaptive outcomes can result and resilience may be lost from a system. If the potential of semi-arid systems like Amboseli is to be reached, development must be sustainable, equitable and climate-resilient.

8.3.3 Critical engagement with the interdisciplinary discourse towards a resilience-based framework for climate change adaptation and sustainable rangeland management

As the concept of resilience gains traction as an analytical framework for addressing the challenges facing social-ecological systems (Boyd et al., 2008, Cannon and Mueller-Mahn, 2010, Mitchell and Harris, 2012), so too does the understanding that maintaining the current state of these systems is, in many cases, neither feasible nor indeed desirable in the face of unprecedented, multiple drivers of change. The capacity for systems to transform and shift into new states has been recognised as necessary for systems to adapt to such change (Folke et al., 2010). Semi-arid systems such as Amboseli are now known to be particularly dynamic and unpredictable. These may be the sites in which such 'tipping points' occur, indeed some researchers have already described the 2009 drought as one such occurrence.

As the focus on climate change adaptation has grown in the past decade, so has the understanding of the scale and complexity of the task at hand. Early efforts at adaptation were focussed around a need to accommodate change while maintaining the same functions and structures of a system (Pelling, 2011), but due to the predicted magnitude of climate risks (New et al., 2011, IPCC, 2013), this is no longer thought to be an adequate response (O'Brien, 2012). There is a growing consensus that current approaches to climate change adaptation, in the context of vulnerable communities, will not be sufficient to avert the impacts of dangerous climate change and that transformational change may be necessary, giving rise to new states with essentially the same structures and functions. However, as described in the previous section, my findings show that the challenges and uncertainties associated with such transformational change (e.g. subdivision of communal rangeland) are problematic and potentially maladaptive, even if the gains associated with positive transformational change may be significant in adapting to climate change.

As described in Chapter 2, resilience theory, and related definitions of adaptation and transformation, is rooted in the natural sciences, as essentially objective concepts, which can overlook the more normative issues of power, knowledge, agency and social capital. The conceptual framework I devised to guide my research, outlined in Chapter 3, explicitly addresses this, incorporating social norms and land-use change as well as climate change and vegetation dynamics. The interactions between these elements of the Amboseli social-ecological system are recognised along with the importance of each to the overall resilience of the system. The way in which I have used modelling approaches, as exploratory and integrating tools has been aimed at elucidating the linkages between elements and resilience.

This thesis has also made a contribution to the literature around maladaptation to climate change. In Chapter 2, the limited available literature on this concept is reviewed and Chapter 5 provides a semi-arid lands case study of potentially maladaptive outcomes (using the framework outlined by Barnett and O'Neill, 2010) as well as discussing some of the likely causes of these outcomes, an area that is under-researched in the literature. Differentiation is made between inadvertent and deliberate maladaptive action, building on the new definition provided by the IPCC (2014a).

8.3.4 Advances in modelling social-ecological systems

As Joshua Epstein, an early proponent of agent-based modelling (ABM) asserts, there are many reasons to model observed phenomena beyond the prediction of outcomes based on simulations (Epstein, 2008). For example, he advocates for the use of ABM in explaining observed patterns, guiding data collection, illuminating core dynamics, discovering new questions and revealing the apparently simple to be complex and vice versa. It is in this spirit that I have employed modelling as an integrating tool for analysing the Amboseli system.

The use of qualitative data and narrative approaches to the explanation of model results is also gaining attention in the ABM community (see contributions to ESSA 2013 special track "Using qualitative data to inform behavioural rules" in Kaminski and Koloch, 2013). In the field of land-use cover and change ABMs, the importance of the social processes of model development is gaining interest. Pignotti *et al.* (2013) have proposed a provenance approach to analysing and documenting the ways in which the modeller's narratives and reasoning have been included in the design of model versions, particularly where these are used in policy-oriented, multidisciplinary and / or participatory research. As Millington *et al.* (2012: 1032) put it, "narrating specific events and relating them to model assumptions, rules and relationships forces reader to think more deeply about those underlying assumptions". Here, I would go further to say that in my experience, building the model also develops understandings of the narratives of specific events captured through qualitative methods.

In exploring the "social and political lives" of models, Leach and Scoones (2013: 10) emphasise that the development of particular models are shaped by the social, cultural and political values and norms of the modellers. As such, models can act to "open up" or "close down" understandings of observed phenomena, especially when informing policy processes. As mentioned above, arid and semi-arid land sciences, rangeland management and pastoralism development policies have been particularly affected by the "closing down" effect of models. Particular models have fuelled the debate that has raged for decades in academic and policy circles about the dynamics of semi-arid systems. Prior to the late 1980s, the dominant paradigm applied to African rangeland ecosystems was driven by a belief that semi-arid lands were in a state of ecological degradation due to unregulated and inefficient grazing pressure from traditional pastoralists (Brown, 1963, Lamprey and Yussuf, 1981, Lamprey, 1983). Based on the ecological models of the day, the prevailing wisdom was that pastoralist systems were potentially stable, with an ideal, attainable equilibrium state and that this equilibrium had not been reached due to the destabilising pressure of pastoralist grazing systems on vegetation. The view that pastoralists had persisted by moving to new pastures after irreversibly degrading their resources also dominated and, crucially for Arid and Semi Arid Lands (ASAL) policy in East Africa, that active interventions were required to return these systems to their optimal equilibria (Ellis and Swift, 1988).

The impacts of this (now wholly rejected) dominant paradigm have been in many cases catastrophic, with a series of failed attempts to regulate the perceived overgrazing catastrophe through destocking, confinement of pastoralists onto community land and other similarly misguided policies (Catley et al., 2013). This historical legacy explains much about the patterns of land use and livelihoods observed in systems like Amboseli today (see Chapter 5 and section 8.3.2) and are critical to understanding their responses and resilience to change. However, alternative paradigms have been developed since the 1980s and models have played a continuing and important role in "opening up" theories, interpretations and policies for the arid and semi-arid lands. What is almost universally agreed across arid and semi-arid lands science and policy is that these systems are characterised by complex, unpredictable and non-linear dynamics, both in their social and ecological elements (see Chapter 2). The role of models as points of triangulation, recognising that outcomes are contingent and plural, will continue to be important in addressing the challenges of climate change and land-use change in systems like Amboseli and ABMs, developed and implemented in this spirit offer great potential.

As explained in Chapter 3, the few existing ABMs of pastoralist systems have focussed on conflict between farmer and pastoralist groups or on measurable flows of assets derived from survey data (e.g. Milner-Gulland, 2006). An ABM (DECUMA) has recently been undertaken for the Kajiado District (Boone et al., 2011a). In this case, DECUMA simulates household economics and cash flows based on quantitative survey data, e.g. wage incomes, livestock prices, school fees, veterinary costs. The findings of DECUMA and the ABM described in my research are different but complementary. Rationality and economic reasoning govern the agents in DECUMA. While this is undoubtedly a large part of the story of livelihoods and land-use change in Kajiado, using a qualitative and grounded theoretical approach has contributed nuance to my narrative. My model design has incorporated the cultural and normative aspects of decision-making processes, which as we have seen earlier in this chapter are increasingly recognised as an important factor in climate change adaptation. While the use of qualitative data in building ABMs is an important future area, particularly for exploring the resilience of semi-arid social-ecological systems, the difficulties and tensions encountered in this research and modelling social-ecological systems more widely, exemplify the scale of the challenge.

8.4 Policy implications

8.4.1 International level

At the highest policy level, the recent series of IPCC reports have emphasised that exposure to climate change is just one of a range of risks and vulnerabilities that social-ecological systems face (IPCC, 2013, IPCC, 2014a, IPCC, 2014b). They underline how resilience to climate change necessarily has to involve resilience to many other things as well, framing climate change adaptation as a risk-management problem to be balanced alongside non-climate related stressors.

One expert research participant took the view that the impacts of the 2009 drought in Amboseli was the result of a gradual loss of resilience over successive, small drought events, due to the kinds of stressors discussed in Chapter 5 (Jan de Leeuw, personal communication, 23/11/2011). In designing this research and interpreting data, I have taken care to think about climate change as a 'threat multiplier', exacerbating the range of stressors I have already observed in Amboseli and other rangeland systems in which I have worked, with the potential in combination to cause complete shifts in system behaviour. Also, I have separated my analysis of the 2009 drought as an extreme weather event and longer-term climate change, aware that the drought cannot necessarily be attributed to climate change in this instance. In these ways, I have endeavoured to conceptualise climate change as one of a range of elements of the system affecting overall resilience (see conceptual framework in section 3.3 of this thesis), rather than an exceptional issue or a problem like no other (Steffen, 2011).

8.4.2 National governance: the Kenya context

8.4.2.1 Development policy

As described in section 8.3.2, semi-arid systems are typically under-developed with high rates of poverty and poor access to markets, services, transportation and infrastructure. This description is certainly true of semi-arid systems in Kenya as compared to the more fertile, wealthier highland regions. Economic opportunities and supporting services, such as the abattoir in Sultan Hamud, are growing as urbanisation of regional towns such as Emali, Sultan Hamud and Machakos in Kajiado District increases. As described in Chapter 5, domestic and export markets for livestock products in the Middle East and elsewhere are growing and will ensure the economic importance of pastoralism in countries like Kenya.

In carrying out this research, I have deliberately explored higher-level (e.g. regional) and lower-level (e.g. group ranch) influences on the Amboseli system (see Chapter 5) to provide findings that are relevant at district or national policy levels. My findings suggest that the changing nature of pastoralism in Amboseli will have winners and losers. As with any sector, sustainable and inclusive growth should be desirable outcomes. The potential for economic growth in the semi-arid lands has yet to be fully explored. My recommendation to policy-makers in Kenya with responsibility for development in the semi-arid lands would be to explicitly acknowledge these issues and work to identify and overcome them, otherwise the economic potential of these areas will not be realised and the populations inhabiting them will continue to live in relative poverty with limited access to services and, in places, at risk of conflict and insecurity.

While I acknowledge the local-level focus of this work, Chapter 6 clearly shows that the modelling approaches I have employed have allowed more generalisable conclusions to be drawn from my findings. The theory of decision-making represented in Table 6.1 and Figure 6.3 recognise the importance of power or access to power as well as resources which can be applicable to semi-arid systems in in Kenya and developing countries elsewhere.

8.4.2.2 Climate policy

While clearly posing a threat multiplier to the Amboseli system and other semi-arid systems, climate change also introduces new opportunities. In Amboseli as in other developing areas, climate change adaptation policies should involve new technologies (e.g. the new cattle breeds and pipeline irrigation in Mbirikani), climate services (e.g. early warning systems for future droughts), ecosystem-based adaptation (e.g. the carbon finance schemes taking place in Mbirikani), economic measures (e.g. index-based livestock insurance and disaster contingency funds), regulatory measures (e.g. defined property rights, land-tenure security and protected areas), social protection (e.g. distribution of food relief in times of drought) and social solutions (e.g. social networks). Depending on the specific policy context, some of these measures will lead to incremental climate change adaptation and greater adaptive capacity to cope with events such as the 2009 drought. Other shifts, including social innovations and changes in behaviour, institutions, cultural norms may be more transformative (IPCC, 2014a). The findings of this research show that these socio-cultural factors that may constitute adaptive capacity are also at risk from climate change impacts and may lead to maladaptation under pressure.

Currently, climate policy frameworks generally remain fragmented, acting as a barrier to adaptation where context-specific cultural factors are ignored (Stringer et al., 2009, Naess et al., 2011, IPCC, 2014a). In Kenya, the Ministry of State for Development of Northern Kenya and other Arid Lands formulated policy priorities for each arid and semi-arid county. For Kajiado, there were two stated priorities. The first was to strengthen climate resilience and ensure sustainable livelihoods through land and natural resource management, integration of climate adaptation and drought risk reduction into planning and institutionalisation and delivery of a drought management system. The second was to promote pastoral mobility and institutional arrangements, including cultural rights, through delivery of services in ways appropriate for nomadic communities. With a change of government in March 2013, the Ministry was dissolved, but it is to be hoped that these priorities will endure in national policies, particularly as climate policy is developed.

My findings support the Ministry's policy priorities for Kajiado, but also are a warning that events at the local level, i.e. subdivision, may overtake these policy processes and hinder achievement of these objectives. In Amboseli, time is short to implement these policies and prevent subdivision, particularly if further shocks are experienced in the coming years. Any delay with a change of government may be detrimental to the sustainability of this system.

8.4.2.3 Building resilience

Inclusive growth and climate-resilient development can reduce poverty and inequality at the same time as adapting to climate change. My findings show that access to resources and access to power and authority is important for sustaining livestock-based livelihoods, and those who cannot access both will suffer during shocks and times of stress (see Chapter 6). Consideration of normative as well as material aspects of well-being will help to achieve equity and social justice. Local control and ownership of resources is also important and, in the case of Amboseli, are most effectively institutionalised in customary norms and traditional knowledge, which should be preserved and integrated alongside more modern political structures. If this cannot be achieved, the risks of maladaptation are greater as actions are taken that limit future choices and erode customary coping mechanisms and new power dynamics increase the vulnerability of sectors of the community (see Chapter 5). Subdivision as an attempt to reduce vulnerability to future shocks is the most significant of the threats of maladaptation for the Amboseli system.

8.4.3 Non-Governmental Organisations and development practitioners

In my experience of the Amboseli system, outside actors often either ignore or misunderstand customary institutions at the project level, which can have an adverse effect on these and alter the balance of power in these communities. A lion-conservation project in the area is an exception in harnessing cultural norms as an entry point to promoting sustainable co-existence between carnivores and the Maasai pastoralists. Some tourist operators have also been more successful than others in integrating their operations with local customary institutions, incorporating traditional knowledge. Where this has not been achieved, these same institutions and norms have formed barriers and conflicts (as in the case of the proposed conservancy area in Mbirikani or the gypsum mining operation). My findings presented in Chapter 5 demonstrate how undesirable outcomes can occur as a result of cultural changes. For example, I have discussed how shifting worldviews, influenced largely by changing economic opportunities offered by outside actors, have influenced the decision to subdivide the communal rangeland, an outcome which is undesirable from the perspective of conservationists or tourist operators, for instance. My recommendation to these projects would be to take note of customary institutions, traditional knowledge, mobility and social networks and work with them to reach shared objectives.

8.5 Recommendations for further research

To build upon the theoretical implications of this research, I would recommend carrying out further qualitative research focussed around the cultural impacts of climate change and cultural aspects of adaptive capacity other semi-arid systems where the combination of stressors may be different. For example, the arid and semi-arid lands of the Horn of Africa or Sahel experience more extreme variability and chronic stress, as well as very different political and economic contexts. These would make very interesting comparable case studies to complement this one. As well as additional case studies, carrying out longitudinal fieldwork in the Amboseli system would strengthen the conclusions of this research, particularly with respect to the impacts of longer-term climate change. An expansion of the work into neighbouring, subdivided group ranches like Kaputei and Kimana would give a greater spectrum of 'traditional' to 'commercial' and further test the theory of decision-making presented in Chapter 6.

I believe there is a huge potential in the field of agent-based modelling to build on this research and other studies like it. Due to the limitations discussed in Chapters 3, 6 and 7, the full potential of my ABM and the grazing sub-model with aDGVM to further elucidate dynamics and test land-use and climate change scenarios has not been reached in this particular study. In exploring vegetation dynamics, it would be fruitful to implement the aDGVM at larger scales for different regions of Africa, to include scenarios for cultivation, wildlife conservation and spatially explicit representations of subdivision. Other rangelands models can also offer a route for further research in this area, e.g. Savanna, (Coughenour et al., 1998) or G-Range (Boone et al., 2011b). Global climate data for the new IPCC scenarios (Representative Concentration Pathways, RCPs) would also provide more up-to-date climate information. Development of a fully implemented ABM to couple with such vegetation models would also be useful for further refining decision-making processes, livelihood strategies and land-use change. This process would give the behavioural rules and theory of decision-making described in Chapter 6 greater generalisability and applicability to similar systems. Engaging with the current theory and literature on qualitative data for ABM, a formal methodology could be developed based on the iterative and participatory approach taken in this research that would be applicable in similar socio-cultural contexts.

This is a programme of work that is beyond the scope of a single PhD and would be best suited to an interdisciplinary team of researchers combining computer scientists at the cutting edge of modelling techniques informed by social scientists skilled in qualitative field research, natural scientists with in-depth knowledge of semi-arid ecosystem dynamics and physical scientists who can elucidate the weather and climate dynamics affecting semi-arid systems where they occur.

8.6 Final remarks

Carrying out this PhD research has given me the opportunity to deepen my understanding of the Kenyan rangelands, the focus of my passionate research interest for more than a decade. In collecting, analysing and interpreting my data, I have been amazed at the amount I did not know about the systems and people I have lived and worked with over this time, and been made very aware of how much more I have yet to learn. In documenting the 2009 drought from the crisis itself, to the relief of the breaking rains and into the successive years of recovery has provided a valuable case study of a climate shock that I felt was important to record both for the communities of Amboseli and for the academy as it strives collectively to understand the challenges of climate change and sustainable development and offer solutions.

In doing so, I have contributed an example of the psychological impacts of climate events to the existing body of work, and of the cultural impacts of climate change and aspects of adaptive capacity that have thus far being underestimated in studies of arid and semi-arid systems, livelihoods, land-use change and climate change. Using an interdisciplinary conceptual framework and modelling as an integrating tool, I have been able to understand the interactions between decisions about livelihoods and land use with climate variability and change at different scales. This mixed methods approach has also allowed me to capture these dynamics from the perspective of the Maasai participants, thus capturing unexpected aspects that tell another side of the story of social-ecological resilience. Previous studies of livelihoods and climate change in pastoralist systems have focussed on socio-economic assets and the material aspects of well-being. Adding the socio-cultural dimensions to the interpretation of social-ecological resilience in Amboseli and to resilience and adaptation theory more generally is a valuable contribution.

Communal rangelands like Amboseli are disappearing rapidly and with them go the unrecognised potential for economic growth, sustainable livelihoods and climate change adaptation and mitigation. It is important to better understand these systems and their value locally, nationally and globally and take action to prevent the loss and degradation of the arid and semi-arid lands.

APPENDIX 1: GUIDE FOR SEMI-STRUCTURED INTERVIEWS

1. Introduction

Introduce the research and interview topics and ask if interviewee has any questions or concerns.

General discussion, including family structure, details of livelihoods activities and natural resource use, services and institutions used by the household etc.

2. 2009 drought

Ask interviewee to describe their experience of the drought, including the impacts of it on their households and how they coped with these.

3. Perceived change

Ask interviewee to talk about what socio-economic, political and environmental changes they perceive in their own lives.

Explore interviewees understanding of drivers of change and linkages between these stressors.

Try to identify the key changes affecting this person, and the reasons behind their priorities.

Which of the threats mentioned worries the interviewee most? Why?

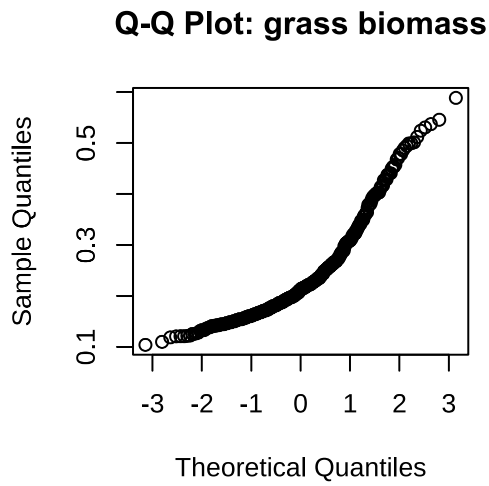
4. Responses

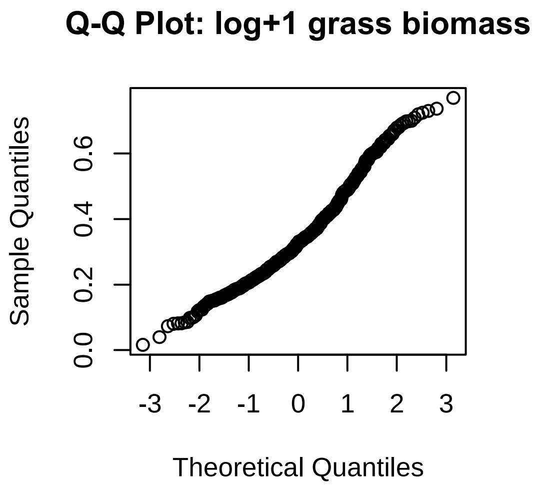
What action is the interviewee taking against the various changes s/he mentioned?

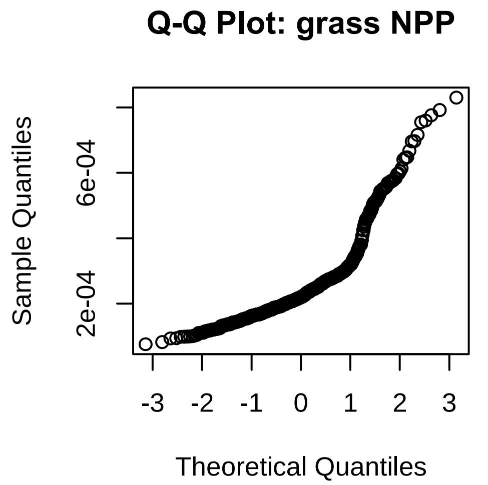
Discuss responses mentioned e.g. alternative livelihoods strategies, land use decisions. If any obvious responses are not mentioned, probe why not. Encourage interviewees to talk about the reasons for their answers.

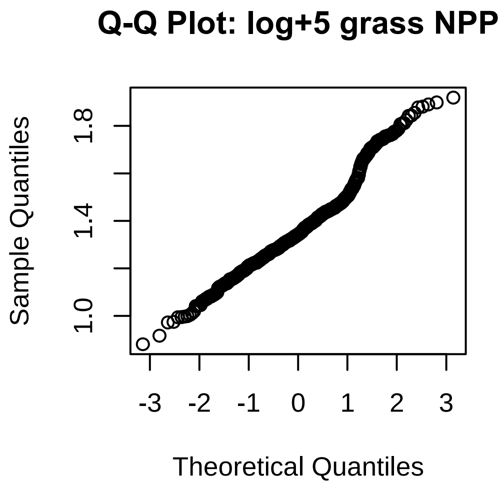
APPENDIX 2: RESULTS FROM CHAPTER 7 ANALYSES

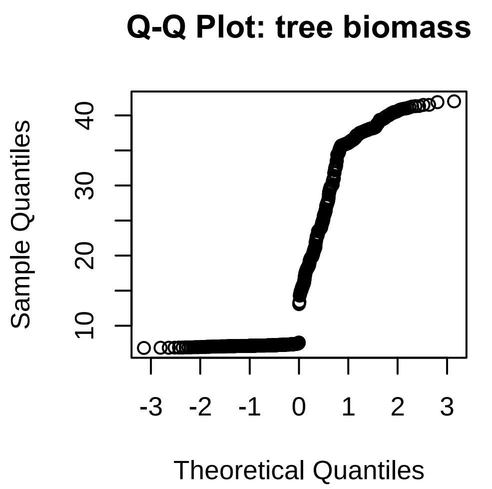
EXPERIMENT 1

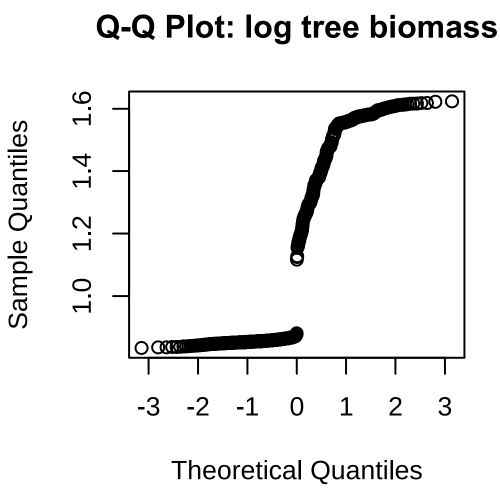


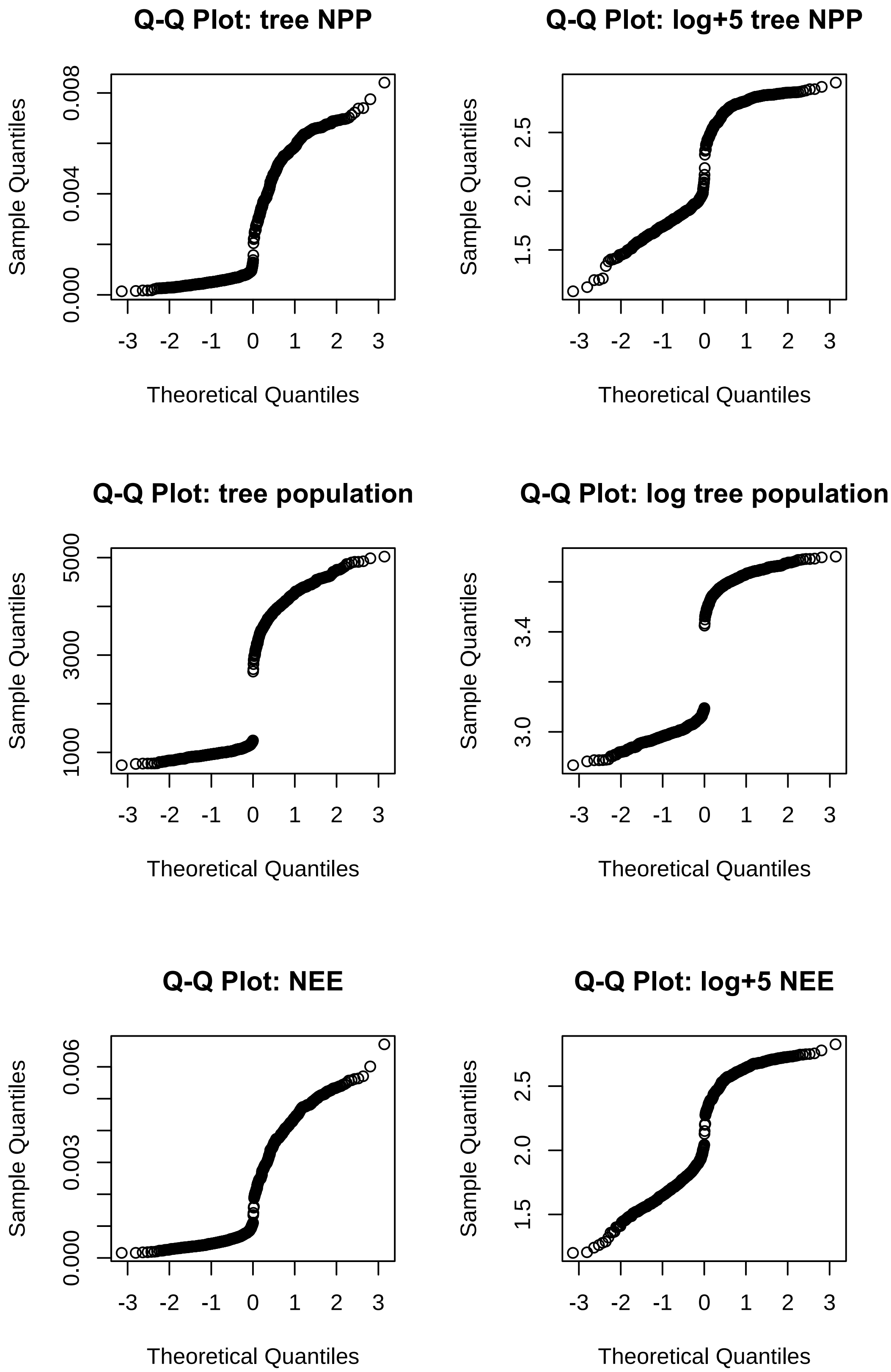


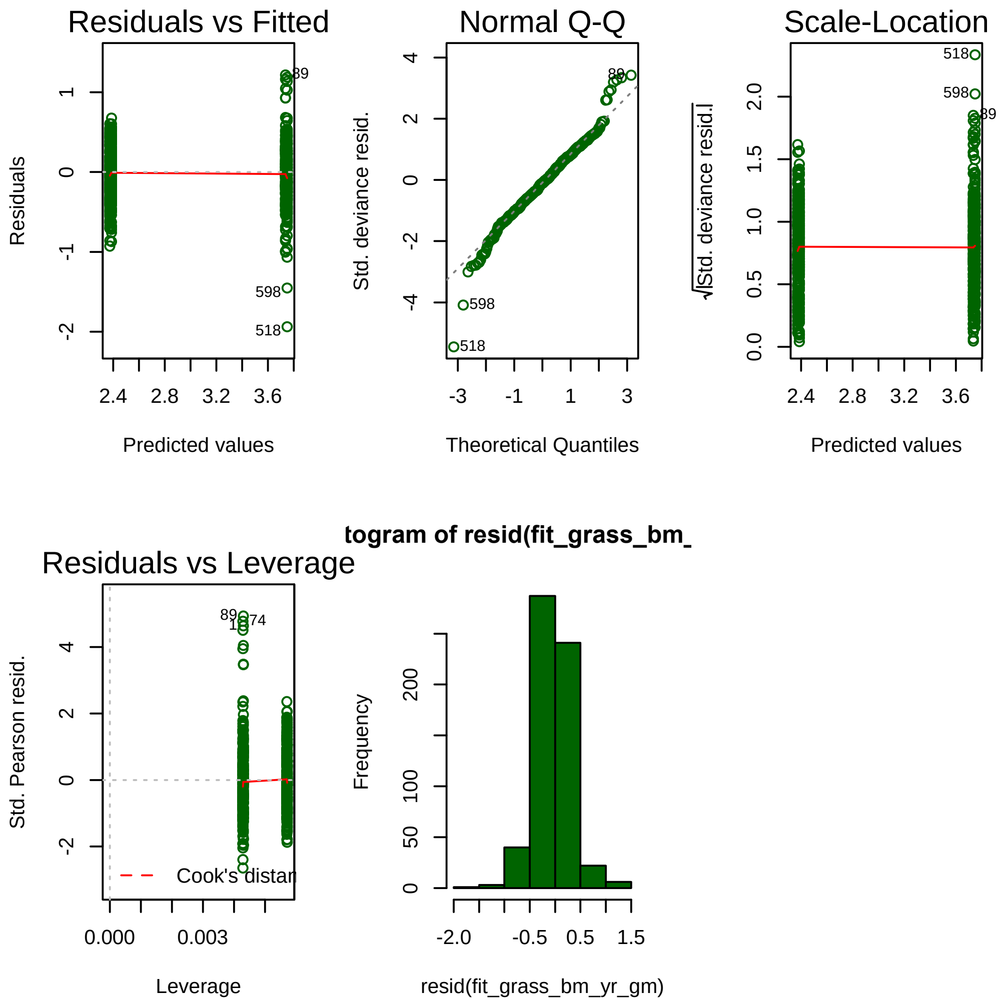






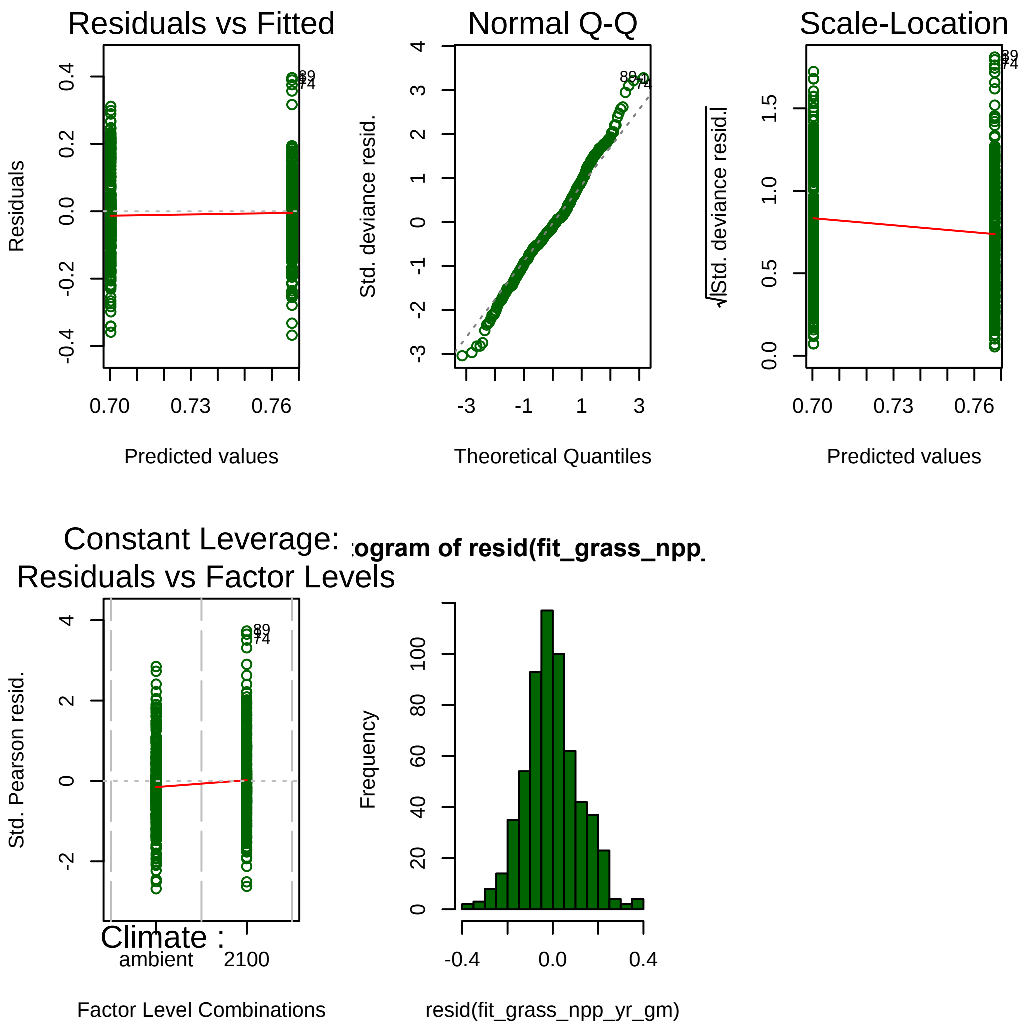



Q-Q Plot: tree NPP
Q-Q Plot: log+5 tree NPP
Q-Q Plot: tree population
Q-Q Plot: log tree population
Q-Q Plot: NEE
Q-Q Plot: log+5 NEE
Sample Quantiles
Theoretical Quantiles
0.000
0.004
0.008
1.5
2.0
2.5
1000
3000
5000
3.0
3.4
0.000
0.003
0.006
-3
-2
-1
0
1
2
3



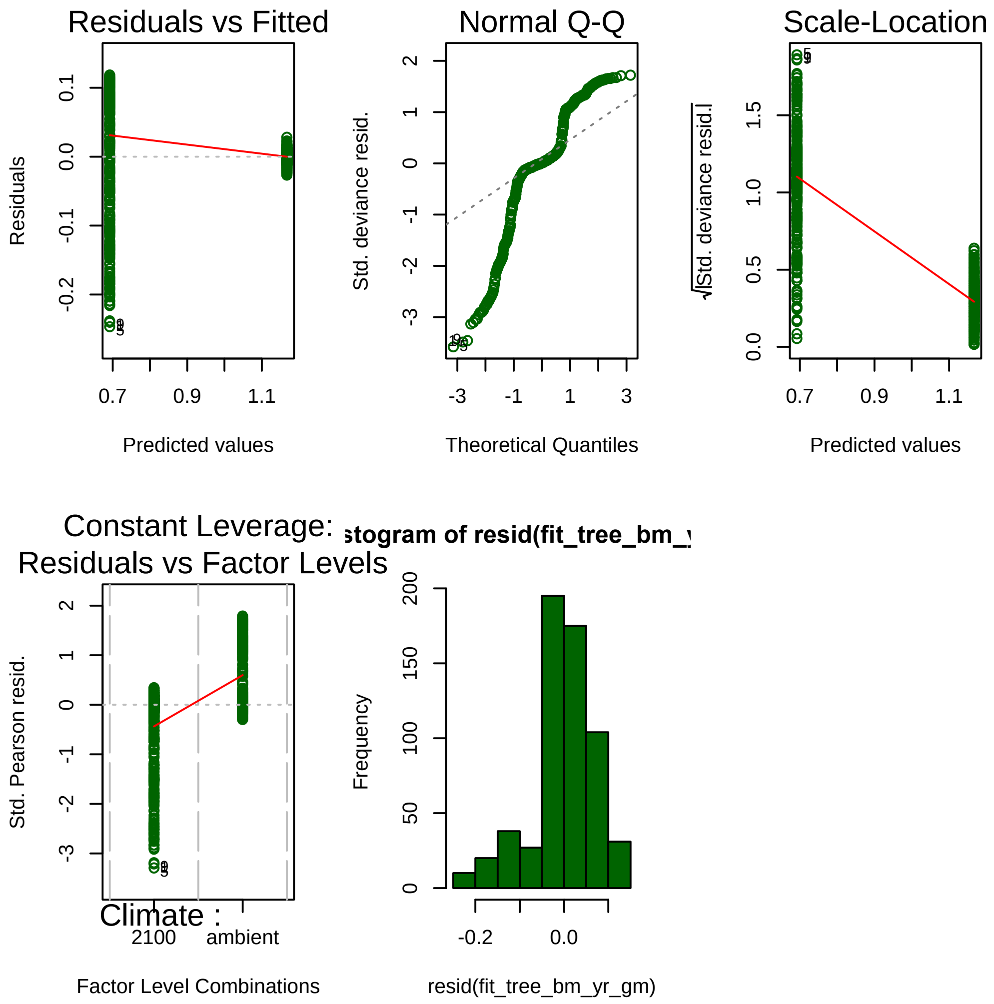

```
Call:
glm(formula = grass_bm_yr_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.93810  -0.25453  -0.03726   0.19398   1.21681

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     3.73609    0.08728   42.81   <2e-16 ***
Climateambient -1.36216    0.09121  -14.93   <2e-16 ***
Tenurenone      0.01319    0.08261    0.16    0.873
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 0.1268549)

    Null deviance: 108.501  on 599  degrees of freedom
Residual deviance:  78.045  on 597  degrees of freedom
AIC: -890.38

Number of Fisher Scoring iterations: 5
```

Diagnostic plots and statistics: Gamma distribution for log+1 grass biomass



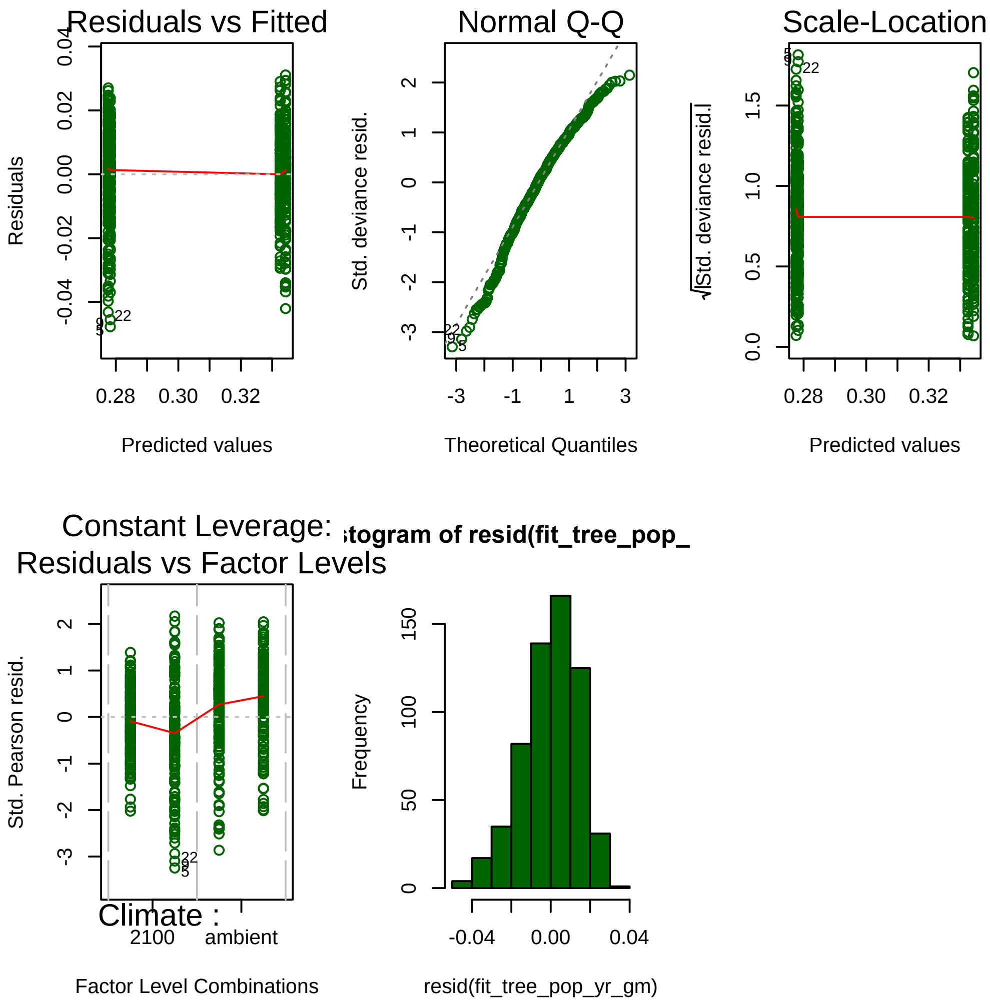

```
Call:
glm(formula = grass_npp_log ~ Climate, family = "Gamma", data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.36765  -0.07318  -0.01045   0.06774   0.39661

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.767539   0.005364 143.086   <2e-16 ***
Climateambient -0.067164   0.007262  -9.249   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.01465299)

    Null deviance: 9.9092  on 599  degrees of freedom
Residual deviance: 8.6518  on 598  degrees of freedom
AIC: -469.56

Number of Fisher Scoring iterations: 4
```

Diagnostic plots and statistics: Gamma distribution for log+5 grass NPP



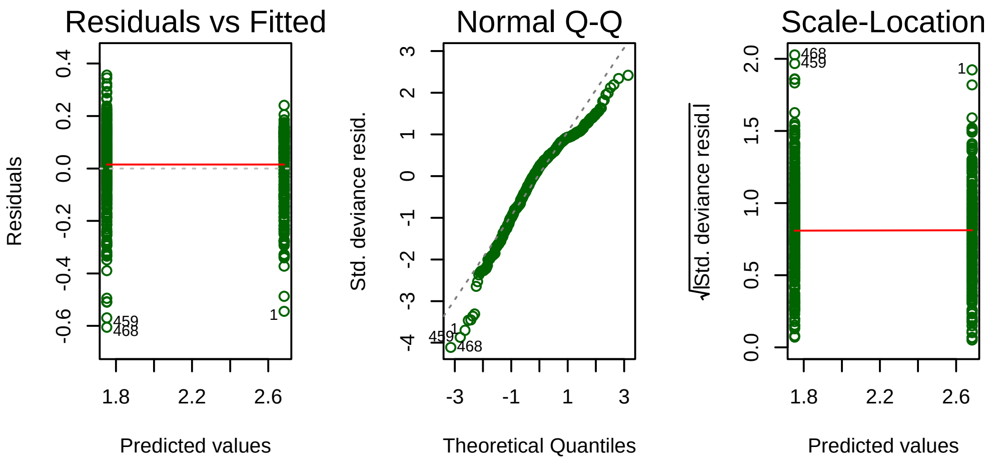

```
Call:
glm(formula = tree_bm_log ~ Climate, family = "Gamma", data = MGR)

Deviance Residuals:
      Min         1Q     Median        3Q        Max
-0.246738  -0.011791  0.000499  0.023195  0.118637

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)    0.692052   0.002758  250.94   <2e-16 ***
Climateambient 0.475067   0.005407   87.86   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.004764225)

    Null deviance: 43.4938  on 599  degrees of freedom
Residual deviance:  2.9801  on 598  degrees of freedom
AIC: -1348.6

Number of Fisher Scoring iterations: 4
```

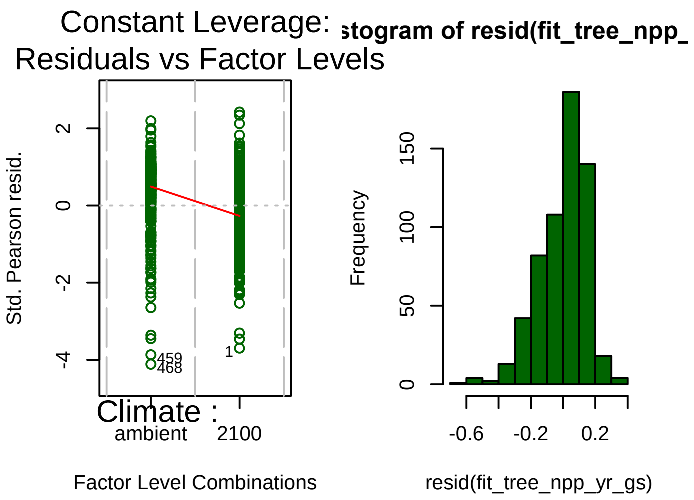
Diagnostic plots and statistics: Gamma distribution for log tree biomass




```
Call:
glm(formula = tree_pop_log ~ Climate * Tenure, family = "Gamma",

    data = MGR)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.047768  -0.008386   0.001746   0.010670   0.031130

Coefficients:
                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                0.2782316  0.0003303 842.413   <2e-16 ***
Climateambient             0.0560769  0.0005163 108.612   <2e-16 ***
Tenurenone                -0.0006559  0.0004665  -1.406    0.160
Climateambient:Tenurenone -0.0010922  0.0007287  -1.499    0.134
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.000211369)

    Null deviance: 5.09997  on 599  degrees of freedom
Residual deviance: 0.12667  on 596  degrees of freedom
AIC: -1938

Number of Fisher Scoring iterations: 3
```

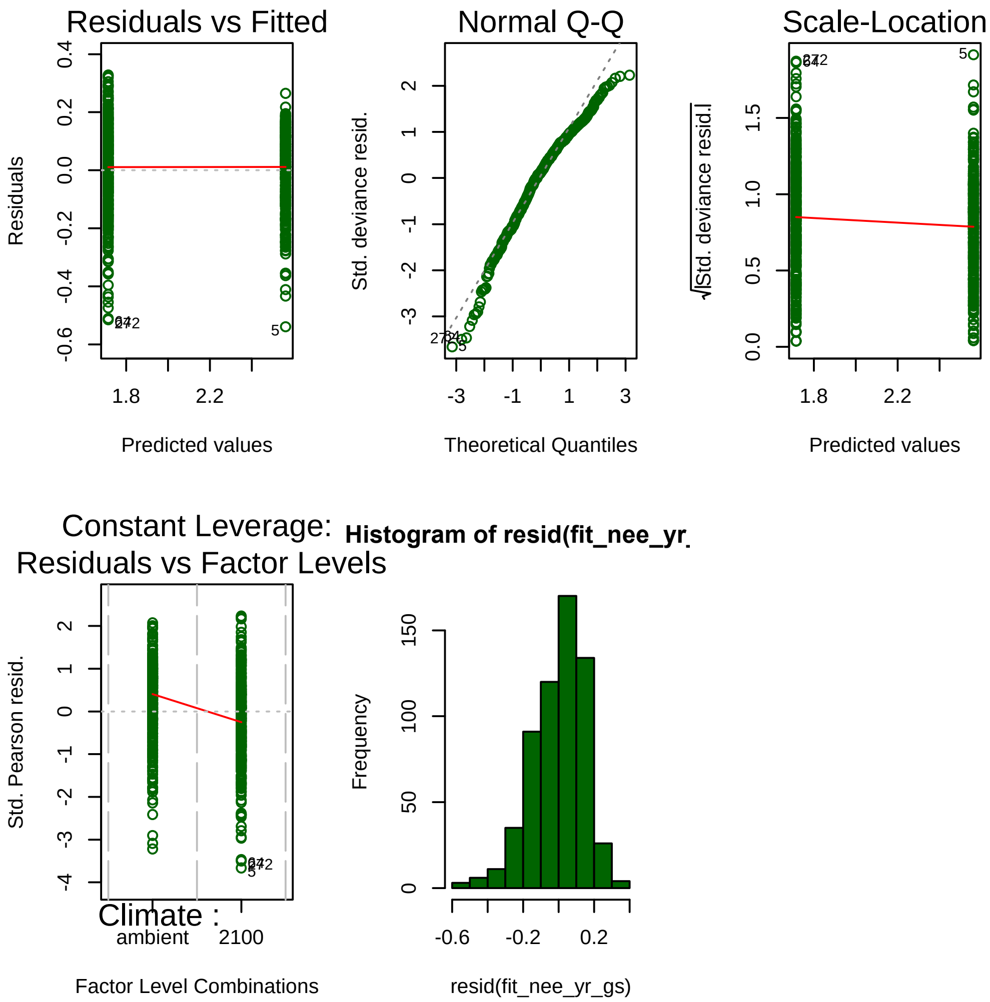
Diagnostic plots and statistics: Gamma distribution for log tree population






```
Call:
glm(formula = tree_npp_log ~ Climate, family = "gaussian", data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.60520  -0.09161   0.03198   0.10822   0.35622

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     2.683952   0.008512  315.32   <2e-16 ***
Climateambient -0.931862   0.012038  -77.41   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.02173543)

    Null deviance: 143.253  on 599  degrees of freedom
Residual deviance:  12.998  on 598  degrees of freedom
AIC: -590.56

Number of Fisher Scoring iterations: 2
```

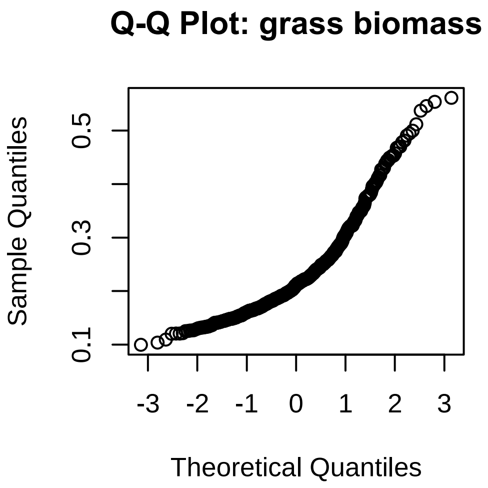
Diagnostic plots and statistics: Gaussian distribution for log+5 tree NPP

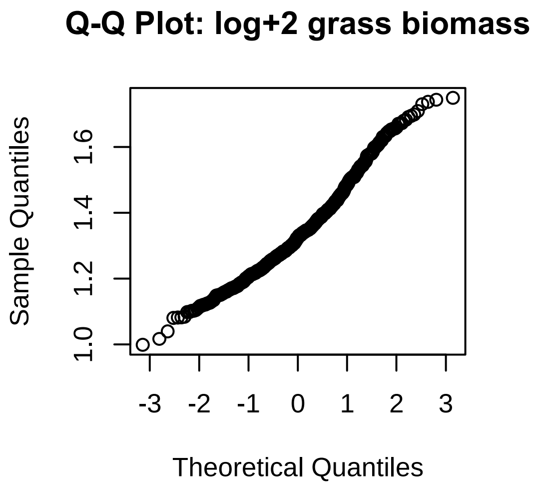


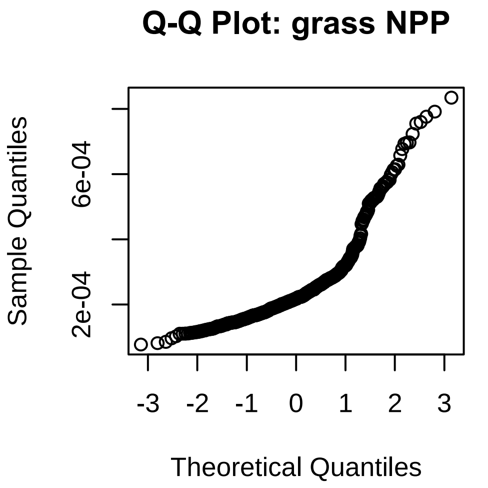

```
Call:
glm(formula = nee_log ~ Climate, family = "gaussian", data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.53916  -0.09395   0.01942   0.11046   0.32857

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     2.561645   0.008515  300.83   <2e-16 ***
Climateambient -0.846725   0.012042  -70.31   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.02175287)

    Null deviance: 120.550  on 599  degrees of freedom
Residual deviance:  13.008  on 598  degrees of freedom
AIC: -590.08

Number of Fisher Scoring iterations: 2
```

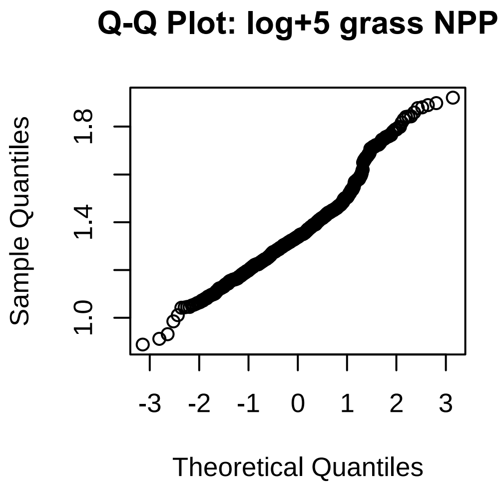
Diagnostic plots and statistics: Gaussian distribution for log+5 NEE

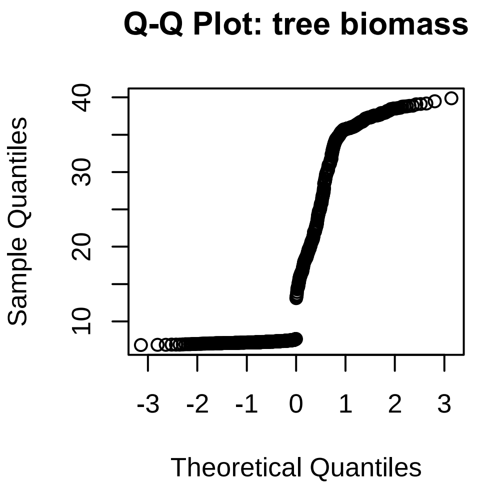
EXPERIMENT 2

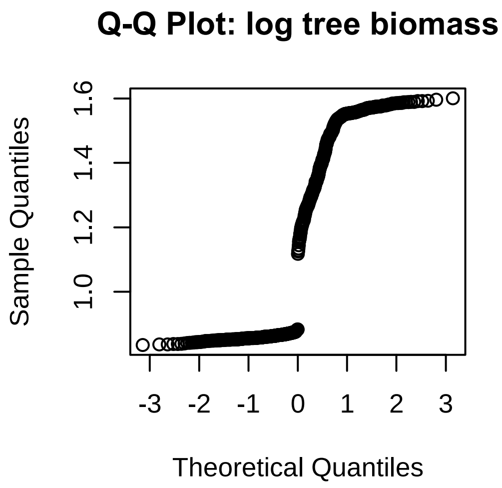


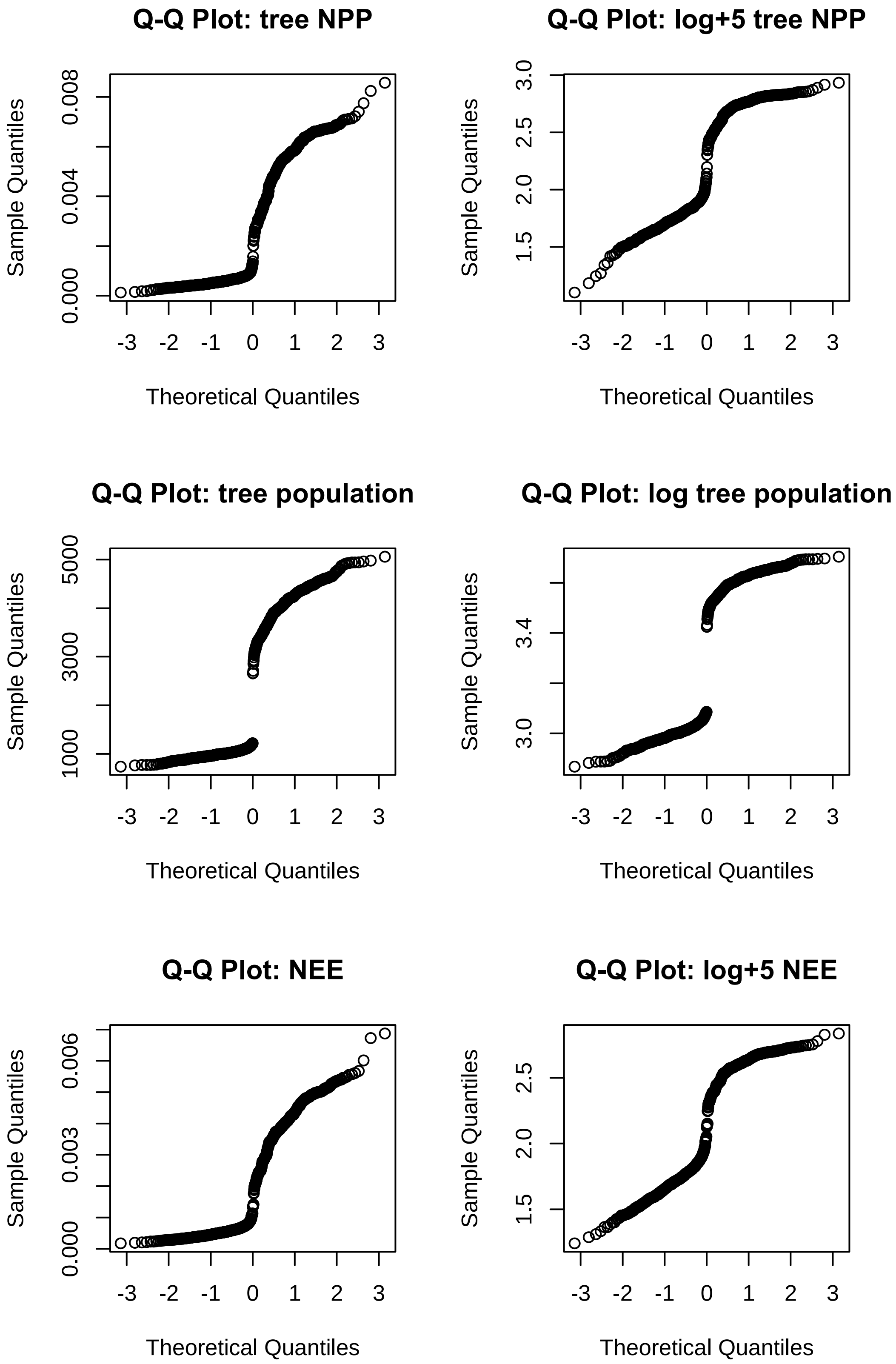


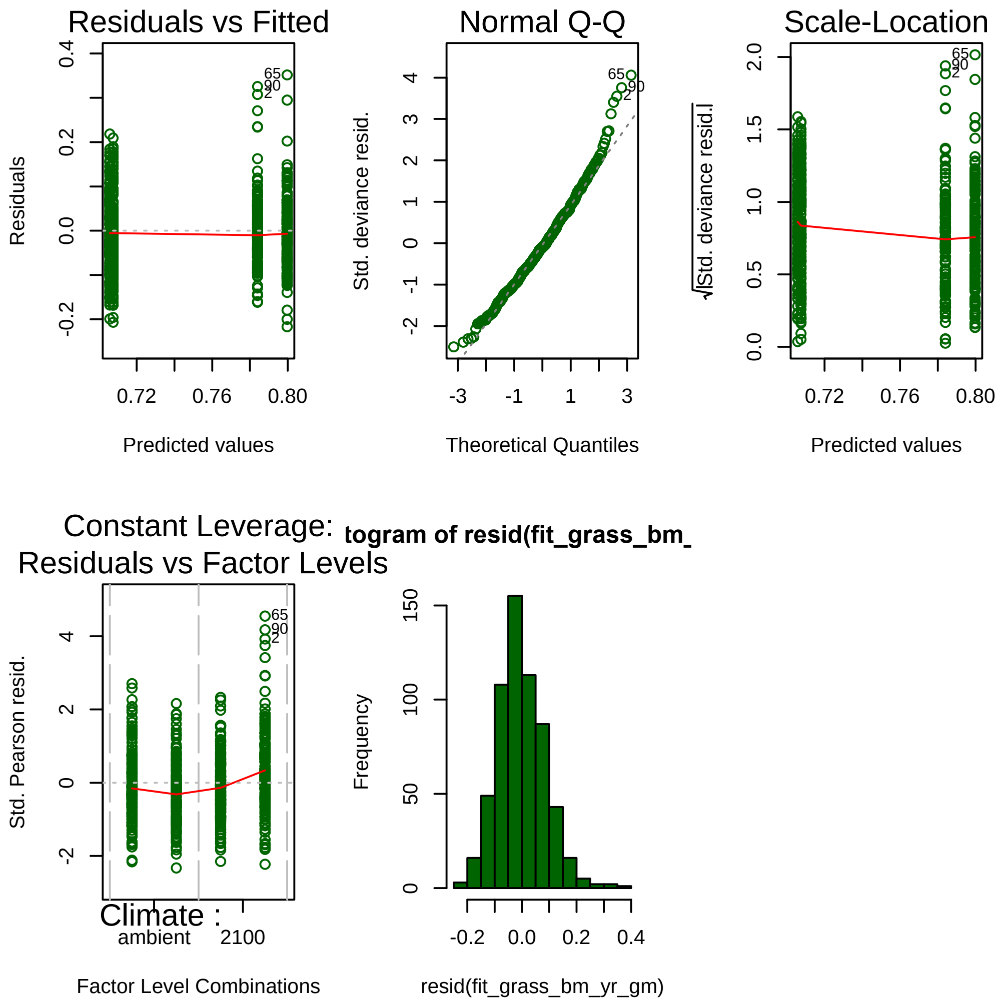






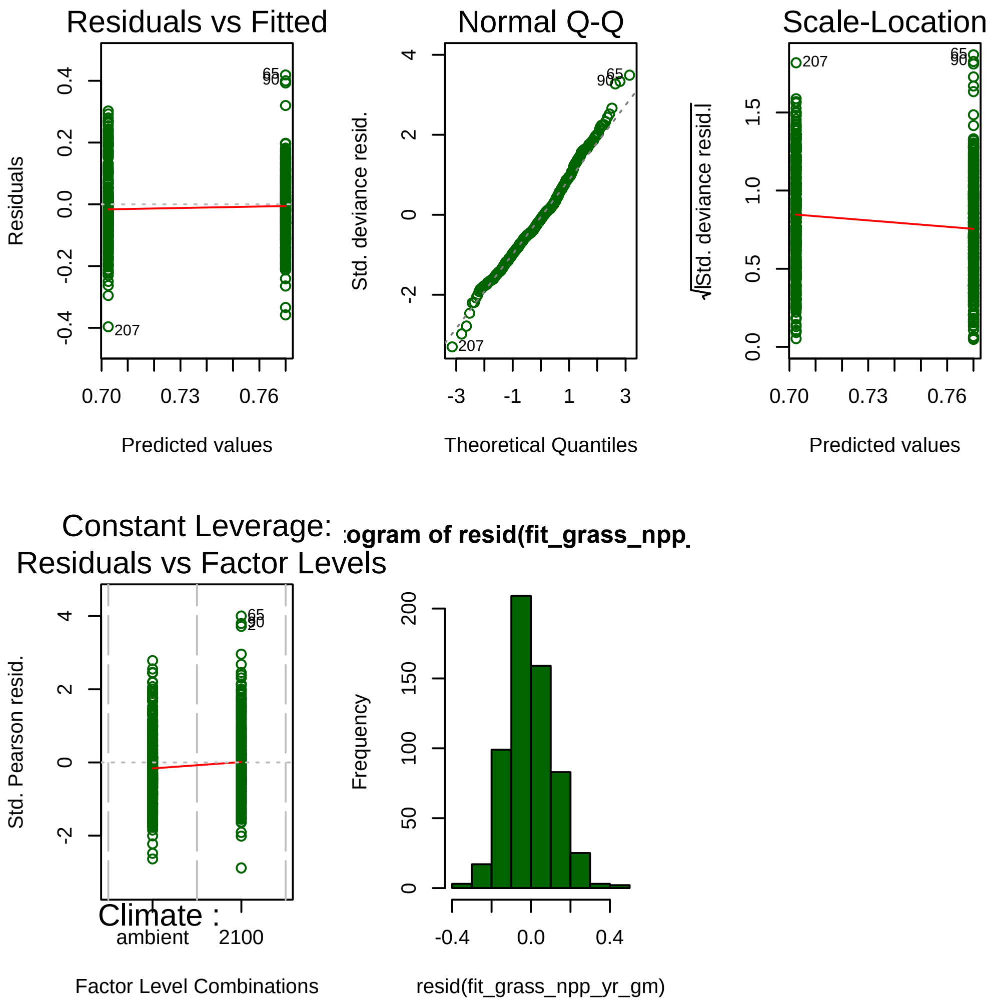



Q-Q Plot: tree NPP
Q-Q Plot: log+5 tree NPP
Q-Q Plot: tree population
Q-Q Plot: log tree population
Q-Q Plot: NEE
Q-Q Plot: log+5 NEE
Sample Quantiles
Theoretical Quantiles
0.000
0.004
0.008
1.5
2.0
2.5
3.0
1000
3000
5000
3.0
3.4
0.000
0.003
0.006
-3
-2
-1
0
1
2
3



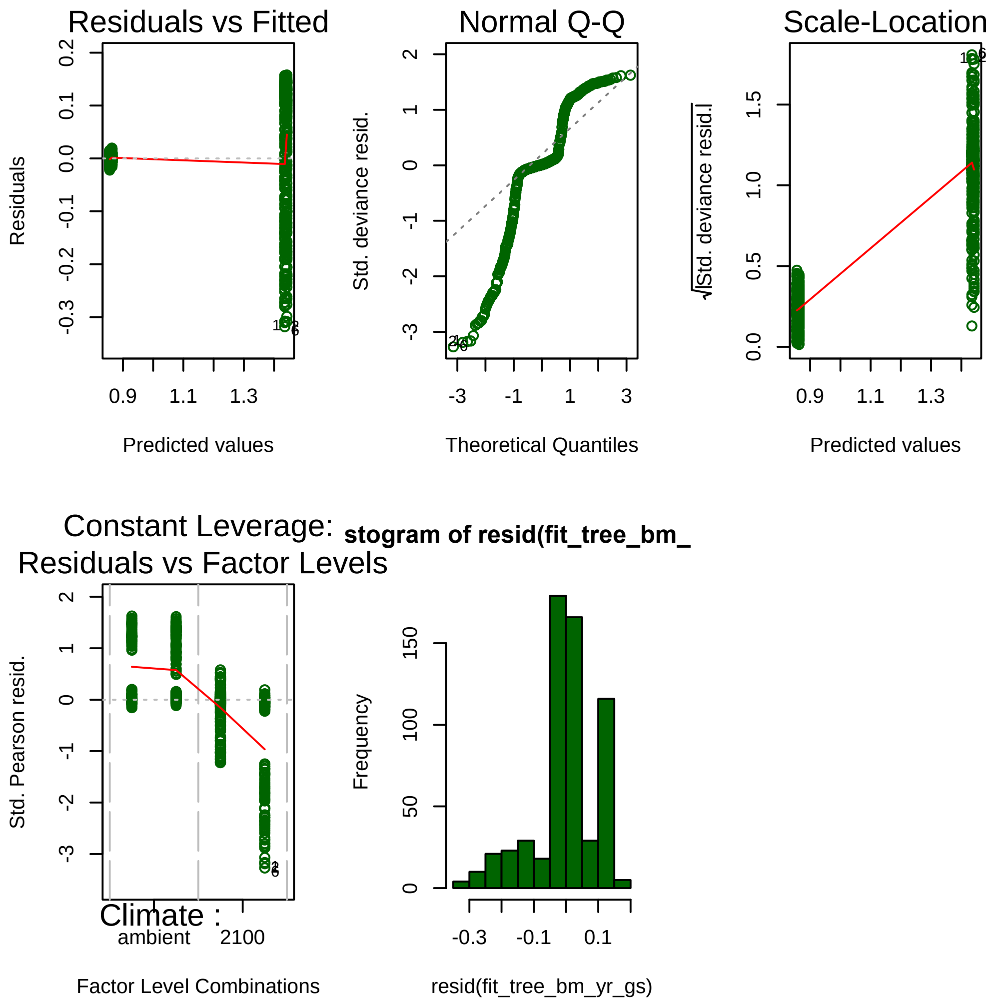

```
Call:
glm(formula = grass_bm_log ~ Climate * Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.21680  -0.05888  -0.00832   0.05278   0.35169

Coefficients:
                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                0.799690   0.005675 140.905   <2e-16 ***
Climateambient            -0.093918   0.007570 -12.407   <2e-16 ***
Tenurecomm                -0.015699   0.007948  -1.975   0.0487 *
Climateambient:Tenurecomm  0.017453   0.010652   1.638   0.1019
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 0.007555073)

    Null deviance: 6.3457  on 599  degrees of freedom
Residual deviance: 4.3766  on 596  degrees of freedom
AIC: -894.92

Number of Fisher Scoring iterations: 4
```

Diagnostic plots and statistics: Gamma distribution for log+2 grass biomass



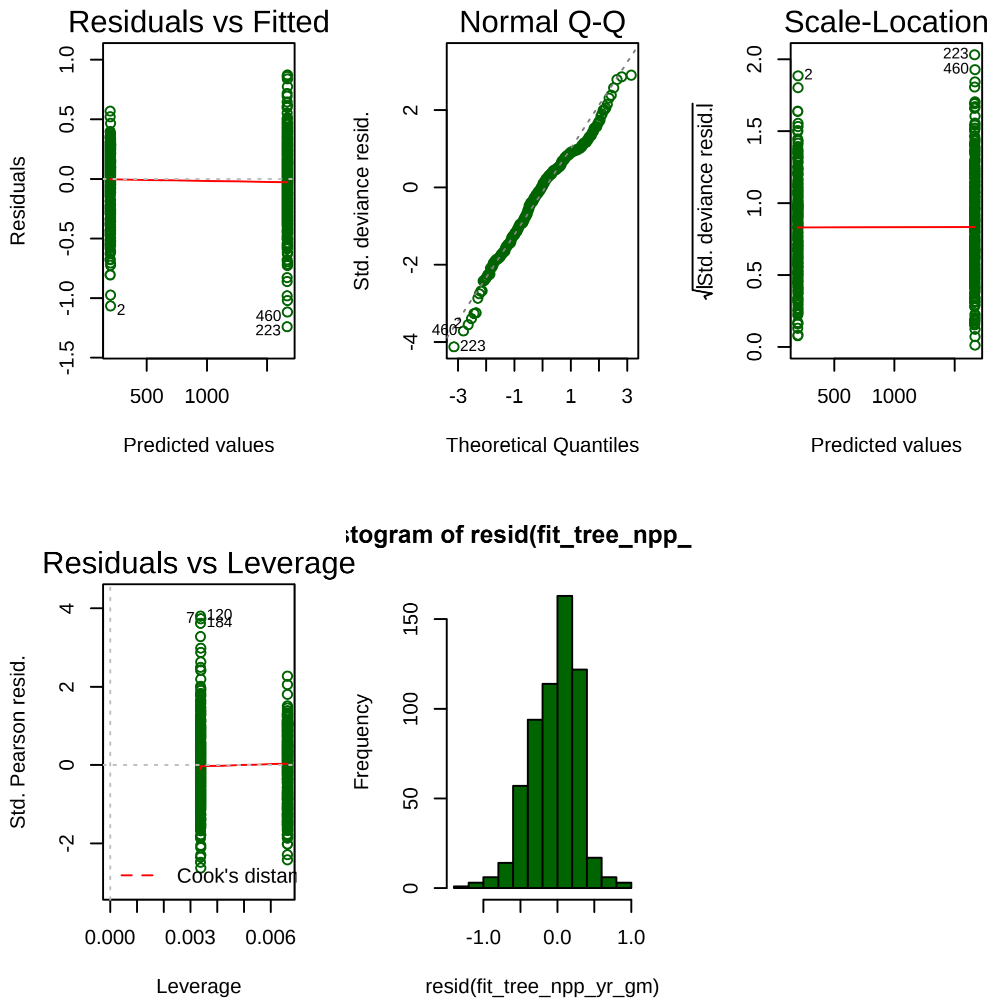

```
Call:
glm(formula = grass_npp_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.39247  -0.08077  -0.01145   0.06873   0.42398

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.773253   0.006461 119.680   <2e-16 ***
Climateambient -0.067433   0.007234  -9.322   <2e-16 ***
Tenurecomm     -0.006477   0.007204  -0.899    0.369
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.01444765)

    Null deviance: 9.6996  on 599  degrees of freedom
Residual deviance: 8.4283  on 597  degrees of freedom
AIC: -486.88

Number of Fisher Scoring iterations: 4
```

Diagnostic plots and statistics: Gamma distribution for log+5 grass NPP



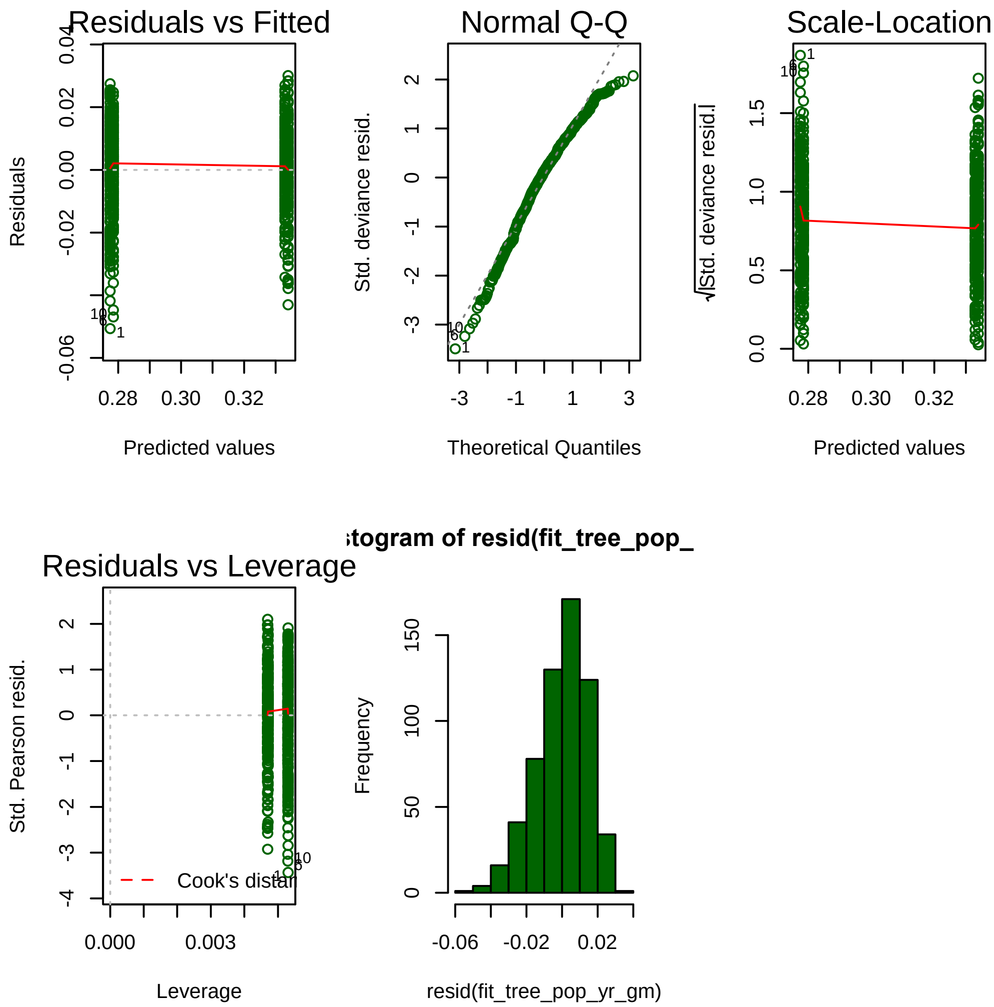

```
Call:
glm(formula = tree_bm_log ~ Climate + Tenure, family = "gaussian",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.31822  -0.01106   0.00112   0.04997   0.15804

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     1.442579   0.006898 209.128   <2e-16 ***
Climateambient -0.579374   0.007965 -72.738   <2e-16 ***
Tenurecomm     -0.007216   0.007965  -0.906    0.365
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.009516697)

    Null deviance: 56.0404  on 599  degrees of freedom
Residual deviance:  5.6815  on 597  degrees of freedom
AIC: -1085.1

Number of Fisher Scoring iterations: 2
```

Diagnostic plots and statistics: Gaussian distribution for log tree biomass



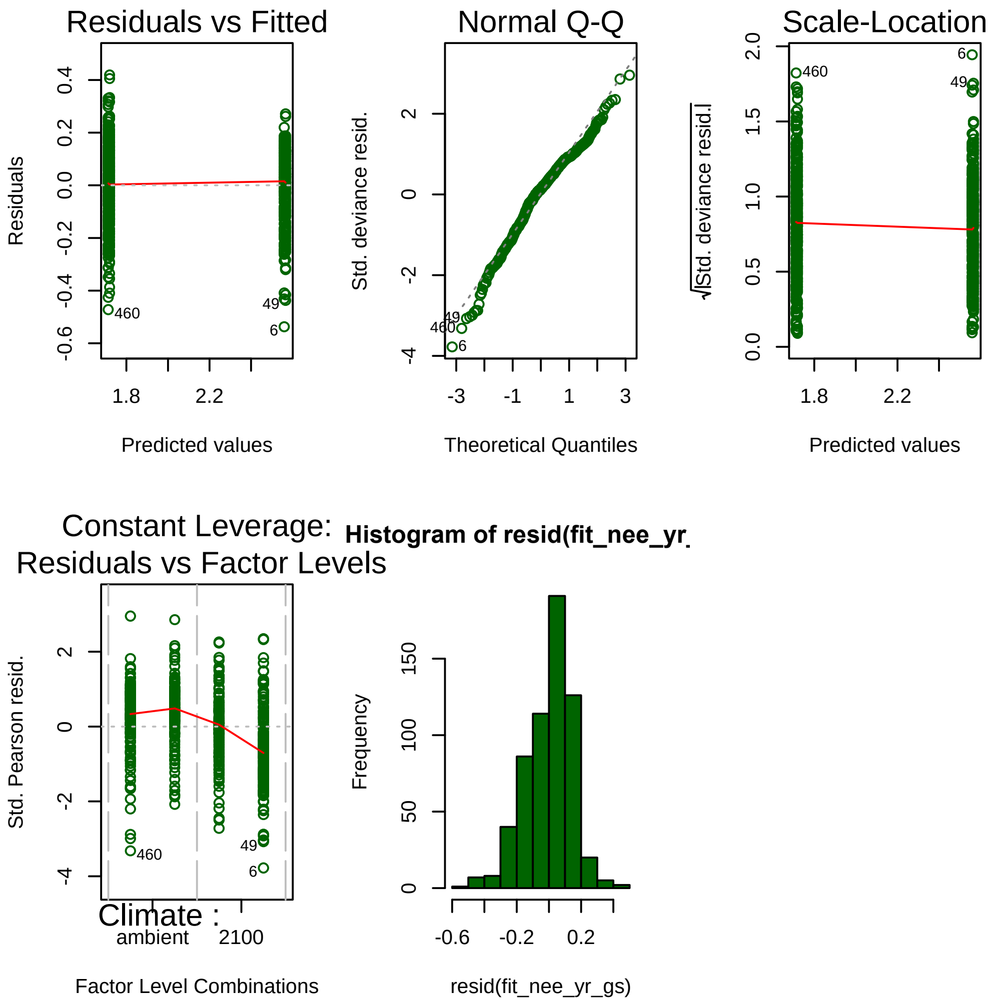

```
Call:
glm(formula = tree_npp_yr$x ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.24009  -0.25703   0.01347   0.19418   0.87254

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     196.057      4.801  40.836   <2e-16 ***
Climateambient 1470.963     29.191  50.390   <2e-16 ***
Tenurecomm        2.800      6.814   0.411    0.681
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.09056936)

    Null deviance: 643.436  on 599  degrees of freedom
Residual deviance:  60.481  on 597  degrees of freedom
AIC: -7339.5

Number of Fisher Scoring iterations: 5
```

Diagnostic plots and statistics: Gamma distribution for log+5 tree NPP




```
Call:
glm(formula = tree_pop_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.050664  -0.009312   0.001883   0.010494   0.030113

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    0.2774638  0.0002939 944.025   <2e-16 ***
Climateambient 0.0555069  0.0003645 152.272   <2e-16 ***
Tenurecomm     0.0010013  0.0003586   2.792   0.0054 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.0002115159)

    Null deviance: 5.09392  on 599  degrees of freedom
Residual deviance: 0.12698  on 597  degrees of freedom
AIC: -1938.7

Number of Fisher Scoring iterations: 3
```

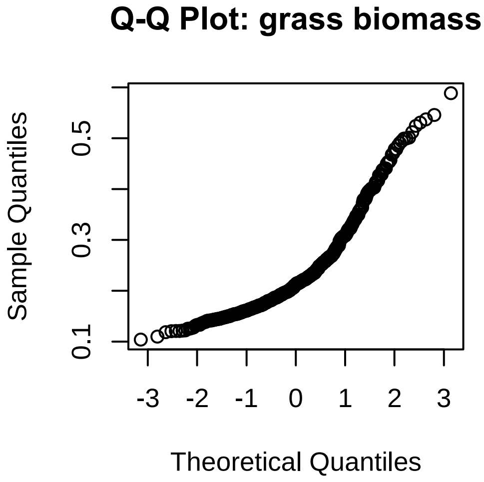
Diagnostic plots and statistics: Gamma distribution for log tree population

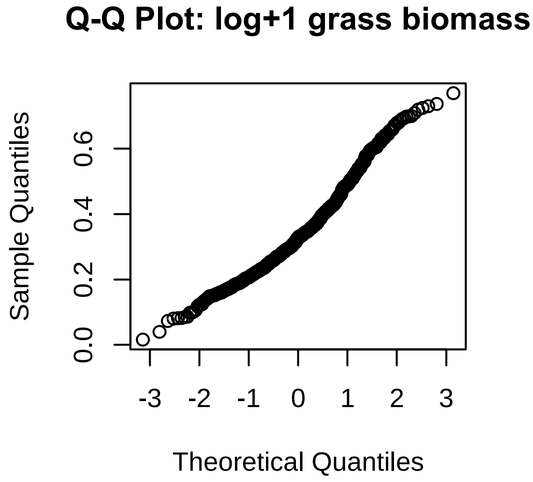


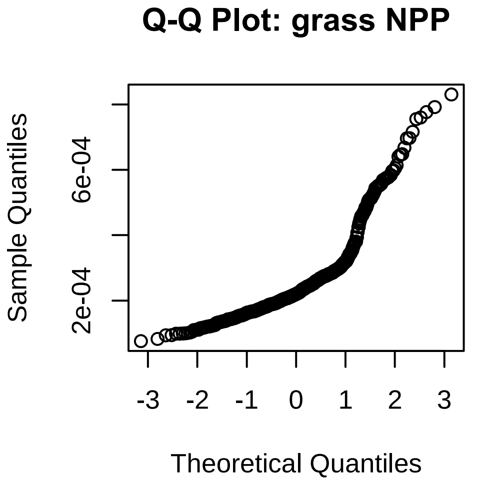

```
Call:
glm(formula = nee_log ~ Climate + Tenure, family = "gaussian",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.53675  -0.09242   0.01911   0.10128   0.41948

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     2.565844   0.010070 254.792   <2e-16 ***
Climateambient -0.846484   0.011628 -72.796   <2e-16 ***
Tenurecomm     -0.006607   0.011628  -0.568     0.57
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.02028236)

    Null deviance: 119.595  on 599  degrees of freedom
Residual deviance:  12.109  on 597  degrees of freedom

AIC: -631.08

Number of Fisher Scoring iterations: 2
```

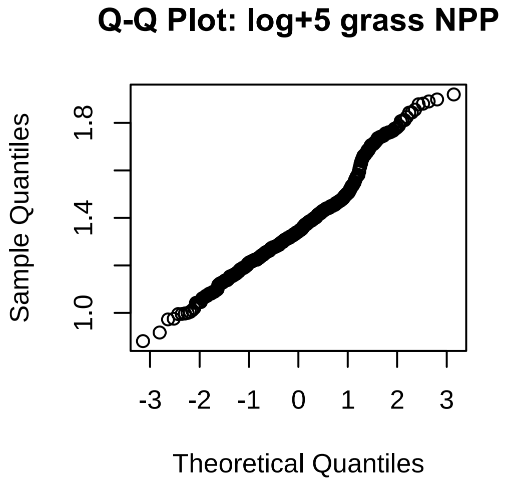
Diagnostic plots and statistics: Gaussian distribution for log+5 NEE

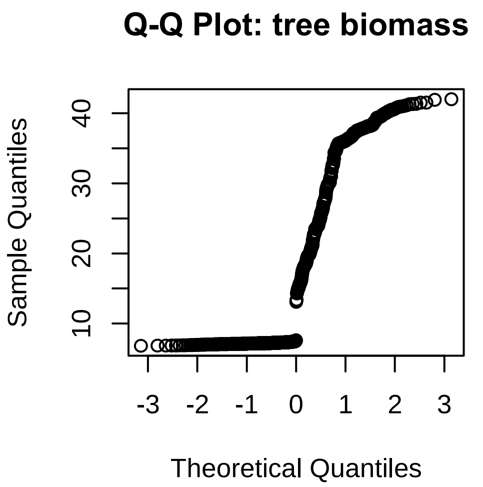
EXPERIMENT 3

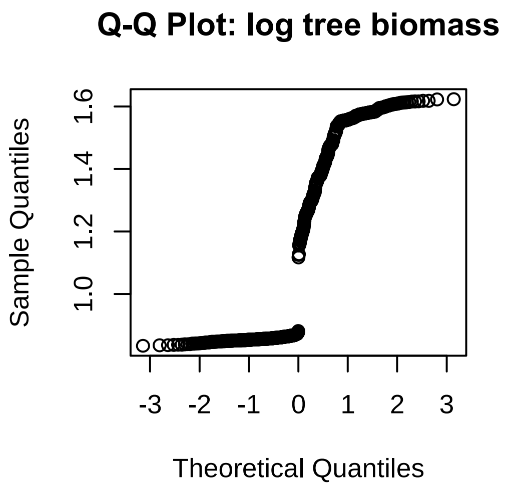


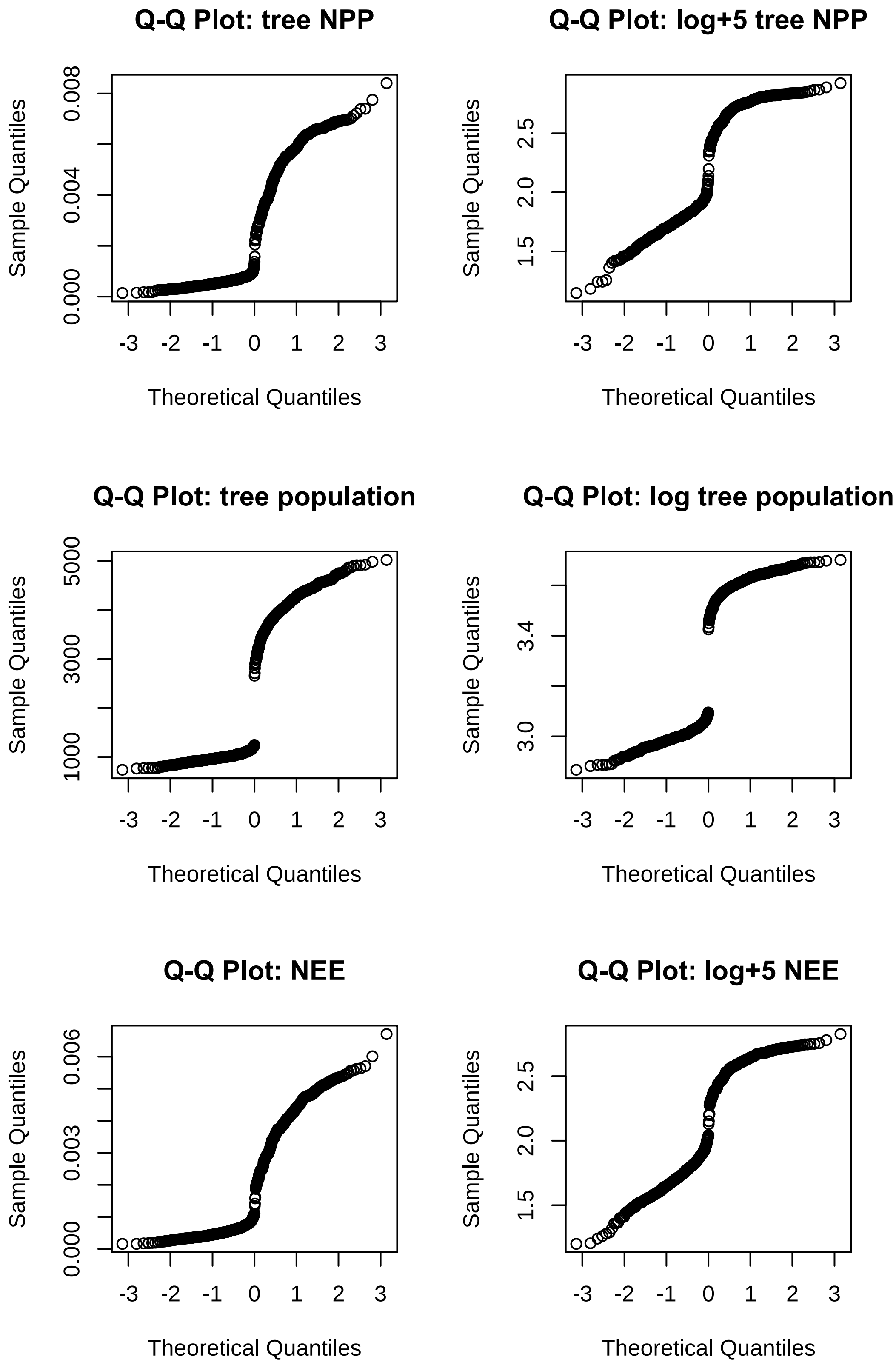


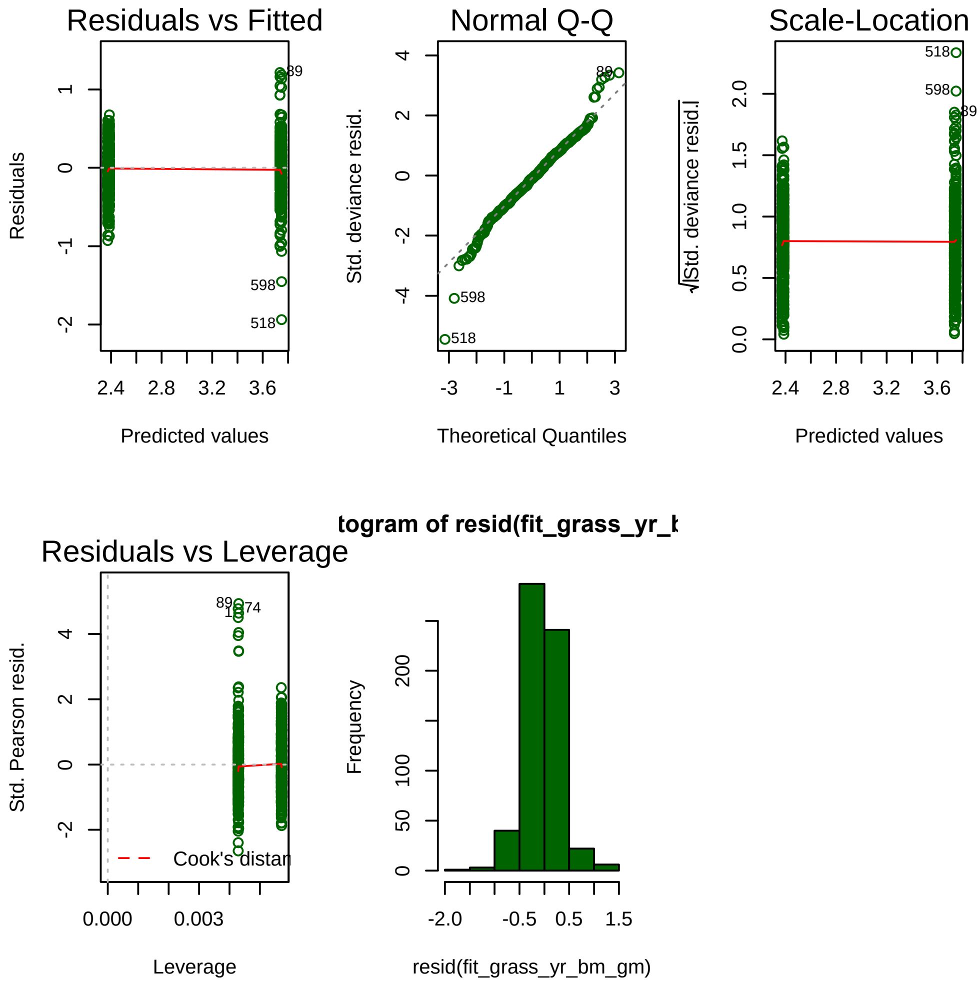






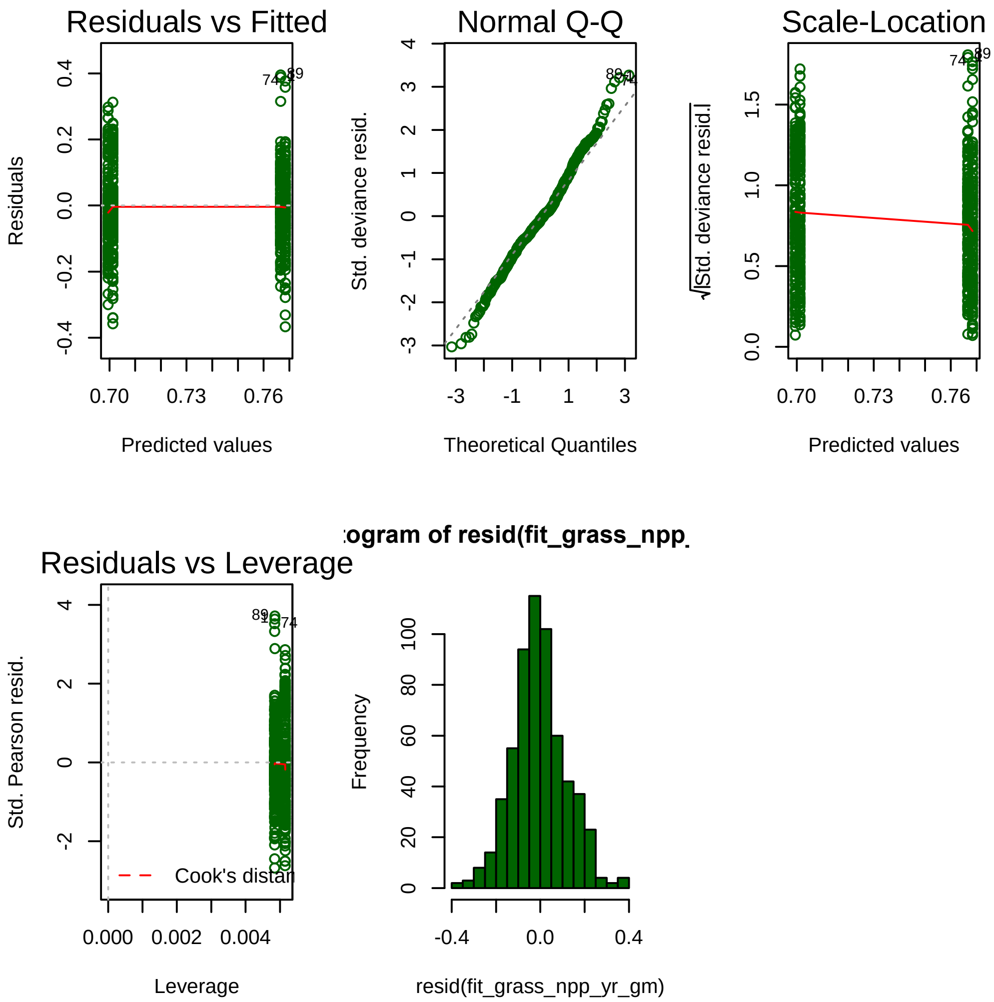



Q-Q Plot: tree NPP
Sample Quantiles
0.000
0.004
0.008
Theoretical Quantiles
-3 -2 -1 0 1 2 3
Q-Q Plot: log+5 tree NPP
Sample Quantiles
1.5
2.0
2.5
Theoretical Quantiles
-3 -2 -1 0 1 2 3
Q-Q Plot: tree population
Sample Quantiles
1000
3000
5000
Theoretical Quantiles
-3 -2 -1 0 1 2 3
Q-Q Plot: log tree population
Sample Quantiles
3.0
3.4
Theoretical Quantiles
-3 -2 -1 0 1 2 3
Q-Q Plot: NEE
Sample Quantiles
0.000
0.003
0.006
Theoretical Quantiles
-3 -2 -1 0 1 2 3
Q-Q Plot: log+5 NEE
Sample Quantiles
1.5
2.0
2.5
Theoretical Quantiles
-3 -2 -1 0 1 2 3



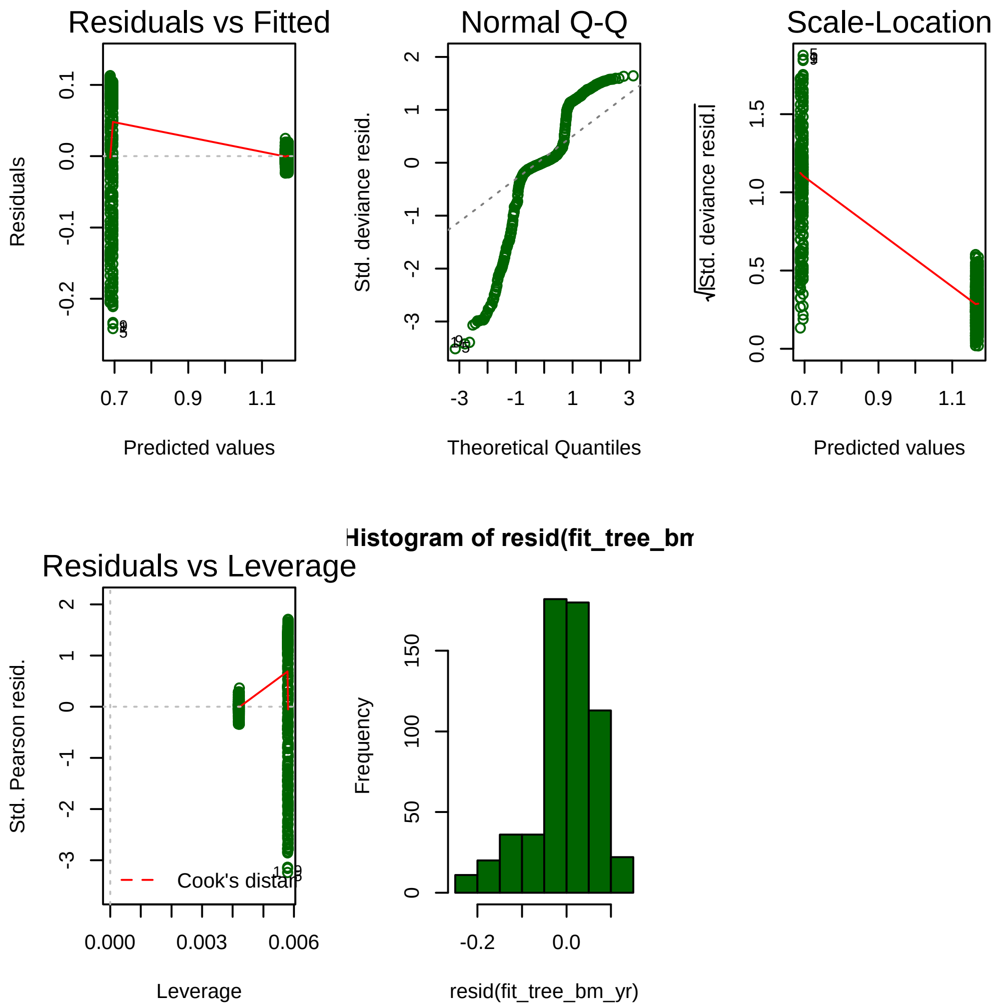

```
Call:
glm(formula = grass_bm_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-1.93810  -0.25453  -0.03726   0.19398   1.21681

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     3.73609    0.08728   42.81   <2e-16 ***
Climateambient -1.36216    0.09121  -14.93   <2e-16 ***
Tenureplots     0.01319    0.08261    0.16    0.873
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 0.1268549)

    Null deviance: 108.501  on 599  degrees of freedom
Residual deviance:  78.045  on 597  degrees of freedom
AIC: -890.38

Number of Fisher Scoring iterations: 5
```

Diagnostic plots and statistics: Gamma distribution for log+1 grass biomass



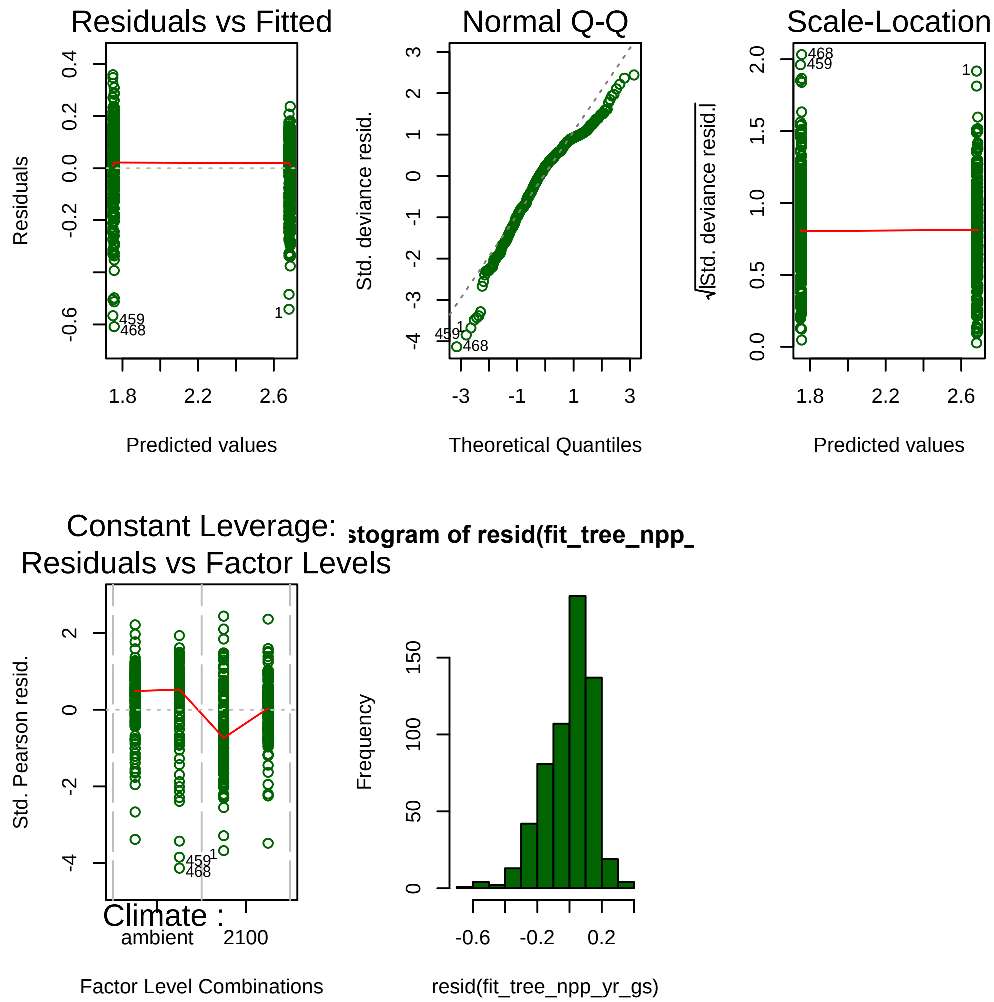

```
Call:
glm(formula = grass_npp_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.36660  -0.07404  -0.00998   0.06650   0.39526

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.766628   0.006470 118.498   <2e-16 ***
Climateambient -0.067164   0.007268  -9.241   <2e-16 ***
Tenureplots     0.001823   0.007237   0.252    0.801
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Gamma family taken to be 0.01467726)

    Null deviance: 9.9092  on 599  degrees of freedom
Residual deviance: 8.6509  on 597  degrees of freedom
AIC: -467.62

Number of Fisher Scoring iterations: 4
```

Diagnostic plots and statistics: Gamma distribution for log+5 grass NPP



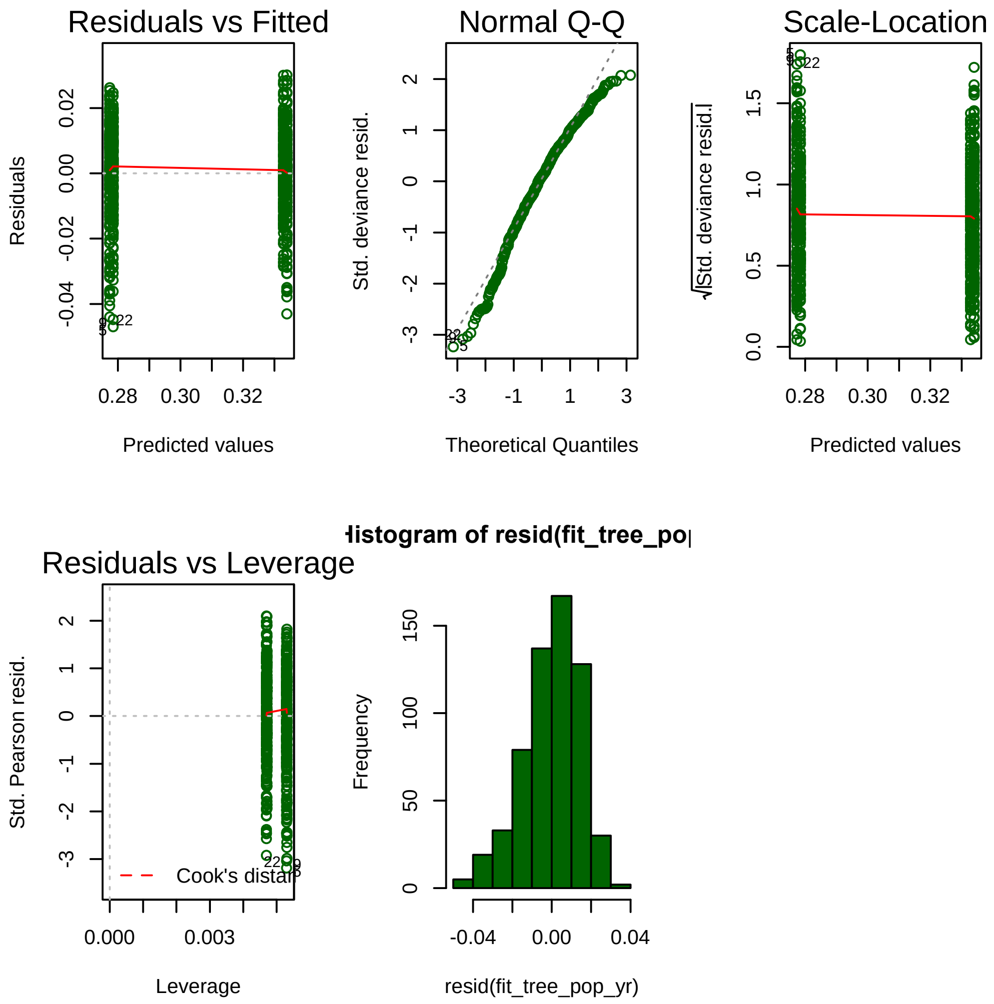

```
Call:
glm(formula = tree_bm_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.241807  -0.011977   0.001043   0.025471   0.113101

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.695770   0.003650 190.612   <2e-16 ***
Climateambient  0.475059   0.005401  87.957   <2e-16 ***
Tenureplots    -0.007396   0.004739  -1.561    0.119
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 0.004753361)

    Null deviance: 43.4938  on 599  degrees of freedom
Residual deviance:  2.9685  on 597  degrees of freedom
AIC: -1348.9

Number of Fisher Scoring iterations: 4
```

Diagnostic plots and statistics: Gamma distribution for log tree biomass



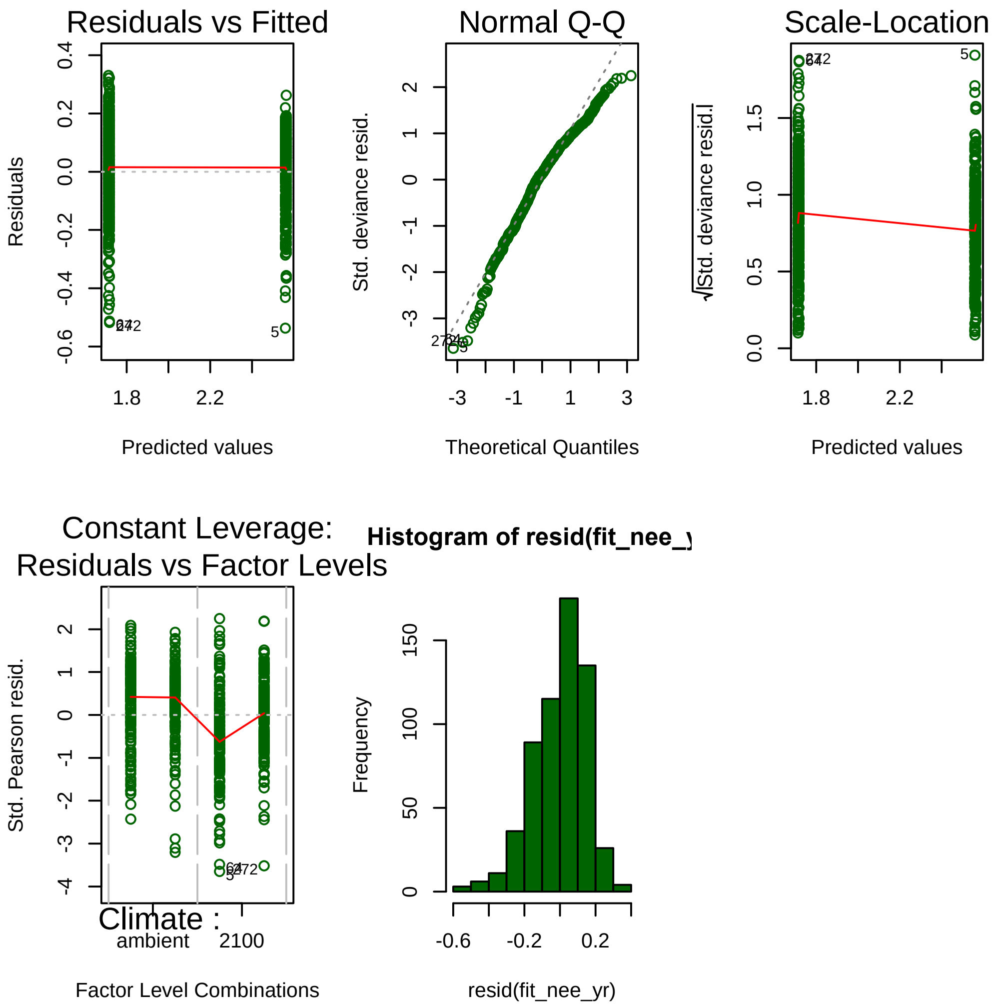

```
Call:
glm(formula = tree_npp_log ~ Climate + Tenure, family = "gaussian",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.60839  -0.09027   0.03437   0.10992   0.35940

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     2.68077    0.01043 256.997   <2e-16 ***
Climateambient -0.93186    0.01205 -77.366   <2e-16 ***
Tenureplots     0.00637    0.01205   0.529    0.597
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.02176165)

    Null deviance: 143.253  on 599  degrees of freedom
Residual deviance:  12.992  on 597  degrees of freedom
AIC: -588.85

Number of Fisher Scoring iterations: 2
```

Diagnostic plots and statistics: Gaussian distribution for log+5 tree NPP




```
Call:
glm(formula = tree_pop_log ~ Climate + Tenure, family = "Gamma",
    data = MGR)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-0.046974  -0.008836   0.001475   0.010491   0.030152

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.2784562  0.0002949 944.382  < 2e-16 ***
Climateambient  0.0555287  0.0003647 152.267  < 2e-16 ***
Tenureplots    -0.0011036  0.0003587  -3.077  0.00219 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 0.0002117627)

    Null deviance: 5.09997  on 599  degrees of freedom
Residual deviance: 0.12714  on 597  degrees of freedom
AIC: -1937.7

Number of Fisher Scoring iterations: 3
```

Diagnostic plots and statistics: Gamma distribution for log tree population




```
Call:
glm(formula = nee_log ~ Climate + Tenure, family = "gaussian",
    data = MGR)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.53687  -0.09506   0.02075   0.11086   0.33086

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     2.559357   0.010436  245.23   <2e-16 ***
Climateambient -0.846725   0.012051  -70.26   <2e-16 ***
Tenureplots     0.004576   0.012051    0.38    0.704
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.02178404)

    Null deviance: 120.550  on 599  degrees of freedom
Residual deviance:  13.005  on 597  degrees of freedom
AIC: -588.23

Number of Fisher Scoring iterations: 2
```

Diagnostic plots and statistics: Gaussian distribution for log+5 NEE

REFERENCES

AARDVARK01. 2009. Self drive to Amboseli and the park. *Amboseli Eco-system Forum* [Online]. Available from: http://www.tripadvisor.co.uk/ShowTopic-g298252-i12675-k3175640-Self_Drive_to_Amboseli_and_the_Park-Amboseli_Eco_system_Rift_Valley_Province.html 2012].

ADAMS, J. & MCSHANE, T. 1996. *The myth of wild Africa: conservation without illusion,* Los Angeles, USA, University of California Press.

ADAMS, W. M. & HUGHES, F. M. R. 1986. The environmental effects of dam construction in tropical Africa: impacts and planning procedures. *Geoforum,* 17**,** 403-410.

ADANO, R. & WITSENBURG, K. 2008. Pastoral sedentarisation: natural resource management and livelihood diversification in Marsabit District, Northern Kenya. Volumes I and II. Wales, UK: Edwin Mellen Press.

ADGER, N. 2000. Social and ecological resilience: are they related? *Progress in Human Geography,* 24**,** 347-364.

ADGER, N. 2008. Resilience and vulnerability. *In:* LEACH, M. (ed.) *Re-framing resilience: a symposium report. STEPS Working Paper 13.* Brighton, STEPS Centre.

ADGER, N., ARNELL, N. & TOMPKINS, E. 2005. Successful adaptation to climate change across scales. *Global Environmental Change,* 15**,** 77-86.

ADGER, N. & BARNETT, J. 2009. Commentary: four reasons for concern about adaptation to climate change. *Environment and Planning A,* 41**,** 2800-2805.

ADGER, N., BROWN, K. & TOMPKINS, E. 2006. The political economy of cross-scale networks in resource co-management. *Ecology and Society,* 10**,** 9.

ADGER, W. N. 2003. Social capital, collective action, and adaptation to climate change. *Economic Geography,* 79.

ADGER, W. N., BARNETT, J., BROWN, K., MARSHALL, N. & O'BRIEN, K. 2013. Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change,* 3**,** 112-117.

ADGER, W. N., BARNETT, J., CHAPIN, F. S., III & ELLEMOR, H. 2011. This Must Be the Place: Underrepresentation of Identity and Meaning in Climate Change Decision-Making. *Global Environmental Politics,* 11.

ADGER, W. N., EAKIN, H. & WINKELS, A. 2009. Nested and teleconnected vulnerabilities to environmental change. *Frontiers in Ecology and the Environment,* 7**,** 150-157.

AGNEW, C. & ANDERSON, E. W. 1992. *Water resources in the arid realm,* London, Routledge.

AGRAWAL, A. & PERRIN, N. 2008. Climate adaptation, local institutions, and rural livelihood. *IFRI Working Paper No. W081-6.* Ann Arbor, USA: International Forestry Resources and Institutions Program, University of Michigan.

ALBRECHT, G. 2005. Solastalgia: a new concept in human health and identity. *Philosophy, Activism, Nature,* 3**,** 41-55.

ALBRECHT, G. 2006. Environmental distress as solastalgia. *Alternatives,* 32**,** 34-35.

ALBRECHT, G. 2010. Solastalgia and the creation of new ways of living. *In:* PILGRIM, S. & PRETTY, J. (eds.) *Nature and culture: rebuilding lost connections.* London: Earthscan.

ALBRECHT, G. 2011. Chronic Environmental Change: Emerging 'Psychoterratic' Syndromes. *In:* WEISSBECKER, I. (ed.) *Climate Change and Human Well-Being: Global Challenges and Opportunities.*

ALBRECHT, G., SARTORE, G.-M., CONNOR, L., HIGGINBOTHAM, N., FREEMAN, S., KELLY, B., STAIN, H., TORMA, A. & POLLARD, G. 2007. Solastalgia: the distress caused by environmental change. *Australasian Psychiatry,* 15.

ALTMANN, J. & ALBERTS, S. 2011. 2011 Amboseli rainfall data.

ALTMANN, J., ALBERTS, S., ALTMANN, S. & ROY, S. 2002. Dramatic change in local climate patterns in the Amboseli basin, Kenya. *African Journal of Ecology,* 40**,** 248-251.

ANDERSON, D. 2000. *Identity and ecology in Arctic Siberia,* Oxford, Oxford University Press.

ANYAH, R. O. & QUI, W. 2012. Characteristic 20th and 21st century precipitation and temperature patterns and changes over the Greater Horn of Africa. *International Journal of Climatology,* 32**,** 347-363.

AWF 2011. Mbirikani carbon, community and biodiversity project: reducing emissions from deforestation and forest degradation (REDD) and protecting a critical landscape for Kenya's wildlife and communities. Nairobi: African Wildlife Foundation.

AYANTUNDE, A. A., DE LEEUW, J., TURNER, M. D. & SAID, M. 2011. Challenges of assessing the sustainability of (agro)-pastoral systems. *Livestock Science,* 139.

BARBOUR, R. 2006. Mixing qualitative methods: quality assurance or qualitative quagmire? *In:* BRYMAN, A. (ed.) *Mixed Methods.* London, UK: Sage

BARNETT, J. & O'NEILL, S. 2010. Maladaptation - editorial. *Global Environmental Change,* 20**,** 211-213.

BAXTER, J. & EYLES, J. 1997. Evaluating qualitative research in social geography: establishing 'rigour' in interview analysis. *Transactions of the Institute of British Geographers,* 22**,** 505-525.

BEHNKE, R. 2008. The drivers of fragmentation in arid and semiarid landscapes. *In:* GALVIN, K., REID, R., BEHNKE, R. & HOBBS, N. (eds.) *Fragmentation of semi-arid and arid landscapes: consequences for human and natural systems.* Dordrecht, Netherlands: Springer.

BEHNKE, R. & KERVEN, C. 2013. Counting the costs: replacing pastoralism with irrigated agriculture in the Awash Valley. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development in Africa: dynamic change at the margins.* Oxon, UK: Routledge.

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

BEHNKE, R., SCOONES, I. & KERVEN, C. (eds.) 1993b. *Range ecology at disequilibruim: new models of natural variability and pastoral adaptation in African savannas,* London, UK.

BEKURE, S., DE LEEUW, P., GRANDIN, B. & NEATE, P. 1991. The long term productivoty of the Maasai livestock production system. *In:* BEKURE, S., DE LEEUW, P., GRANDIN, B. & NEATE, P. (eds.) *Maasai herding: an analysis of the livestock production system of the Maasai pastoralists in Eastern Kajiado, Kenya.* Addis Ababa: ILCA.

BELL, R. H. V. 1982. The effect of soil nutrient availability on community structure in African ecosystems. *Ecological Studies,* 42**,** 193-216.

BERKES, F. 2002. Cross-scale institutional linkages: perspectives from the bottom up. *In:* OSTROM, E., DIETZ, T., DOLSAK, N., STERN, P., STONICH, S. & WEBER, E. (eds.) *The drama of the commons.* Washington DC: National Academy Press.

BERKES, F. & FOLKE, C. 1998. *Linking social and ecological systems: management practices and social mechanisms for building resilience,* Cambridge, UK, Cambridge University Press.

BITHELL, M. & BRASINGTON, J. 2009. Coupling agent-based models of subsistence farming with individual-based forest models and dynamic models of water distribution. *Environmental Modelling and Software,* 24**,** 173-190.

BLAIKIE, P. & BROOKFIELD, H. 1985. *The Political Economy of Soil Erosion in Developing Countries,* London, Longman.

BOND, W. 2008. What limits trees in C4 grassland and savannas? *Annual Review of Ecology and Systematics,* 39**,** 641-659.

BOND, W. & KEELEY, J. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends in Ecology and Evolution,* 20**,** 387-394.

BOND, W., WOODWARD, F. & MIDGELY, G. 2005. The global distribution of ecosystems in a world without fire. *New Phytologist,* 165**,** 525-537.

BOND, W. J. & MIDGLEY, G. F. 2000. A proposed CO2-controlled mechanism of woody plant invasion in grasslands and savannas. *Global Change Biology,* 6**,** 865-869.

BOND, W. J. & MIDGLEY, G. F. 2012. Carbon dioxide and the uneasy interaction of trees and savannah grasses. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 367**,** 601-612.

BOONE, R., GALVIN, K., BURNSILVER, S., THORNTON, P., OJIMA, D. & JAWSON, J. 2011a. Using coupled simulation models to link pastoral decision making and ecosystem services. *Ecology and Society,* 16**,** 6.

BOONE, R. B., CONANT, R. T. & HILLINSKI, T. E. 2011b. G-Range: Development and Use of a Beta Global Rangeland Model. *In:* LABORATORY, N. R. E. (ed.). Fort Collins, CO: Colorado State University.

BOONE, R. B. & COUGHENOUR, M. B. 2001. A system for integrated management and assessment of East African pastoral lands: balancing food security, wildlife conservation and ecosystem integrity. *Final report to the Global Livestock Collaborative Research Support Program.* Davis, CA: University of California, Davis.

BOUSQUET, F., BARRETEAU, O., D'AQUINO, P., ETIENNE, M., BOISSAU, S., AUBERT, S., LE PAGE, C., BABIN, D. & CASTELLA, J.-C. 2002. Multi-agent systems and role games: collective learning processes for ecosystem management. *In:* JANSSEN, M. (ed.) *Complexity and Ecosystem Management: The Theory and Practice of Multi-Agent Systems.* Cheltenham, UK: Edward Elgar Publishers.

BOUSQUET, F. & LE PAGE, C. 2004. Multi-agent simulations and ecosystem management: a review. *Ecological Modelling,* 176**,** 313-332.
BOX, G. & DRAPER, N. 1987. *Empirical model-building and response surfaces,* New York, Wiley.
BOYD, E., OSBAHR, H., ERICKSEN, P., TOMPKINS, E., LEMOS, M. & MILLER, F. 2008. Resilience and 'climatizing' development: examples and policy implications. *Development,* 51**,** 390-396.
BREAKWELL, G. 1996. The identity of places and place identity. *Conference on Representations of the Landscape.* Torino, Italy.
BROVKIN, V., BOYSEN, L., RADDATZ, T., GAYLER, V., LOEW, A. & CLAUSSEN, M. 2013. Evaluation of vegetation cover and land-surface albedo in MPI-ESM CMIP5 simulations. *Journal of Advances in Modeling Earth Systems,* 5**,** 48-57.
BROWN, L. 1963. The development of the semi-arid areas of Kenya. Nairobi: Ministry of Agriculture
BRYANT, R. L. & BAILEY, S. 1997. *Third world political ecology,* London, Routledge.
CAMPBELL, B. D. & STAFFORD SMITH, D. M. 2000. A synthesis of recent global change research on pasture and rangeland production: reduced uncertainties and their management implications. *Agriculture, Ecosystems and Environment,* 82**,** 39.
CAMPBELL, D. J. 1993. Land as ours, land as mine: economic, political and ecological marginalisation in Kajiado District. *In:* SPEAR, T. & WALLER, R. (eds.) *Being Maasai.* London: James Currey.
CAMPBELL, D. J. 1999. Response to drought among farmers and herders in southern Kajiado District, Kenya: A comparison of 1972-1976 and 1994-1995. *Human Ecology,* 27.
CANNON, T. & MUELLER-MAHN, D. 2010. Vulnerability, resilience and development discourses in context of climate change. *Natural Hazards,* 55**,** 621-635.
CATLEY, A. & AKLILU, Y. 2013. Moving up or moving out? Commercialisation, growth and destitution in pastoralist areas. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and Development in Africa: dynamic change at the margins.* Abingdon, Oxon: Routledge.
CATLEY, A., LIND, J. & SCOONES, I. 2013. Development at the margins: pastoralism in the Horn of Africa. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and Development in Africa: dynamic change at the margins.* New York, USA: Routledge.
CAVAGNARO, T. R., GLEADOW, R. M. & MILLER, R. M. 2011. Viewpoint: plant nutrition in a high CO2 world. *Functional Plant Biology,* 38**,** 87-96.
COMIM, F., KUMAR, P. & SIRVEN, N. 2009. Poverty and environment links: an illustration from Africa. *Journal of International Development,* 21**,** 447-469.
CONANT, R. 2010. Challenges and opportunities for carbon sequestration in grassland systems. A technical report on grassland management and climate change mitigation. Rome, Italy: Food and Agricultural Organisation of the United Nations.
COPE, M. 2003. Coding transcripts and diaries. *In:* CLIFFORD, N. & VALENTINE, G. (eds.) *Key methods in geography.* London, UK: Sage Publications.

COSTANZA, R., WAIGNER, C., FOLKE, C. & MAELER, K. 1993. Modelling complex ecological economic systems: toward an evolutionary dynamic understanding of people and nature. *BioScience,* 43**,** 545-555.

COUGHENOUR, M. B., SWIFT, D. M., GALVIN, K. A. & ELLIS, J. E. 1998. Savanna - Landscape and Regional Ecosystem Model. *In:* LABORATORY, N. R. E. (ed.). Fort Collins, CO: Colorado State University.

COUSINS, B. 2010. The politics of communal tenure reform: a South African case study. *In:* ANSEEUW, W. & ALDEN, C. (eds.) *The struggle over land in Africa: conflicts, politics and change.* Pretoria, South Africa: HSRC Press.

CRAMER, W., BONDEAU, A., WOODWARD, F., PRENTICE, C., BETTS, R., BROVKIN, V., COX, P., FISHER, V., FOLEY, J., FRIEND, A., KUCHARIK, C., LOMAS, M., RAMANKUTTY, N., SITCH, S., SMITH, B., WHITE, A. & YOUNG-MOLLING, C. 2001a. Global response of terrestrial ecosystem structure and function to CO2 and climate change: results from six dynamic global vegetation models. *Global Change Biology,* 7**,** 357-373.

CRAMER, W., BONDEAU, A., WOODWARD, F. I., PRENTICE, I. C., BETTS, R. A., BROVKIN, V., COX, P. M., FISHER, V., FOLEY, J. A., FRIEND, A. D., KUSHARIK, C., LOMAS, M. R., RAMANKUTTY, N., SITCH, S., SMITH, B., WHITE, A. & YOUNG-MOLLING, C. 2001b. Global response of terrestrial ecosystem structure and function to CO2 and climate change: results from six dynamic global vegetation models. *Global Change Biology,* 7**,** 357-373.

CRANE, T. A. 2010. Of Models and Meanings: Cultural Resilience in Social-Ecological Systems. *Ecology and Society,* 15.

CRANG, M. & COOK, I. 2007. *Doing ethnographies,* London, UK, Sage Publications.

CRATE, S. A. 2008. Gone the Bull of Winter? Grappling with the Cultural Implications of and Anthropology's Role(s) in Global Climate Change. *Current Anthropology,* 49.

CUNSOLO WILLOX, A., HARPER, S. L., FORD, J. D., LANDMAN, K., HOULE, K., EDGE, V. L. & RIGOLET INUIT COMMUNITY, G. 2012. "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. *Social science & medicine (1982),* 75.

DEVEREUX, S. & TIBBO, K. 2013. Social protection for pastoralists. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development in Africa: dynamic change at the margins.* Oxford: Routledge.

DOHERTY, T. J. & CLAYTON, S. 2011. The Psychological Impacts of Global Climate Change. *American Psychologist,* 66.

DORIA, M. D., BOYD, E., TOMPKINS, E. L. & ADGER, W. N. 2009. Using expert elicitation to define successful adaptation to climate change. *Environmental Science and Policy,* 12**,** 810-819.

DOUGILL, A. J., FRASER, E. D. G. & REED, M. S. 2010. Anticipating vulnerability to climate change in drylands pastoral systems: using dynamic systems models for the Kalahari. *Ecology and Society,* 15**,** 17.

DOUGILL, A. J., STRINGER, L. C., LEVENTON, J., RIDDELL, M., RUEFF, H., SPRACKLEN, D. V. & BUTT, E. 2012. Lessons from community-based payment for ecosystem service schemes: from forests to rangelands. *Philosophical Transactions of the Royal Society B Biological Sciences,* 367**,** 3178-3190.

DRURY, R., HOMEWOOD, K. & RANDALL, S. 2011. Less is more: the potential of qualitative approaches in conservation research. *Animal Conservation,* 14**,** 18-24.

DU TOIT, J. 2010. Considerations of scale in biodiversity conservation. *Animal Conservation,* 13**,** 229-236.

EASEDALE, M. H. & DOMPTAIL, S. E. 2014. Fate can be changed! Arid rangelands in a globalizing world - A complementary co-evolutionary perspective on the current 'desert syndrome'. *Journal of Arid Environments,* 100-101**,** 52-62.

ELLIS, F. & SWIFT, D. 1988. Stability of African pastoralist ecosystems: alternate paradigms and implications for development. *Journal of Range Management,* 41**,** 450-459.

ELMI, M. & BIRCH, I. 2013. Creating policy space for pastoralism in Kenya. *In:* CONSORTIUM, F. A. (ed.) *Working Paper.* Brighton, UK.

EPSTEIN, J. 2007. *Generative Social Science: Studies in Agent-Based Computational Modelling,* Princeton, NJ, Princeton University Press.

EPSTEIN, J. 2008. Why model? *Journal of Artificial Societies and Social Simulation,* 11**,** 12.

ERICKSEN, P., DE LEEUW, J., THORNTON, P., SAID, M., HERRERO, M. & NOTENBAERT, A. 2013. Climate change in sub-Saharan Africa: what consequences for pastoralism? *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development in Africa: synamic change at the margins.* Oxford: Routledge.

EVANS-PRITCHARD, E. 1940. *The Nuer,* Oxford, Clarendon.

FAIRHEAD, J. & LEACH, M. 1996. Misreading the African landscape: society and ecology in a forest-savanna mosaic. Cambridge: Cambridge University Press.

FAO 2009. A review of evidence on drylands pastoral systems and climate change: implications and opportunities for mitigation and adaptation. *Land and Water Discussion Paper.* Rome: Food and Agriculture Organization of the United Nations.

FEWS-NET. 2014. *Kenya food security outlook update:Below average March to May rains likely to slow recovery in pastoral areas* [Online]. Available: http://www.fews.net/east-africa/kenia/food-security-outlook-update/tue-2014-03-18 [Accessed 1 April 2014].

FIELD, A. C. 1979. The impact of sheep-goats on the vegetation in the arid zone. *Technical Report E2.* UNEP-MAB-IPAL.

FINCH, V. & WESTERN, D. 1977. Cattle colors in pastoral herds: natural selection or social preference? *Ecology,* 58**,** 1384-1392.

FOLKE, C. 2006. Resilience: the emergence of a perspective for social-ecological systems analyses. *Global Environmental Change,* 16**,** 253-267.

FOLKE, C., CARPENTER, S. R., WALKER, B. H., SCHEFFER, M., CHAPIN III, F. S. & ROCKSTROM, J. 2010. Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society,* 15**,** 20.

FOLKE, C., PRITCHARD, L., BERKES, F., COLDING, J. & SVEDIN, U. 2007. The problem of fit between ecosystems and institutions: ten years later. *Ecology and Society,* 12**,** 30.

FRANKLIN, J. 1995. Predictive vegetation mapping:geographic modeling of biospatial patterns in relation to environmental gradients. *Progress in Physical Geography,* 19**,** 474-499.

FRASER, E. D. G., DOUGILL, A. J., HUBACEK, K., QUINN, C. H., SENDZIMIR, J. & TERMANSEN, M. 2011. Assessing Vulnerability to Climate Change in Dryland Livelihood Systems: Conceptual Challenges and Interdisciplinary Solutions. *Ecology and Society,* 16.

FRESQUE-BAXTER, J. A. & ARMITAGE, D. 2012. Place identity and climate change adaptation: a synthesis and framework for understanding. *Wiley Interdisciplinary Reviews-Climate Change,* 3.

FRIEDLINGSTEIN, P., JOEL, G., FIELD, C. B. & FUNG, I. Y. 1999. Toward an allocation scheme for global terrestrial carbon models. *Global Change Biology,* 5**,** 755-770.

GACHIMBI, L. 2002. Technical report of soil survey and sampling: Loitokitok Division, Kajiado District. *Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 10.* Nairobi, Kenya: International Livestock Research Institute.

GALATY, J. 2002. How visual figures speak: narrative inventions of "the pastoralist". *Visual Anthropology,* 15**,** 299-319.

GALATY, J. G. 1994. Hal(v)ing land in common: the subdivision of Maasai group ranches in Kenya. *Nomadic Peoples,* 34/35**,** 109-122.

GALATY, J. G. 2013. Land grabbing in the Eastern African rangelands. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development in Africa: dynamic change at the margins.* Oxford: Routledge.

GALVIN, K. 2009. Transitions: pastoralists living with change. *Annual Review of Anthropology,* 38**,** 185-198.

GALVIN, K., BOONE, R., OJIMA, D., THORNTON, P. & JAWSON, J. 2006. Decision-making in rangeland systems: an integrated ecosystem-agent-based modeling approach to resilience and change (DREAMER). *Poster presented at the NSF Human and Social Dynamics PI meeting.* Washington DC.

GALVIN, K. A. 2008. *Responses of pastoralists to land fragmentation: Social capital, connectivity, and resilience*.

GAVENTA, J. 2006. Finding the spaces for change: a power analysis. *Institute for Development Studies Bulletin,* 37**,** 23-33.

GILBERT, N. 2008. *Agent-Based Models,* London, Sage Publications.

GITHAGA, J., REID, R., MUCHIRU, A. & VAN DJIK, S. 2003. Survey of water quality changes with land use type in the Loitokitok Area, Kajiado District, Kenya. *Land Use Change, Impacts and Dynamics (LUCID) Project Working Paper 35.* Nairobi, Kenya: International Livestock Research Institute.

GOLDSTEIN, D. G. & GIGERENZER, G. 2002. Models of ecological rationality: the recognition heuristic. *Psychological Review,* 109**,** 75-90.

GRANDIN, B. 1992. The Maasai: socio-historical context and group ranches. *In:* BEKURE, S., DE LEEUW, P., GRANDIN, B. & NEATE, P. (eds.) *Maasai herding: an analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya.* Addis Ababa, Ethiopia: International Livestock Centre for Africa.

GRANDIN, B. E. 1987. Land tenure, sub-division and residential changes on a Maasai Group Ranch. *Development Anthropology Bulletin,* 4**,** 9-13.

GRIMM, V. & RAILSBACK, S. 2005. *Individual-based Modeling and Ecology,* Princeton, NJ, Princeton University Press.

GROUP, G. S. D. T. 2000. Global gridded surfaces of selected soil characteristics (International Geosphere-Biosphere Programme). Oak Ridge National Laboratory Distributed Active Archive Center.

GSDTG 2000. Global gridded surfaces of selected soil characteristics (International Geosphere-Biosphere Programme). *Oak Ridge National Laboratory Distributed Active Archive Center.* Global Soil Data Task Group.

GUYOT, P. & HONIDEN, S. 2006. Agent-based participatory simulations: merging multi-agent systems and role-playing games. *Journal of Artificial Societies and Social Simulation,* 9**,** 8.

HECHT, S. B. & COCKBURN, A. 1990. *The fate of the forest: developers, destroyers and defenders of the Amazon,* New York, Harper Perennial.

HECKBERT, S., BAYNES, T. & REESON, A. 2010. Agent-based modeling in ecological economics. *Annals of the New York Academy of Sciences,* 1185**,** 39-53.

HERRERO, M., THORNTON, P., GERBER, P. & REID, R. 2009. Livestock, livelihoods and the environment: understanding the trade-offs. *Current Opinion in Environmental Sustainability,* 1**,** 111-120.

HERRERO, M., THORNTON, P., NOTENBAERT, A., WOOD, S., MSANGI, S., FREEMAN, H., BOSSIO, D., DIXON, J., PETERS, M., VAN DE STEEG, J., LYNAM, J., RAO, P., MACMILLAN, S., GERARD, B., MCDERMOTT, J., SERE, C. & ROSEGRANT, M. 2010. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. *Science,* 327**,** 822-825.

HESS, J. J., MALILAY, J. N. & PARKINSON, A. J. 2008. Climate Change The Importance of Place. *American Journal of Preventive Medicine,* 35.

HEYD, T. & BROOKS, N. 2009. Exploring cultural dimensions of adaptation to climate change. *In:* ADGER, W. N., LORENZONI, I. & O'BRIEN, K. L. (eds.) *Adapting to climate change: thresholds, values, governance.* Cambridge, UK: Cambridge University Press.

HIGGINS, S., BOND, W., FEBRUARY, E., BRONN, A., EUSTON-BROWN, D., ENSLIN, B., GOVENDER, N., RADEMAN, L., O'REGAN, S., POTGIETER, A., SCHEITER, S., SOWRY, R., TROLLOPE, L. & TROLLOPE, W. 2007. Effects of four decades of fire manipulation on woody vegetation structure in savanna. *Ecology,* 88**,** 1119-1125.

HIGGINS, S., BOND, W. & TROLLOPE, W. 2000. Fire, resprouting and variability: a recipe for tree-grass coexistence in savanna. *Journal of Ecology,* 88**,** 213-229.

HOBBS, N., GALVIN, K., STOKES, C., LACKETT, J., ASH, A., BOONE, R., REID, R. & THORNTON, P. 2008a. Fragmentation of rangelands: implications for humans, animals and landscapes. *Global Environmental Change,* 18.

HOBBS, N., GALVIN, K., STOKES, C., LACKETT, J., ASH, A., BOONE, R., REID, R. & THORNTON, P. 2008b. Global Environmental Change. *18*.

HOLLING, C. 1986a. The resilience of terrestrial ecosystems: local surprise and global change. *In:* CLARK, W. & MUNN, R. (eds.) *Sustainable development of* *the biosphere.* Cambridge, UK: International Institute for Applied Systems Analysis.

HOLLING, C. 1986b. The resilience of terrestrial ecosystems: local surprise and global change. *In:* CLARK, W. & MUNN, R. (eds.) *Sustainable development of the biosphere.* Cambridge, UK: International Institute for Applied Systems Analysis.

HOLLING, C. & GUNDERSON, L. 2002. *Panarchy: understanding transformations in human and natural systems,* Washington DC, Island Press.

HOMEWOOD, K. 2008. *Ecology of African pastoralist societies,* Athens, Ohio, Ohio University Press.

HOMEWOOD, K., KRISTJANSON, P. & TRENCH, P. 2009. *Staying Maasai? Livelihoods, conservation and development in East African rangelands,* New York, USA, Springer.

HOMEWOOD, K., LAMBIN, E. F., COAST, E., KARIUKI, A., KIKULA, I., KIVELIA, J., SAID, M., SERNEELS, S. & THOMPSON, M. 2001. Long-term changes in Serengeti-Mara wildebeest and land cover: Pastoralism, population, or policies? *Proceedings of the National Academy of Sciences of the United States of America,* 98**,** 12544-12549.

HOMEWOOD, K. & LEWIS, J. 1987. Impact of drought on pastoral livestock in Baringo, Kenya 1983-85. *Journal of Applied Ecology,* 24**,** 617-631.

HOMEWOOD, K. & RODGERS, W. 1991. *Maasailand Ecology,* Cambridge, UK, Cambridge University Press.

HOSONUMA, N., HEROLD, M., V., D. S., DE FRIES, R. S., BROCKHAUS, M., VERCHOT, L., ANGELSEN, A. & ROMIJN, E. 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters,* 7.

HUGHES, L. 2006a. "Beautiful beasts" and brave warriors: the longevity of a Maasai stereotype. *In:* ROMANUCCI-ROSS, L., DE VOS, G. A. & TSUDA, T. (eds.) *Ethnic identity: problems and prospects for the twenty-first century.* Lanham, MD: AltaMira Press.

HUGHES, L. 2006b. *Moving the Maasai: a colonial misadventure,* Basingstoke, Palgrave MacMillan.

HUIGEN, M. 2004. First principles of the MameLuke multi-actor modelling framework for land use change, illustrated with a Phillipine case study. *Journal of Environmental Management,* 72**,** 5-21.

IGAD 2013. The contribution of livestock to the economies of Kenya, Ethiopia, Uganda and Sudan. *In:* (IGAD-ICPALD), I. A. O. D.-C. F. P. A. A. L. D. (ed.). Policy Brief Series.

IIED 2009. Incentives to sustain forest ecosystem services: a review and lessons for REDD. London: International Institute for Environment and Development.

IIED 2013. Following the herd: why pastoralism needs better media coverage. *In:* SHANAHAN, M. (ed.) *Briefing: Climate resilient drylands development.* London, UK: Institute of Environment and Development.

INGOLD, T. 2000. *The perception of the environment: essays on livelihood, dwelling and skill,* London and New York, Routledge.

IPCC 2007. *Fourth Assessment Report of the IPCC,* Cambridge, UK and New York, USA, Cambridge University Press.

IPCC 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. *In:* FIELD, C. B., BARROS, V., STOCKER, T. F., QIN, D., DOKKEN, D. J., EBI, K. L., MASTRANDREA, M. D., MACH, K. J., PLATTNER, G.-K., ALLEN, S. K., TIGNOR, M. & MIDGLEY, P. M. (eds.). Cambridge, UK and New York, USA.

IPCC 2013. Climate Change 2013: The Physical Science Basis. Contributions of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *In:* STOCKER, T. F., QIN, D., PLATTNER, G.-K., TIGNOR, M., ALLEN, S. K., BOSCHUNG, J., NAUELS, A., XIA, Y., BEX, V. & MIDGLEY, P. M. (eds.). Cambridge, United Kingdom and New York, USA.

IPCC 2014a. Climate Change 2014: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA.

IPCC 2014b. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel for Climate Change. Cambridge, UK and New York, USA: Cambridge University Press.

JACKSON, P. 2001. Making sense of qualitative data. *In:* LIMB, M. & DWYER, C. (eds.) *Qualitative methodologies for geographers.* London, UK: Arnold.

JACOBS, A. 1965. *The traditional political organisation of the pastoral Maasai.* D.Phil, Oxford.

JADORA LLC. 2012. *Mbirikani grassland carbon project* [Online]. Available: http://www.jadorallc.com/mbirikani_project.html [Accessed 04 April 2014].

JANSSEN, M., BODIN, O., ANDERIES, J., ELMQVIST, T., ERNSTSON, H., MCALLISTER, R., OLSSON, P. & RYAN, P. 2006. Toward a network perspective of the study of resilience in social-ecological systems. *Ecology and Society,* 11**,** 15.

JANSSEN, M. & OSTROM, E. 2006. Empirically based, agent-based models. *Ecology and Society,* 11**,** 37.

JOHANSSON, S. 1991. Ecological implications for Tana River Basin forestry and irrigated agriculture. *In:* BAXTER, P. T. W. (ed.) *When the Grass is Gone: development intervention in African arid lands.* Uddevalla, Sweden: Nordiska Afrikainstitutet.

JONES, H., JONES, N., SHAXSON, L. & WALKER, D. 2012. *Knowledge, Policy and Power in International Development: a Practical Guide,* Chicago, The Policy Press.

JONES, L. & CARABINE, E. 2013. Exploring political and socio-economic drivers of transformational climate policy: early insights from the design of Ethiopia's Climate Resilient Green Economy strategy. *In:* INSTITUTE, O. D. (ed.) *Research Report.* London, UK.

JONES, P. & THORNTON, P. 2009. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science and Policy,* 12**,** 427-437.

JUBB, I., CANADELL, P. & DIX, M. 2013. Representative Concentration Pathways (RCPs). *Information Paper.* Australian Climate Change Science Program.

KAMINSKI, B. & KOLOCH, G. Advances in Social Simulation: Proceedings of the 9th Conference of the European Social Simulation Association. 2013. Springer.

KATAMPOI, K., GENGA, G., MWANGI, M., KIPKAN, J., SEITAH, J., VAN KLINKEN, M. & MWANGI, M. 1990. Kajiado District Atlas. *ASAL Programme.* Kajiado, Kenya.

KENYA WILDLIFE SERVICE, AFRICAN CONSERVATION CENTRE & AMBOSELI CONSERVATION PROGRAM. Proceedings of the Amboseli Ecosystem workshop. The impact of the 2009 drought on wildlife, livestock and tourism in the Amboseli Ecosystem: recommendations for promp action and ecosystem restoration, 9 December 2009 Amboseli Serena Lodge.

KENYA WILDLIFE SERVICE & INSTITUTE, T. W. R. 2010. Aerial total count: Amboseli-West Kilimanjaro and Magadi-Natron cross border landscape (wet season, March 2010).

KEYA, G. A. 1991. Alternative policies and models for arid and semi-arid lands in Kenya. *In:* BAXTER, P. T. W. (ed.) *When the Grass is Gone: Development intervention in African arid lands.* Uddevalle, Sweden: Nordiska Afrikainstitutet.

KING, J. M. 1983. Livestock water needs in pastoral Africa in relation to climate and forage. Addis Ababa, Ethiopia: International Livestock Centre for Africa.

KORPELA, K. 1989. Place-identity as a product of environmental self-regulation. *Journal of Environmental Psychology,* 9**,** 241-256.

KUMSSA, A. & JONES, J. F. 2010. Climate change and human security in Africa. *International Journal of Sustainable Development and World Ecology,* 17**,** 453-461.

KWS & TAWIRI 2010. Aerial total count: Amboseli-West Kilimanjaro and Magadi-Natron Corss Border Landscape, Wet Season 2010. Kenya Wildlife Service & Tanzania Wildlife Research Institute.

LAMPREY, H. 1983. *Pastoralism yesterday and today: the overgrazing problem,* Amsterdam, Elsevier Scientific Publishing Co.

LAMPREY, H. F. & YUSSUF, H. 1981. Pastoralism and desert encroachment in Northern Kenya. *Ambio,* 10**,** 131-134.

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

LEACH, M. & SCOONES, I. 2013. The social and political lives of zoonotic disease models: narratives, science and policy. *Social Science and Medicine,* 88**,** 10-17.

LEMOS, M., BOYD, E., TOMPKINS, E., OSBAHR, H. & LIVERMAN, D. 2007. Developing adaptation and adapting development. *Ecology and Society,* 12**,** 26.

LETAI, J. & LIND, J. 2013. Squeezed from all sides: changing resource tenure and pastoralist innovation on the Laikipia Plateau, Kenya. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development: dynamic change at the margins.* Oxford: Routledge.

LEVIN, S. 1992. The problem of pattern and scale in ecology. *Ecology,* 73**,** 1943-1967.

LEVIN, S. 1999. *Fragile dominion: complexity and the commons,* Reading, Massachusetts, Perseus Books.

LEWICKA, M. 2011. Place attachment: how far have we come in the last 40 years? *Journal of Environmental Psychology,* 31**,** 207-230.

LI, W. & HUNTSINGER, L. 2011. China's grassland contract policy and its impacts on herder ability to benefit in Inner Mongolia: tragic feedbacks. *Ecology and Society,* 16**,** 1.

LINDSAY, K. 1987. Integrating parks and pastoralism: some lessons from Amboseli. *In:* ANDERSON, D. & GROVE, R. (eds.) *Conservation in Africa: people, policies and practice.* Cambridge: Cambridge University Press.

LION GUARDIANS 2010. Annual Report.

LISKI, J., PALOSUO, T., PELTONIEMI, M. & SIEVANEN, R. 2005. Carbon and decomposition model Yasso for forest soils. *Ecological Modelling,* 189**,** 168-182.

LITTLE, P. D. 2013. Reflections on the future of pastoralism in the Horn of Africa. *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development in Africa: dynamic change at the margins.* Oxon, UK: Routledge.

LONGSTAFF, P. H. 2005. Security, resilience and communication in unpredictable environments such as terrorism, natural disasters, and complex technology. *Center for Information Policy Research: Harvard University Program on Information Resources Policy.* Syracuse.

LOVATT-SMITH, D. 2008. *Amboseli: a miracle too far?,* Herstmonceaux, Mawenzi.

LUKES, S. 1974. *Power: a radical view,* London, Macmillan.

MANEZ COSTA, M. A., MOORS, E. J. & FRASER, E. D. G. 2011. Socioeconomics, policy or climate change: what is driving vulnerability in southern Portugal? *Ecology and Society,* 16**,** 1.

MATHEWS, R., GILBERT, N., ROACH, A., POLHILL, J. & GOTTS, N. 2007. Agent-based land-use models: a review of applications. *Landscape Ecology,* 22**,** 1447-1459.

MCCABE, J. 2006. Pastoral land tenure, livelihood diversification, and wildlife conservation: a case study from Northern Tanzania. *In:* KOCK, R. & DEUTSCH, J. (eds.) *Wild rangelands: conservation in the world's grazing ecosystems.* London, UK: Zoological Society of London.

MCCONNELL, T. 2009. *Drought hits Kenya's wildlife: Millions in East Africa are on food aid, but the animals are still dying* [Online]. Global Post. Available: http://www.globalpost.com/dispatch/africa/091008/drought-africa-wildlife-wildebeast-famine-maasai [Accessed 13 August 2011].

MCCONNELL, T. 2010. *Kenya throws zebras to the lions: Kenya is rounding up zebras and moving them to drought-stricken Amboseli Park so the lions will have enough food* [Online]. Global Post. Available: http://www.globalpost.com/dispatch/kenya/100307/kenya-throws-zebra-the-lions?page=full [Accessed 13 August 2012].

MCNAUGHTON, S. J. 1979. Grazing as an optimisation process: grass-ungulate relationships in the Serengeti. *The American Naturalist,* 113**,** 691-703.

MCPEAK, J. & LITTLE, P. 2005. Cursed if you do, cursed if you don't: the contradictory processes of pastoral sedentarization in northern Kenya. *In:* FRATKIN, E. & ROTH, E. (eds.) *As pastoralists setlle: social health and economic consequences of pastoral sedentarization in Marsabit District, Kenya.* New York, USA: Kluwer Academic Publishers.

MEA 2005. Ecosystems and Human Well-being: Current State and Trends. Washington DC: Millennium Ecosystem Assessment.

MET OFFICE. 2013. *Human influence on East Africa drought* [Online]. Available: http://www.metoffice.gov.uk/news/releases/archive/2013/east-africa-drought [Accessed 4 April 2014].

METCALFE, S. & KEPE, T. 2008. Dealing land in the midst of poverty: Commercial access to communal land in Zambia. *African and Asian Studies,* 7.

MILLER, F., OSBAHR, H., BOYD, E., THOMALLA, F., BHARWANI, S., ZIERVOGEL, G., WALKER, B., BIRKMANN, J., VAN DER LEEUW, S., ROCKSTROM, J., HINKEL, J., DOWNING, T., FOLKE, C. & NELSON, D. 2010. Resilience and vulnerability: complementary or conflicting concepts? *Ecology and Society,* 15**,** 11.

MILLINGTON, J., ROMERO-CALCERRADA, R., WAINWRIGHT, J. & PERRY, G. 2008. An agent-based model of Mediterranean agricultural land-use/cover change for examining wildlife risk. *Journal of Artificial Societies and Social Simulation,* 11**,** 4.

MILLINGTON, J. D. A., O'SULLIVAN, D. & PERRY, G. L. W. 2012. Model histories: narrative explanation in generative simulation modelling. *Geoforum,* 43**,** 1025-1034.

MILNER-GULLAND, E., KERVEN, C., BEHNKE, R., WRIGHT, I. & SMAILOV, A. 2006. A multi-agent system model of pastoralist behaviour in Kazakhstan. *Ecological Complexity,* 3**,** 23-36.

MITCHELL, T. & HARRIS, K. 2012. Resilience: a risk management approach. Background Note. London, UK: Overseas Development Institute.

MONBIOT, G. 2003. *No Man's Land: an investigative journey through Kenya and Tanzania,* London, UK, Macmillan.

MORITZ, M. 2010. Crop-livestock interactions in agricultural and pastoral systems in West Africa. *Agriculture and Human Values,* 27**,** 119-128.

MUELLER, E. N., WAINWRIGHT, J., PARSONS, A. J. & TURNBULL, L. 2014. Land degradation in drylands: an ecogeomorphological approach. *In:* MUELLER, E. N., WAINWRIGHT, J., PARSONS, A. J. & TURNBULL, L. (eds.) *Patterns of land degradation in drylands: understanding self-organised ecogeomorphic systems.* Dordrecht: Springer Science+Business Media.

MUTAI, C. & WARD, M. 2000. East African rainfall and the tropical circulation/convection on intraseasonal to interannual timescales. *Journal of Climate,* 13**,** 3915-3939.

MWANGI, E. 2007. The puzzle of group ranch subdivision in Kenya's Maasailand. *Development and Change,* 38**,** 890-910.

NAESS, L. O., POLACK, E. & CHINSINGA, B. 2011. Bridging research and policy processes for climate change adaptation. *IDS Bulletin,* 42**,** 97-103.

NAVAS, M.-L. 1998. Individual species performance and response of multispecific communities to elevated CO2: a review. *Functional Ecology,* 12**,** 721-727.

NAVEH, Z. 2000. The total human ecosystem: integrating ecology and economics. *BioScience,* 50**,** 357-361.

NELSON, D., ADGER, N. & BROWN, K. 2007. Adaptation to environmental change: contributions of a resilience framework. *Annual Review of Environment and Resources,* 32**,** 395-419.

NELSON, D. R. & FINAN, T. J. 2009. Praying for Drought: Persistent Vulnerability and the Politics of Patronage in Ceara, Northeast Brazil. *American Anthropologist,* 111.

NEUMANN, R. 2010. Political ecology III: theorizing landscape. *Progress in Human Geography,* 35**,** 843-850.

NEW, M., LISTER, D., HULME, M. & MAKIN, I. 2002. A high-resolution data set of surface climate over global land areas. *Climate Research,* 21**,** 1-25.

NEW, M., LIVERMAN, D., SCHROEDER, H. & ANDERSON, K. 2011. Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. *Philosophical Transactions of the Royal Society A - Mathematical Physical and Engineering Sciences,* 369**,** 6-19.

NG'ETHE, J. C. 1992. Group ranch concept and practice in Kenya with special emphasis on Kajiado District. *In:* KATEGILE, J. A. & MUBI, S. (eds.) *Future of livestock industries in East and southern Africa. Proceedings of a workshop held at Kadoma Ranch Hotel, Zimbabwe, 20-23 July 1992.* Addis Ababa, Ethiopia: International Livestock Centre for Africa.

NGUYEN-DUC, M. & DROGOUL, A. 2007. Using computational agents to design participatory social simulations. *Journal of Artificial Societies and Social Simulation,* 8**,** 13.

NIAMIR-FULLER, M. 1998. The resilience of pastoral herding in Sahelian Africa. *In:* BERKES, F. & FOLKE, C. (eds.) *Linking social and ecological systems: management practices and social mechanisms for building resilience.* Cambridge, UK: Cambridge University Press.

NIELSEN, J. O. & REENBERG, A. 2010. Cultural barriers to climate change adaptation: a case study from northern Burkina Faso. *Global Environmental Change,* 20**,** 142-152.

NIEMEYER, S., PETTS, J. & HOBSON, K. 2005. Rapid climate change and society: assessing responses and thresholds. *Risk Analysis,* 25**,** 1443-1456.

NKEDIANYE, D., DE LEEUW, J., OGUTU, J., SAID, M., SAIDIMU, T., KIFUGO, S., KAELO, D. & REID, R. 2011. Mobility and livestock mortality in communally used pastoral areas: the impact of the 2005-2006 drought on livestock mortality in Maasailand. *Pastoralism: Research, Policy and Practice,* 1**,** 17.

NOFOOTPRINT. 2009. The terriible (sic) drought in Amboselli (sic). *Igougo* [Online]. Available from: http://www.igougo.com/story-s1367325-Amboseli_National_Park-The_Terriible_Drought_in_Amboselli.html 2012].

NORGAARD, R. 1989. The case for methodological pluralism. *Ecological Economics,* 1**,** 37-58.

NORRIS, F. H., STEVENS, S. P., PFEFFERBAUM, B., WYCHE, K. F. & PFEFFERBAUM, R. L. 2008. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology,* 41.

NORTON, A. 1996. Experiencing nature: The reproduction of environmental discourse through safari tourism in East Africa. *Geoforum,* 27.

NORTON-GRIFFITHS, M. 2006. Kenya's rangelands: an economic perspective. *In:* KOCK, R. & DEUTSCH, J. (eds.) *Wild rangelands: conservation in the world's grazing ecosystems.* London, UK: Zoological Society of London.

NTIATI, P. 2002. Group ranches subdivision study in Loitokitok Division of Kajiado District, Kenya. *Land Use Change Impacts and Dynamics (LUCID) Project Working Paper 7.* Nairobi, Kenya: International Livestock Research Institute.

O'BRIEN, K. 2012. Global environmental change II: from adaptation to deliberate transformation. *Progress in Human Geography,* 36**,** 667-676.

O'CONNOR, T. G. 1994. Composition and population responses of an African savanna grassland to rainfall and grazing. *Journal of Applied Ecology,* 31**,** 155-171.

OBA, G. 2001. The effect of multiple droughts on cattle in Obbu, northern Kenya. *Journal of Arid Environments,* 49**,** 375-386.

OBA, G., STENSETH, N. C. & LUSIGI, W. J. 2000. New perspectives on sustainable grazing management in arid zones of sub-Saharan Africa. *Bioscience,* 5**,** 35-51.

ORESKES, N., SCHRADER-FRECHETTE, K. & BELITZ, K. 1994. Verification, validation, and confirmation of numerical models in the earth sciences. *Science,* 263**,** 641-646.

OSBAHR, H., TWYMAN, C., ADGER, N. & THOMAS, D. 2008. Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum,* 39**,** 1951-1964.

OSBAHR, H., TWYMAN, C., ADGER, N. & THOMAS, D. 2010. Evaluating successful livelihood adaptation to climate variability and change in southern Africa. *Ecology and Society,* in press.

PARKER, D., MANSON, S., JANSSEN, M., HOFFMANN, M. & DEADMAN, P. 2003. Multi-agent systems for the simulation of land-use and land-cover change: a review. *Annals of the Association of American Geographers,* 93**,** 314-337.

PAVANELLO, S. & LEVINE, S. 2011. Rules of the range: natural resources management in Kenya-Ethiopia border areas. *In:* GROUP, H. P. (ed.) *Working Paper.* London, UK: Overseas Development Institute.

PELL FRISCHMANN 2011. Konza technology city: where Africa's silicon savannah begins - summary document. Nairobi.

PELLING, M. 2011. *Adaptation to Climate Change: from Resilience to Transformation,* Abingdon, Routledge.

PELUSO, N. 1992. Rich forests, poor people: resource control and resistance in Java. Berkeley: University of California Press.

PETERS, D., BESTELMEYER, B. & TURNER, M. 2007. Cross-scale interactions and changing pattern-process relationships: consequences for system dynamics. *Ecosystems,* 10**,** 790-796.

PETERS, D., YAO, J., HUENNEKE, L., HAVSTAD, K., HERRICK, J., RANGO, A. & SCHLESINGER, W. 2006. A framework and methods for simplifying complex landscapes to reduce uncertainty in predictions. *In:* WU, J., JONES, B. & LOUCKS, O. (eds.) *Scaling and uncertainty analysis in ecology.* New York, USA: Columbia University Press.

PIGNOTTI, E., POLHILL, G. & EDWARDS, P. 2013. Using provenance to analyse agent-based simulations. *EDBT/ICDT '13 March 18-22.* Genoa, Italy.

PILGRIM, S. & PRETTY, J. 2010. Nature and culture: an introduction. *In:* PILGRIM, S. & PRETTY, J. (eds.) *Nature and culture: rebuilding lost connections.* London: Earthscan.

PITTOCK, J. 2011. National climate change policies and sustainable water management: conflicts and synergies. *Ecology and Society,* 16**,** 1-25.

POLHILL, J., SUTHERLAND, L. & GOTTS, N. 2010. Using qualitative evidence to enhance an agent-based modelling system for studying land use change. *Journal of Artificial Societies and Social Simulation* 13**,** 10.

POLLEY, H. W. 1997. Implications of rising atmospheric carbon dioxide concentration for rangelands. *Journal of Range Management,* 50**,** 562-577.

PRETTY, J. 2011. Interdisciplinary progress in approaches to address social-ecological and ecocultural systems. *Environmental Conservation,* 38.

PROHANSKY, H. 1978. The city and self-identity. *Environmental Behaviour,* 10**,** 147-169.

PROHANSKY, H., FABIAN, A. & KAMINOFF, R. 1983. Place-identity: physical world socialisation of the self. *Environmental Psychology,* 3**,** 57-83.

QUINN, C. H., ZIERVOGEL, G., TAYLOR, A., TAKAMA, T. & THOMALLA, F. 2011. Coping with multiple stresses in rural South Africa. *Ecology and Society,* 16**,** 2.

RAO, A. & GEORGEFF, M. BDI agents: from theory to practice. International Conference on Multi-agent Systems (ICMAS-95), 1995. 312-319.

RAPPORT, D. & MAFFI, L. 2010. The dual erosion of biological and cultural diversity: implications for the health of ecocultural systems. *In:* PILGRIM, S. & PRETTY, J. (eds.) *Nature and culture: rebuilding lost connections.* London: Earthscan.

RAPPORT, D. J. & MAFFI, L. 2011. Eco-cultural health, global health, and sustainability. *Ecological Research,* 26.

RAVERA, F., TARRASON, D. & SIMELTON, E. 2011. Envisioning adaptive strategies to change: participatory scenarios for agropastoral semiarid systems in Nicaragua. *Ecology and Society,* 16**,** 20.

RESILIENCEALLIANCE. 2010. *Resilience Alliance* [Online]. Available: http://www.resalliance.org/index.php/resilience.

REYNOLDS, J., STAFFORD SMITH, D., LAMBIN, E., TURNER, B., MORTIMORE, M., BATTERBURY, S., DOWNING, T., DOWLATABADI, H., FERNANDEZ, R., HERRICK, J., HUBER-SANNWALD, E., JIANG, H., LEEMANS, R., LYNAM, T., MAESTRE, F., AYARZE, M. & WALKER, B. 2007. Global desertification: building a science for dryland development. *Science,* 316**,** 847-851.

ROBINSON, D. & BROWN, D. 2009. Evaluating the effects of land use development policies on ex-urban forest cover: an integrated agent-based GIS approach. *International Journal of Geographical Information Science,* 23**,** 1211-1232.

ROBINSON, L. 2009. A complex-systems appraoch to pastoral commons. *Human Ecology,* 37**,** 441-451.

ROQUES, K., O'CONNOR, T. & WATKINSON, A. 2001. Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. *Journal of Applied Ecology,* 38**,** 268-280.

ROUCHIER, J., BOUSQUET, F., REQUIER-DESJARDINS, M. & ANTONA, M. 2001. A multi-agent model for describing transhumance in North Cameroon: comparison of different rationality to develop a routine. *Journal of Economic Dynamics and Control,* 25**,** 527-559.

ROUNSEVELL, M. D. A., ARNETH, A., ALEXANDER, P., BROWN, D. G., DE NOBLET-DUCOUDRE, N., ELLIS, E., FINNIGAN, J., GALVIN, K., GRIGG, N., HARMAN, I.,

LENNOX, J., MAGLIOCCA, N., PARKER, D., O'NEILL, B. C., VERBURG, P. H. & YOUNG, O. 2014. Towards decision-based global land use models for improved understanding of the Earth system. *Earth System Dynamics,* 5**,** 117-137.

ROUNSEVELL, M. D. A. & METZGER, M. J. 2010. Developing qualitative scenario storylines for environmental change assessment. *WIREs Climate Change,* 1**,** 606-619.

ROUNSEVELL, M. D. A., ROBINSON, D. T. & MURRAY-RUST, D. 2012. From actors to agents in socio-ecological systems models. *Philosophical Transactions of the Royal Society B Biological Sciences,* 367**,** 259-269.

RUTTEN, M. 1992. *Selling wealth to buy poverty: the process of the individualisation of land ownership among the Maasai pastoralists of Kajiado District, Kenya 1890-1990.*

RYKIEL, E. J. 1996. Testing ecological models: the meaning of validation. *Ecological Modelling,* 90**,** 229-244.

SABATES-WHEELER, R., MITCHELL, T. & ELLIS, F. 2008. Avoiding repetition: time for CBA to engage with the livelihoods literature? *IDS Bulletin,* 39**,** 53-59.

SAKELLERIOU, I., KEFALAS, P. & STAMATOPOULOU, I. Enhancing NetLogo to simulate BDI communicating agents. 5th Hellenic Conference on Artificial Intelligence, SETN, 2008 Syros.

SALLU, S., TWYMAN, C. & STRINGER, L. 2010. Resilient of vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. *Ecology and Society,* 15**,** 3.

SANDFORD, S. 2013. Pastoralists and irrigation in the Horn of Africa: time for a rethink? *In:* CATLEY, A., LIND, J. & SCOONES, I. (eds.) *Pastoralism and development in Africa: dynamic change at the margins.* Oxon, UK: Routledge.

SANDKER, M., CAMPBELL, B. M., RUIZ-PEREZ, M., SAYER, J. A., COWLING, R., KASSA, H. & KNIGHT, A. T. 2010. The role of participatory modeling in landscape approaches to reconcile conservation and development. *Ecology and Society,* 15**,** 13.

SANKARAN, M., HANAN, N., SCHOLES, R., RATNAM, J., AUGUSTINE, D., CADE, B., GIGNOUX, J., HIGGINS, S., LE ROUX, X., LUDWIG, F., ARDO, J., BANYIKWA, F., BRONN, A., BUCINI, G., CAYLOR, K., COUGHENOUR, M., DIOUF, A., EKAYA, W., FERAL, C., FEBRUARY, E., FROST, P., HIERNAUX, P., HRABAR, H., METZGER, K., PRINS, H., RINGROSE, S., SEA, W., TEWS, J., WORDEN, J. & ZAMBATIS, N. 2005. Determinants of woody cover in African savannas. *Nature,* 438**,** 846-849.

SANKARAN, M., JAYASHREE, R. & HANAN, N. 2004. Tree-grass coexistence in savannas revisited - insights from an examination of assumptions and mechanisms invoked in existing models. *Ecology Letters,* 7**,** 480-490.

SANKARAN, M., RATNAM, J. & HANAN, N. 2008. Woody plant cover in African savannas: the role of resources, fire and herbivory. *Global Ecology and Biogeography,* 17**,** 236-245.

SATTERTHWAITE, D., HUQ, S., REID, H., PELLING, M. & ROMERO LANKAO, P. 2009. Adapting to climate change in urban areas: the possibilities and constraints in low- and middle-income nations. *In:* BICKNELL, J., DODMAN, D. &

SATTERTHWAITE, D. (eds.) *Adapting cities to climate change.* London, UK: Earthscan.
SCHEITER, S. & HIGGINS, S. 2008a. aDGVM: an adaptive dynamic global vegetation model for tropical ecosystems. Version 1.0. unpublished.
SCHEITER, S. & HIGGINS, S. 2008b. Supplementary material S1 for: Impacts of climate change on the vegetation of Africa: an adaptive dynamic vegetation modelling approach. *Global Change Biology*.
SCHEITER, S. & HIGGINS, S. 2009. Impacts of climate change on the vegetation of Africa: an adaptive dynamic vegetation modelling approach *Global Change Biology,* 15**,** 2224-2246.
SCHEITER, S. & HIGGINS, S. 2010a. aDGVM: technical documentation. Update 1. unpublished.
SCHEITER, S. & HIGGINS, S. 2010b. The elephant impact model. unpublished.
SCHEITER, S. & HIGGINS, S. I. 2012. How many elephants can you fit into a conservation area. *Conservation Letters,* 5**,** 176-185.
SCHOLES, A. & ARCHER, S. 1997. Tree-grass interactions in savannas. *Annual Review of Ecology, Evolution and Systematics,* 28**,** 517-544.
SCHOLES, R. J. 1990. The influence of soil fertility on the ecology of southern African dry savannas. *Journal of Biogeography,* 17**,** 415-419.
SCOONES, I. 2009. Livelihoods perspectives and rural development. *The Journal of Peasant Studies,* 36**,** 171-196.
SCOONES, I. & ADWERA, A. 2009. Pastoral Innovation Systems: Perspectives from Ethiopia and Kenya. *In:* CONSORTIUM, F. A. (ed.) *Occasional Paper.* Brighton, UK.
SENDZIMIR, J., REIJ, C. P. & MAGNUSZEWSKI, P. 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. *Ecology and Society,* 16**,** 1.
SHELL04PA. 2009. drought effects and current conditions. *Amboseli Eco-system Forum* [Online]. Available from: http://www.tripadvisor.co.uk/ShowTopic-g298252-i12675-k3238124-Drought_effects_and_current_conditions-Amboseli_Eco_system_Rift_Valley_Province.html [Accessed 3 August 2012].
SIMON, H. 1997. Behavioural economics and bounded rationality. *In:* SIMON, H. (ed.) *Models of Bounded Rationality.* Cambridge, MA: MIT Press.
SINDIGA, I. 1984. Land and population problems in Kajiado and Narok, Kenya. *African Studies Review,* 27**,** 23-29.
SLIM, T. & THOMPSON, A. 1994. *Listening for a change: oral testimony and development* London, UK, Panos.
SMAJGL, A., BROWN, D., VALBUENA, D. & HUIGEN, M. 2011. Empirical characterisation of agent behaviours in socio-ecological systems. *Environmental Modelling and Software,* 26**,** 837-844.
SOUTHGATE, C. & HULME, D. 2000. Uncommon property: the scramble for wetland in southern Kenya. *In:* WOODHOUSE, P., BERNSTEIN, H. & HULME, D. (eds.) *African enclosures? The social dynamics of wetlands in drylands.* Oxford: James Currey Ltd.
SPEAR, T. 1993. Introduction. *In:* SPEAR, T. & WALLER, R. (eds.) *Being Maasai.* London: James Currey.
SPEAR, T. & WALLER, R. (eds.) 1993. *Being Maasai,* London: James Currey.

STAFFORD SMITH, D., ABEL, N., WALKER, B. & CHAPIN, S. 2009. Drylands: coping with uncertainty, thresholds, and changes in state. *In:* CHAPIN, S., KOFINAS, G. & FOLKE, C. (eds.) *Principles of ecosystem stewardship: resilience-based natural resource management in a changing world.* Dordrecht, Netherlands: Springer.

STAIN, H. J., KELLY, B., CARR, V. J., LEWIN, T. J., FITZGERALD, M. & FRAGAR, L. 2011. The psychological impact of chronic environmental adversity: Responding to prolonged drought. *Social Science & Medicine,* 73.

STEDMAN, R. 2002. Toward a social psychology of place: predicting behaviour from place-based cognitions, attitude, and identity. *Environment and Behaviour,* 34**,** 561-581.

STEFFEN, W. 2011. A truly complex and diabolical policy problem. *In:* DRYZEK, J. S., NORGAARD, R. B. & SCHLOSBERG, D. (eds.) *Oxford Handbook of Climate Change and Society.* Oxford: Oxford University Press.

STRINGER, L. C., DOUGILL, A. J., THOMAS, A. D., SPRACKLEN, D. V., CHESTERMAN, S., SPERANZA, C. I., RUEFF, H., RIDDELL, M., WILLIAMS, M., BEEDY, T., ABSON, D. J., KLINTENBERG, P., SYAMPUNGANI, S., POWELL, P., PALMER, A. R., SEELY, M. K., MKWAMBISI, D. D., FALCAO, M., SITOE, A., ROSS, S. & KOPOLO, G. 2012. Challenges and opportunities in linking carbon sequestration, livelihoods and ecosystem service provision in drylands. *Environmental Science and Policy,* 19-20**,** 121-135.

STRINGER, L. C., DYER, J. C., REED, M. S., DOUGILL, A. J., TWYMAN, C. & MKWAMBISI, D. 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy,* 12**,** 748-765.

SULLIVAN, S. & ROHDE, R. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography,* 29**,** 1595-1618.

SUTTON, J. 1993. Becoming Maasailand. *In:* SPEAR, T. & WALLER, R. (eds.) *Being Maasai.* London: James Currey.

SVEJCAR, T., ANGELL, R., BRADFORD, J. A., DUGAS, W., EMMERICH, W., FRANK, A. B., GILMANOV, T., HAFERKAMP, M., JOHNSON, D. A., MAYEUX, H., MIELNICK, P., MORGAN, J., SALIENDRA, N. Z., SCHUMAN, G. E., SIMS, P. L. & SNYDER, K. 2008. Carbon fluxes in North American rangelands. *Rangeland Ecology and Management,* 61**,** 465-474.

TALBOT, L. 1972. Ecological consequences of rangeland development in Maasailand, East Africa. *In:* FARVAR, M. & MILTON, J. (eds.) *The careless technology.* New York: Doubleday.

TANNER, T. & HORN-PHATHANOTHAI, L. 2014. *Climate change and development,* Oxon, Routledge.

THOMAS, D. & TWYMAN, C. 2004. Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamcs in the Kalahari. *Land Degradation and Development,* 15**,** 215-231.

THOMSEN, D. C., SMITH, T. F. & KEYS, N. 2012. Adaptation or manipulation? Unpacking climate change response strategies. *Ecology and Society,* 17**,** 20.

THOMSON, J. 1887. *Through Masai land: a journey of exploration through snowclad volcanic mountains and strange tribes of equatorial Africa,* London, Low, Marston, Searle and Rivington.

THORNTON, P., BOONE, R., GALVIN, K., BURNSILVER, S., WAITHAKA, M., KUYIAH, J., KARANJA, S., GONZALEZ-ESTRADA, E. & HERRERO, M. 2007. Coping strategies in livestock-dependent households in East and southern Africa: a synthesis of four case studies. *Human Ecology,* 35**,** 461-476.

THORNTON, P., JONES, P., ERICKSEN, P. & CHALLINOR, A. 2011. Agriculture and food systems in sub-Saharan Africa in a 4 C+ world. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences,* 369**,** 117-136.

THORNTON, P. K. 2010. Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B-Biological Sciences,* 365**,** 2853-2867.

THORNTON, P. K. & GERBER, P. J. 2010. Climate change and the growth of the livestock sector in developing countries. *Mitigation and Adaptation Strategies for Global Change,* 15**,** 169-184.

THORNTON, P. K., JONES, P. G., ALAGARSWAMY, G., ANDRESEN, J. & HERRERO, M. 2010. Adapting to climate change: Agricultural system and household impacts in East Africa. *Agricultural Systems,* 103**,** 73-82.

TILMAN, D. 1988. *Plant Strategies and the Dynamics and Structure of Plant Communities,* Princeton, Princeton University Press.

TOMPKINS, E. L., NICHOLSON-COLE, S. A., HURLSTON, L.-A., BOYD, E., BROOKS HODGE, G., CLARKE, J., GRAY, G., TROTZ, N. & VARLACK, L. 2005. Surviving climate change in small islands - a guidebook. Norwich, United Kingdom: Tyndall Centre for Climate Change Research.

TOUBER, L. 1983. Soils and vegetation of the Amboseli-Kibwezi area. *Kenya Soil Survey Project, Reconnaissance Soil Survey Report no. R6.* Nairobi, Kenya: Ministry of Agriculture.

TSCHAKERT, P. & TUTU, R. 2010. *Solastalgia: Environmentally Induced Distress and Migration Among Africa's Poor Due to Climate Change*.

TUAN, Y. 1974. *Topophilia: a study of environmental perception, attitudes and values,* Englewood Cliffs, NJ, Prentice Hall.

TURNER, B., KASPERSON, R., MATSON, P., MCCARTHY, J., CORELL, R., CHRISTENSEN, L., ECKLEY, N., KASPERSON, J., LUERS, A., MARTELLO, M., POLSKY, C., PULSIPHER, A. & SCHILLER, A. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences,* 100**,** 8074-8079.

TURNER, M. D. 2013. Political ecology I: an alliance with resilience? *Progress in Human Geography***,** 1-8.

TWIGGER-ROSS, C., BONAIUTO, M. & BREAKWELL, G. 2003. Identity theories and environmental psychology. *In:* BONNAS, M., LEE, T. & BONAIUTO, M. (eds.) *Psychological theories and environmental issues.* Aldershot: Ashgate.

TWIGGER-ROSS, C. L. & UZZELL, D. L. 1996. Place and identity processes. *Journal of Environmental Psychology,* 16**,** 205-220.

TWYMAN, C., FRASER, E. D. G., STRINGER, L. C., QUINN, C., DOUGILL, A. J., RAVERA, F., CRANE, T. A. & SALLU, S. M. 2011. Climate Science, Development Practice, and Policy Interactions in Dryland Agroecological Systems. *Ecology and Society,* 16.

UNEP & GOK 2000. Devastating drought in Kenya, environmental impacts and responses. Nairobi: United Nations Environment Programme.

UNEP & GOK 2006. Kenya drought impacts on agriculture, livestock and wildlife. Nairobi: United Nations Environment Programme.

UNOCHA-PCI 2007. The future of pastoralism in Ethiopia. Addis Ababa, Ethiopia: UNOCHA - Pastoral Communications Initiative.

VALBUENA, D., VERBURG, P., BREGT, A. & LIGTENBERG, A. 2010. An agent-based approach to model land-use change at a regional scale. *Landscape Ecology,* 25**,** 185-199.

VETTER, S. 2005. Rangelands at equilibrium and non-equilibrium: recent developments in the debate. *Journal of Arid Environments,* 62**,** 321-341.

VOINOV, A. & BOUSQUET, F. 2010. Modelling with stakeholders. *Environmental Modelling and Software,* 25**,** 1268-1281.

WAINWRIGHT, J. & MILLINGTON, J. 2010. Mind, the gap in landscape-evolution modelling. *Earth Surface Processes and Landforms,* 35**,** 842-855.

WALKER, B. 2006. Riding the rangelands piggyback: a resilience approach to conservation management. *Wild rangelands: conservation in the world's grazing ecosystems.* London, UK: Zoological Society of London.

WALKER, B., HOLLING, C., CARPENTER, S. & KINZIG, A. 2004. Resilience: adaptability and transformability in social-ecological systems. *Ecology and Society,* 9**,** 5.

WALKER, B. & JANSSEN, M. 2002. Rangelands, pastoralists and governments: interlinked systems of people and nature. *Philosophical Transactions of the Royal Society B-Biological Sciences,* 357.

WARD, S. 2009. Devastating drought in Amboseli. *Baraza* [Online]. Available from: http://baraza.wildlifedirect.org/tag/tourism 2012].

WESTERN, D. 1982. Amboseli. *Swara,* 5**,** 8-14.

WESTERN, D. 2010. The worst drought: tipping or turning point? *Swara***,** 16-22.

WESTERN, D., GROOM, R. & WORDEN, J. 2009. The impact of subdivision and sedentarisation of pastoral lands on wildlife in an African savanna ecosystem. *Biological Conservation,* 142**,** 2538-2546.

WHO 1992. Psychosocial Consequences of Disasters: Prevention and Management. World Health Organization,.

WIGLEY, B., BOND, W. & HOFFMAN, M. 2010. Thicket expansion in a South African savanna under divergent land use: local vs. global drivers. *Global Change Biology,* 16**,** 964-976.

WILBANKS, T. 2007. Scale and sustainability. *Climate Policy,* 7**,** 278-287.

WILENSKY, U. 1999. NetLogo. *In:* MODELING, C. F. C. L. A. C.-B. (ed.). Evanston, IL: Northwestern University.

WILHITE, D. & GLANTZ, M. 1985. Understanding the drought phenomenon: the role of definitions. *Water International,* 10**,** 111-120.

WILLIAMS, A. & FUNK, C. 2011. A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. *Climate Dynamics*.

WILLIAMS, C., HANAN, N., NEFF, J., SCHOLES, R., BERRY, J., DENNING, A. & BAKER, D. 2007. Africa and the global carbon cycle. *Carbon Balance and Management,* 2**,** 1-13.

WILLIS, J. 1999. Enkurma Sikitoi: commoditization, drink, and power among the Maasai. *International Journal of African Historical Studies,* 32**,** 339-57.

WORLD BANK 2010. World development report: development in a changing climate - concept note. Washington DC, USA: World Bank.

YANG, L. & GILBERT, N. 2008. Getting away from numbers: using qualitative observation for agent-based modelling. *Advances in Complex Systems,* 11**,** 1-11.

YEE, T. W. & MITCHELL, N. D. 1991. Generalized additive models in plant ecology. *Journal of Vegetation Science,* 2**,** 587-602.

YOUNG, H., OSMAN, A. M., ABUSIN, A. M., ASHER, M. & EGEMI, O. 2009. *Livelihoods, power and choice: the vulnerability of the Northern Rizaygat, Darfur, Sudan,* Boston, USA, Feinstein International Center.

ZAMANI, G. H., GORGIEVSKI-DUIJVESTEIJN, M. J. & ZARAFSHANI, K. 2006. Coping with drought: Towards a multilevel understanding based on conservation of resources theory. *Human Ecology,* 34.

ZWAAGSTRA, L., SHARIF, Z., WAMBILE, A., DE LEEUW, J., SAID, M., JOHNSON, N., NJUKI, J., ERICKSEN, P. & HERRERO, M. 2010. An assessment of the response to the 2008 2009 drought in Kenya. A report to the European Union Delegation to the Republic of Kenya. Nairobi, Kenya: International Livestock Research Institute.