Propositions

1. The key to climate change adaptation is to build and maintain assets and high quality institutions.
   (this thesis)
2. Interventions to manage climate-related risks must account for differentiated responses undertaken by households.
   (this thesis)
3. Instability and insecurity prevent mankind from engaging in strategic investments.
4. Education equips people with skills and knowledge that enable them not only to open up opportunities but also to solve social challenges for the community.
5. Working with many PhD supervisors is similar to an animal carcass being flown over by vultures.
6. In life, what matters most is not the challenges that a person endures, but rather the lessons learned and experience gained.

Propositions belonging to the PhD dissertation,

“Exploring the strategies for households to adapt to climate-change in arid and semi-arid East Africa”.

Stanley K. Ng’ang’a

Wageningen, January 9, 2018

Exploring the strategies for households to adapt to climate-change in arid and semi-arid East Africa

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Exploring the strategies for households to adapt to climate-change in arid and semi-arid East Africa

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This research was conducted under the auspices of the Wageningen School of Social Sciences (WASS) and Production Ecology and Resource Economics (PE & RC) Graduate Schools

Exploring the strategies for households to adapt to climate-change in arid and semi-arid East Africa

Stanley K. Ng'ang'a

Thesis

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To all who seeks knowledge

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CHAPTER 1

General introduction

1.1 Problem statement

In the arid and semi-arid lands (ASALs)[1] of East Africa, most of the people are pastoralists and agro-pastoralists; their agricultural production depends primarily on livestock keeping and to a lesser extent on the cultivation of maize, millet and sorghum and legumes such as beans, green gram, pigeon pea and cowpea (FAO, 2013). These pastoralists and agro-pastoralists face major risks of livestock death and crop failures. The loss of assets impoverishes them, and disrupts their livelihoods (Ouma et al., 2011). Many households in ASALs are living in extreme poverty (i.e. they live on less than one US dollar per day) (Homewood et al., 2012; Jane et al., 2013). Food shortages are common. The vulnerability to climate variability and progressive climate change is high, because of low soil fertility, and a poor adoption of new farming technologies (IPCC, 2014; Cooper et al., 2008; Mwang'ombe et al., 2011). This means that food security is threatened increasingly (see Kahan, 2013).

This situation is aggravated by environmental degradation, cultivation in marginal lands where water scarcity limits plant growth, low input use in production (i.e. the use of fertilizer, improved seeds, pesticides, manure) (Salami et al., 2010), and poor access to markets (McPeak et al., 2012) and credits (Mohajan, 2014; World Bank, 2015). The low input use results in low productivity of crops and livestock (ibid.). Erosion by water and wind further impoverishes the soils (Nguru and Rono, 2013).

Studies in East Africa point to four main categories of risks: climate-related risks, diseases, market exclusion and policy shocks (Mude et al., 2007). The most severe and constraining of these risks are those related to climate change, including climate variability and extreme events such as droughts and floods. During the last five decades, ten major droughts have occurred in Africa: in 1965-1966, 1972-1974, 1981-1984, 1986-1987, 1991-1992, 1994-1995, 1999-2001, 2005-2006, 2009 and 2011; the last one being the worst in 60 years in East Africa (Ouma et al., 2011). Climate-related risks

[1]See box 1 for the definition of key terms

affect the livelihoods of pastoral and agro-pastoral households both directly and indirectly. They lead to livestock death, lower livestock prices, lower livestock productivity and reduced crop yields (Thornton and Herrero, 2010; Adhikari et al., 2015); thus they limit households' ability to produce and purchase food (McPeak, 2006). They also influence the spatio-temporal variability in water and pastures availability (Nardone et al., 2010). Projections indicate that if risks related to climate change (e.g. droughts) continue to increase, about US$ 630 million worth of cattle and production will be lost by 2030 (Ericksen et al., 2011), and the households will lack the financial power to buy enough cereals (Ringler et al., 2010).

Global warming trends are likely to alter weather patterns and to lead to increasingly severe and frequent local extreme climatic events (IPCC, 2014). Although climate models project an increase in the mean precipitation in East Africa, they also suggest a shortening of the growing period by up to 20% (Jones and Thornton, 2003), and a reduction in the yield of crops, such as maize and beans, by between 50-70% in the potential cropped area by 2050 (Thornton et al., 2010). Household livelihoods will be affected negatively by these changes, and poverty will increase (Thornton et al., 2014).

It is of vital importance, therefore, to respond timely to the impact of climate variability and change, and offer adequate support to the most vulnerable communities, with a view to helping them adapt (Thornton et al., 2007). In order to guide future adaptation, we need to understand how households are adapting today. An evaluation of the suitability of the existing adaptation practices, will allow us to see how they can be modified and improved.

The scientific literature shows that groups in Africa are coping with climate change in different ways. Diversification of livelihood activities, such as changes in crop and livestock management practices, the selling of labour (i.e. migration) and engaging in trade and off-farm jobs, have been noted as key adaptation options among households in ASALs (Bryan et al., 2013; Kabubo-Mariara, 2009). Often, farmers create social safety nets, allowing them to manage risks through collective asset accumulation (Fratkin, 1991; Santos and Barrett, 2005). However, the success of using social safety nets as way of coping with and adapting to risks and shocks depends largely on the availability of local networks and social capital (Campbell, 1999; Ellis, 2003). Specific institutions may be designed in order to reduce transaction costs, to facilitate cooperation between decision makers and farmers (Adhikari and Lovett, 2006), to enhance capital endowment, and to help households modify their technologies, capital use and property rights (Kirsten et al., 2009). Such institutions offer structures and strategies that are essential for tapping into formal risk-reducing strategies (Djalante and Thomalla, 2012; Wamsler and Lawson, 2011), and help simplify communal decision-making (Negassa, 2013).

A household's ability to adapt depends to a large extent on human capital (enhanced by education), assets, social capital and the availability of income-generating activities (Gupta et al., 2010; Kratli et al., 2012). Smit et al. (2001) speak of an 'adaptive capacity' – built up over time – which reflects the household's investment or accumulation strategy. Therefore, if we want to formulate policy options that can enhance pastoral and agro-pastoral households' ability to adapt in the future, we need a thorough understanding of the strategies adopted by them, and of their reasons for adopting them (Smit et al., 2001).

Recent research on adaptation and adaptive capacity related to climate change in East Africa shows that adaptation leads to an increase in food production and household income (Bryan et al., 2013; Di Falco et al., 2012; Thornton et al., 2011), and provides flexibility in livelihood options (Thornton et al., 2007). However, studies assessing adaptation options specific to pastoralists and agro-pastoralists in East Africa are still rare. This thesis aims to fill this gap by documenting strategies and local practices that support adaptation among households in the ASALs of Kenya and Ethiopia, with a view to creating a scientific basis for policies tailored to the needs of specific households in specific sites, and also for developing appropriate policies that can be applied in dry environments elsewhere.

Box 1: Definitions of key terms and concepts used in this thesis

Arid areas: areas that are known to have high average temperatures and an evapotranspiration that is more than double the average rainfall, which varies from 150 mm to 450 mm annually (FAO, 2010).
Semi-arid areas: areas with an annual rainfall ranging between 450 mm and 850 mm, which are able to support some rainfall-dependent agriculture (FAO, 2010).
Coping: actions taken in response to an extreme event, like a drought, to ensure survival; often they result in a long-term decrease in well-being (Eriksen et al., 2005).
Adaptation: actions and adjustments that are undertaken to maintain the capacity to deal with shocks and stresses induced by current and expected changes (Eriksen et al., 2005).
Diversification: the pursuit of off-farm earning activities, whether in rural or urban areas (Little et al., 2001).
Drought: extended period (months or years) during which the precipitation is below average and in which water scarcity occurs (Wetherald and Manabe, 2002).
Adoption: use of a new technology by farmers after having acquired knowledge of its potential benefits (Feder et al., 1985).
Pastoralism: an economic activity based on livestock keeping, and the associated cultural identity (Kratli et al., 2012).
Climate change: a change to a new state of climate that lasts for an extended period (IPCC, 2001), identifiable by changes in the mean and/or the variability in some of its properties. Climate change may be caused by anthropogenic changes (including a change in land use systems) or natural processes.
Climatic variability: deviation in the mean state, standard deviation, and extremes of climate on a spatio-temporal scale (IPCC, 2001). Climate variability may be caused by natural processes within the climate system (internal variability) or by anthropogenic forces (external variability).

1.2 Objectives

In this thesis, I describe how pastoral and agro-pastoral households in semi-arid areas of Kenya and Ethiopia cope with and adapt to climate variability and change, and estimate the effects of the strategies they use on their livelihoods, in order to identify opportunities for enhancing adaptive capacity.

The specific objectives of my research project are:

1. To explore whether households accumulate livestock wealth and social capital as insurance against risks and shocks associated with climate change in dry areas;
2. To analyse whether the migration of household members facilitates the adoption of agricultural innovations that provide protection against weather shocks in semi-arid areas;
3. To ascertain whether the quality of local institutions determines adaptation at the household level;
4. To further the understanding of how the adoption of adaptation practices is related to food security and farm income in different types of agro-pastoral households.

1.3 Study area

The study was carried out at two sites: Samburu County in Kenya and Borena region in Southern Ethiopia. These sites fall within the belt of arid and semi-arid lands. ASALs comprise 84% and 63% of the total area in Kenya and Ethiopia respectively (Government of Kenya, 2012; SOS Sahel Ethiopia, 2008). Therefore, these sites can be seen to exhibit the environmental and agro-ecological diversity found in the semi-arid areas in the two countries. Pastoralism and agro-pastoralism are the main sources of livelihood for about 80% of the households in the two study sites. The majority of the households depend on products provided by their livestock (e.g. milk, blood and meat) for food and cash income (Bailey et al., 1999). The livestock consists mainly of goats, sheep, cattle, and camels. Cash for buying maize, the staple food, is derived mainly from livestock sales. Some households integrate livestock keeping with crop farming. Households in the two study sites are often faced with food shortages, which usually are remedied through short-term relief supplies (GoK 2009; Negassa 2013). Although the Borena region and Samburu County are similar in terms of climatic conditions and sources of livelihoods, the two study sites differ in biophysical, socio-economic, institutional and in ethnocultural aspects (Government of Kenya, 2009; Negassa, 2013). There are differences in access to agricultural input and output markets, off-farm jobs and education. For example, although Borena exports 90% of its marketed livestock to the Arabian peninsula through Addis Ababa (http://www.landbou.com), most of the livestock from Samburu County is sold in the Kenyan capital Nairobi (www.kenya-information-guide.com/samburu-county.html). Ethnic factors in the two sites also determine production activity choices. For example, the Borena region has been under the Borena generation grade *Gada* governing system (headed by the *Abba gada*) for the last five centuries (Watson, 2003). The Gada governing system regulates the use of water sources, pasture resources and even the behaviour of the households (ibid.). In Samburu, village elders head the governance structures in charge of water, pasture and the use of forest resources.

1.4 Outline of the thesis

This thesis consists of six chapters, including this General Introduction. Chapter 2 explores whether households in ASALs accumulate livestock wealth and invest in structural and cognitive social capital in order to protect themselves against climate risks.

Whether migration and the adoption of adaptive measures are complementary or alternative mechanisms for protecting households against adverse risks and shocks, is examined in Chapter 3. Specifically, the question is addressed whether remittances relax capital constraints and facilitate the uptake of adaptive measures, or render the adaptation to risks and shocks superfluous.

Chapter 4 focuses on the motives for adopting agricultural practices that can decrease the vulnerability to climate change among households. Specifically, the question is being raised whether adaptation at the household level is determined to a greater extent by the characteristics of the household or by the quality of local institutions.

The effects of the adoption of adaptation practices on food security and farm income for different types of agro-pastoralist households are explored in Chapter 5. A dynamic-optimization modelling approach is used to identify the optimal combination of activities that maximize farm income subject to constraints, using data collected in a household survey. Specifically, the modelling was used to see how the adoption of adaptation practices can improve food security and farm income in agro-pastoralists households.

The main findings of this research project are discussed in Chapter 6. Here, the fact is stressed that we should look at what farmers are aiming for independently of climate variability and change. Also, the relevance of this thesis to the research on adaptation to climate change in ASALs, and for the policy making process, is brought out.

CHAPTER 2

Livestock wealth and social capital as insurance against climate risk: A case study of Samburu County in Kenya

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Abstract:

We use data from 500 households in Samburu County (Kenya) to explore how natural environment and market accessibility affect coping and adaptation strategies of pastoralists. In particular, we ask whether households accumulate livestock wealth and invest in structural and cognitive social capital to protect themselves against climate risks. We find weak evidence that households accumulate livestock wealth in response to living in a drier environment, and no evidence that households invest in either structural or cognitive social capital as insurance against climate risks. However, coping strategies vary across social groups. For example, while rainfall does not robustly affect cognitive social capital (trust) – we find that the "poor" and "financially-integrated" households (i.e., those who have relatively good access to credit and capacity to save money) show greater mutual trust in drier environments. The results from this study can be used for priority setting by policy makers and development agencies for programs aimed at safeguarding household livelihoods in arid and semi-arid lands (ASALs).
Keywords: Climate, Risks, Insurance, Social capital, Cognitive Capital, Structural Capital.

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2.1 Introduction

Households, communities and nations have to cope with a changing climate and increased climate variability. Predictions from climate research suggests that negative effects in terms of increased frequency and intensity of droughts are likely to be felt strongly in sub-Saharan Africa (SSA), where most households are poor and relies on rain fed agriculture (Davies et al., 2009). Agriculture accounts for a large share of SSA gross domestic product (GDP), and is susceptible to climate shocks. This is particularly true for agriculture in so-called arid and semi-arid Lands (ASALs). Approximately 41% of ASALs in SSA are situated in East and Southern Africa, and they are mainly inhabited by pastoralists and agro-pastoralists (Tessema, 2012). Pastoralists are households whose way of life, socio-cultural norms, values and indigenous knowledge revolves around livestock keeping and transhumance to use natural pastures (Ayantunde et al., 2011). Agro-pastoralists incorporate some crop farming alongside livestock keeping and transhumance.

In Kenya, ASALs occupy 87% of the land area and support more than 30% of the human population. ASALs are also home to the entire camel population, 50% of the cattle, and some 70% of all sheep and goats. Pastoral and agro-pastoral households in ASALs are exposed to the risk of losing part of their asset base because of climate shocks (Mude et al., 2007). Other potential shocks include livestock diseases and price fluctuations (Mude et al., 2007; Ouma et al., 2008), but climate shocks (droughts and floods) are considered the most constraining factors for agro-pastoralism. Some households respond to climate change by changing the intensity of exploiting own and common resources, and incorporating crop farming in their livelihood (Bryan et al., 2011; Davies et al., 2009; Lang, 2007; Speranza, 2010).

The way households and communities respond to increased climate shocks are of interest for policy makers seeking to improve the resilience of (agro) pastoral livelihoods (Fratkin et al., 1999; Schlenker and Roberts, 2009). Because of the temporal nature of climate change it is difficult to study household responses in real-time, and a dynamic setting. This paper proposes a "short cut" approach, and considers the relation between climate shocks and responses in a cross-sectional setting, exploiting spatial variation in climate patterns. Specifically, we ask whether households change their investment in livestock and social capital to protect themselves along an ecological gradient from "relatively wet" to "relatively dry." While not denying that alternative protective measures may be equally important for (agro) pastoral households – including altering the crop mix (if any) or engaging in migration – we believe a focus on these complementary dimensions are of interest for policy making. Informal sharing, facilitated by high levels of intra-community trust and altruism, is a well-known strategy enabling communities to cope with (idiosyncratic) risk (Binswanger and McIntire, 1987). We regard this as a group response to shocks. In contrast, accumulation of livestock wealth reflects choices by individual households and, while "herd building" or "herd reconstituting" may entail collective action via lending out of heifers and cows (Sutter, 1987), to a large extent this is a private activity (albeit one with external effects). We analysed whether different types of households respond differently to exposure to climate shocks by selectively investing in two forms of capital – social capital and natural capital. We also ask whether access to (road) infrastructure and markets is a relevant mediating factor.

As mentioned above, we use cross sectional data to understand how households protect themselves against climate risks. We translate the findings of our static approach to progressive climate change, and to explore how households and communities may respond to a changing climate over time. This not only requires that climate patterns change over time in a similar fashion as they do when moving along the ecological gradient in our study, it also requires that the nature of alternative adaptation strategies does not change over time, or that these strategies are stable. Both conditions are unlikely to hold, so the findings of this paper are not intended to "predict" how pastoral households will respond to climate shocks in the future. Instead, they represent a modest step towards the understanding about climate shocks and self-protection in ASALs.

We find there is a weak association between rainfall and livestock wealth as we move from wet to drier environments, and households in drier settings tend to accumulate more livestock. In addition, we find no relationship between average investment in social capital and rainfall. Social networks do not become more tight or dense in response to climate shocks. However, coping strategies vary across social groups. Poor households, wealthier households and financially-integrated households have to some extent different coping strategies. These insights may potentially inform policies particularly those targeting intervention and designing of institutions that support self-protection measures to climate shocks related risks.

2.1.1 Coping and adaptation strategies in arid and semi-arid areas

In East Africa, (agro) pastoral households are exposed to many risks, including price risk, but also diseases, ethno-political violence, crime and corruption. While it is not evident that climate shocks are necessarily the most debilitating factor for rural livelihoods, it has been documented that exposure to droughts and floods has significant adverse effects on the lives of these poor. From a research perspective, focusing on climate shocks has the advantage that such shocks – gauged by low rainfall in what follows – are plausibly exogenous to household choices and to most other socio-economic variables including the other risk factors mentioned above. This facilitates the interpretation of correlations between rainfall and self-protection as causal relationships – even if attribution concerns obviously remain in a cross-sectional setting.

Households in ASALs have devised various strategies for coping and adapting to the risks associated with climate shocks. Coping strategies refers to the use of endowments and entitlements by households to ensure survival after a shock has occurred (Ouma et al., 2011), while adaptation strategies, though crafted in part by coping strategies, are a long-term set of actions taken to maintain the ability to deal with, and recover from, stress and shocks, while maintaining assets and capabilities (ibid). Common coping and adaptation responses to climate risks used by (agro) pastoralist involve introduction of breeds, reduced consumption, new approaches to farming, diversification, livestock accumulation, livestock sharing, migration to urban areas, and exit from livestock husbandry (Binswanger and McIntire, 1987; Little, 2001; Little et al., 2001; Mude et al., 2007; Ouma et al., 2008; Silvestri et al., 2012). While some coping and adaptation strategies are slowly becoming less effective (e.g., livestock migration due to privatization of rangelands, see Ouma et al. (2008)), investing in livestock and social capital are still ranked as some of the most effective coping strategies (e.g., Mude et al., 2007). They are at the heart of strategies that most households use to respond to shocks.

In ASALs two main types of risks are identified: covariant and idiosyncratic risks. Covariant risks affect all farmers of a particular area, and could arise due to government policy, economic forces (price volatility), or large-scale acts of nature such as drought. Idiosyncratic risks, in contrast, affect individual households – such as individual health shocks (Binswanger and McIntire, 1987). Livestock accumulation may be effective when confronted with covariant risks, such as drought because accumulating livestock implies improved odds that some animals will survive a drought (ceteris paribus). Hence, families with more livestock are expected to recover more quickly, and claim a larger share of communal pasture resources. Instead, investing in social capital and networks is particularly effective in the presence of idiosyncratic shocks – affecting some members of the network but not others. If so, households within socially-knit networks can informally insure one another via sharing arrangements based on altruism or well-understood expected reciprocity (e.g., Coate and Ravallion, 1993; Ligon and Thomas, 2003; Townsend, 1994; van Rijn et al., 2012). Investing in social capital and livestock wealth may provide complementary mechanisms to protect households against shocks, and theory suggests that especially livestock accumulation will be effective in the context of co-variant climate shocks.

Households do not invest in livestock and social capital exclusively for insurance purposes – in fact, the need for insurance may not even be the major consideration for such investments. There are various other uses for livestock (Livestock in Development., 1998). They are a source of income; one of the few assets available to the poor to save (especially women); and livestock manure and draught power are important for soil fertility and the sustainable intensification of farming systems.

Moreover, livestock allow poor households to exploit common property resources and diversify and stabilize incomes. Livestock are also used to pay bride wealth (Herskovits, 1926), and the accumulation of livestock helps households to accrue social status (Kaye-Zwiebel and King, 2014). Similarly, alternative benefits or uses of social capital, other than mutual insurance, include economizing on transaction cost by speeding up search, increasing trust and facilitating information circulation (Fukuyama, 2001), facilitating coordination and cooperation (Putnam, 1993), and increasing loan repayment rates in rotating savings and credit societies. However, even in situations where households may decide to invest in accumulating livestock wealth for several reasons, it is still possible to identify the impact of rainfall on insurance component. This is particularly so in situation where this other seasons are not systematically different along the two gradient in our sample. But if other reasons for investing in social capital and livestock also evolve along the gradients, then the demand for insurance cannot be identified because it will be confounded.

The literature shows that pastoralists consider access to markets as an important factor that might mediate (climate) risks (Smith et al., 2014). The reason is that market access (captured using distance to markets in this study) affects decision-making related to marketing of livestock (Bailey et al., 1999). The explanation is the transaction costs associated with buying and selling animals. Ease of market access reduces the tendency to hold on to livestock wealth (Barnett et al., 2008). Interventions and policies intended to help people manage climate related risks may need to account for variation in strategies undertaken by households over space to prove effective. The main objective of this study is to explore how changing socio-economic and ecological conditions affect coping and adaptations strategies among (agro) pastoral households. Specifically, we ask whether households accumulate livestock wealth and invest in social capital to protect themselves against climate shocks.

2.2 Study area

The study was conducted in the Samburu County, one of the 47 counties of Kenya. The county is bordered to the East and North East by Marsabit County, to the South East by Isiolo County, to the South by Laikipia County, to the South West by Baringo County and to the West and North West by Turkana County (Government of Kenya, 2007). The county lies between 00° 36 and 02° 40 N and 36° 20 and 38° 10 E covering an area of 21,000 km^2 with a population density of 11 inhabitants per km^2 (Government of Kenya, 2009b). Samburu County is divided into six administrative divisions, with 39 locations and 104 sub-locations (Government of Kenya, 2007). The climate is hot and dry with mean monthly temperature ranging between 24°C (July) and 33°C (December). Rainfall is highly variable, ranging between 250 and 700 mm in the plains, and between 750 and 1250 mm in the highlands. The rainfall distribution is bimodal with the long rains occurring between March and May, and short rains between July and August in the north and October and November in the East. The altitude ranges between 1,000 m above sea level on the plains to 2,752 m in the highlands. The county is ranked the second poorest in Kenya (Government of Kenya, 2009a). Pastoralism is the main economic activity, with about 80% of the households being livestock keepers. The main livestock includes goats, sheep, cattle and camels. Cash for buying maize, the staple food, is derived mainly from livestock sales. Wage labour (mainly from herding) to supplement household income is also common.

A field survey was conducted from February to May 2012 covering 500 households sampled randomly from five locations: Maralal (Block I), Londunokwe (Block II), Wamba (Block III), Swari (Block IV) and Barsaloi (Block V (Fig. 2.1). Sites selection was done purposively to take into account environmental “dryness” and market access. The two gradients were aimed at generating a unique dataset that captures relative variation in agricultural potential, market access, and rainfall variability.

In site selection, we first distinguished three locations along the West-East gradient: location near the urban centre (Maralal or Block I), location at medium distance from the urban centre (Londunokwe or Block II) and location far away from the urban centre (Wamba or Block III). Along this West-East gradient, the geophysical conditions are rather constant (i.e. average rainfall is about similar at 735 mm, 695 mm and 620 mm for blocks I, II and III, respectively), while distance to the urban market increased significantly (at $p<0.001$) from 13km in Block I to 67km in Block V (Fig. 2.2).

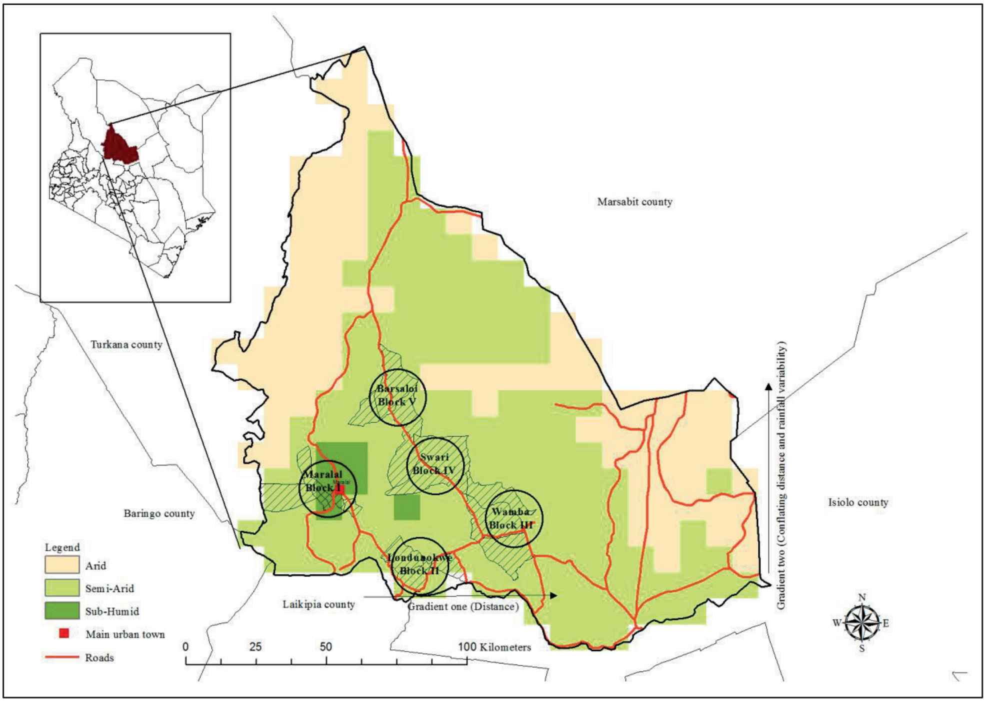
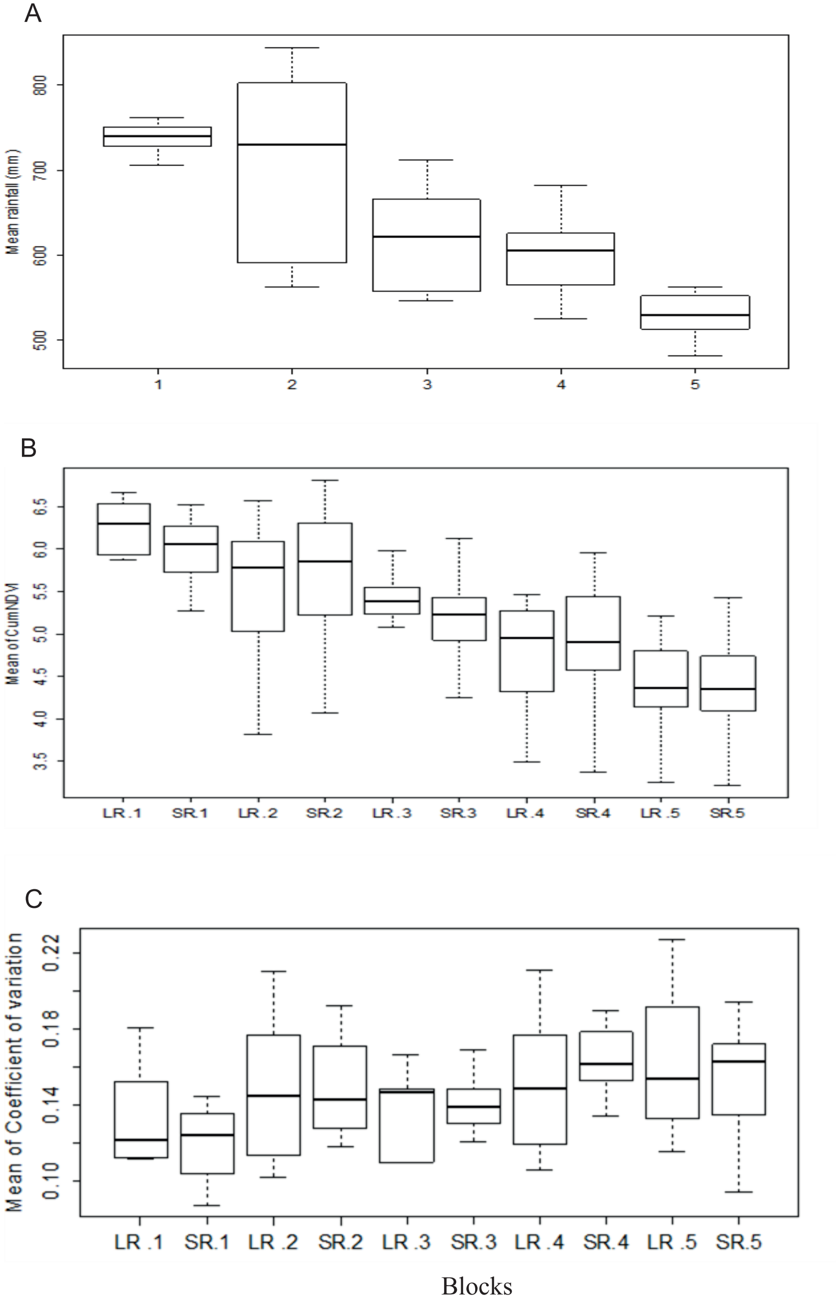


Figure 2.1: Map of Kenya showing Samburu County and the five Locations (Maralal, Londunokwe, Wamba, Swari and Barsaloi) from which our sample households were selected



LR stands for long rain season, SR stands for short rain season, Error bars are the standard deviations

Figure 2.2(A). Average annual rainfall. Error bars are the standard deviations. (B). Cumulative NDVI for the long rain (LR) and short rain (SR) season for 11 years. Error bars are the standard deviations. (C). Temporal variability as captured by the coefficient of variation (CV) for both LR and SR seasons for the last 11 years.

Then, using the location at the medium distance (i.e., Block II) – of the West-East gradient – as a starting point, we developed a second gradient (orthogonal to the West-East) by moving north (i.e., to block IV and V). Along this second gradient the environment becomes drier (i.e., Normalized Difference Vegetation Index (NDVI) decreases) and rains become more unpredictable (i.e., mean annual rainfall decreases while coefficient of variation for both long and short rain increases) (Fig. 2.2a, b, and c), and as we move farther from the road trading cost increased. Thus while the second gradient conflates market distance and rainfall, the first gradient captures the distance effect (market access) cleanly.

The selection of households was done through multi-stage cluster sampling. In the first stage cluster sampling, three sub-locations were selected from each of the five locations (i.e., Blocks I–V). In the second stage, 10 villages were randomly selected from the three sub-locations, to end up with a total of 10 villages in each of the five blocks. In the third stage, 10 households were randomly selected from village sampling frames developed with the assistance of local chiefs (Nyariki, 2009). Finally, interviews were conducted using structured questionnaires with the help of five trained local enumerators.

2.3 Data

In this study we used the sustainable livelihood framework (SLF) approach (Scoones, 1998) to guide the collection of household level data on the various forms of capital: human capital, natural capital, financial capital, and physical capital. We also collected data on access to markets and information, and on environmental variables (see online appendix 2.1 for data and details). Table 2.1 summarizes these variables that were subsequently used to cluster the households in three homogenous groups (HGs): (i) poor pastoralists, (ii) wealthy pastoralists and (iii) financially-integrated pastoralists. These categories were developed by "letting the data speak" and not explicitly based on theory. The wealthy (HG1) are largely dependent on income from crop farming and communal grazing resources. The financially-integrated (HG3) have relatively better access to credit and ability to save money. Most of the poor (HG2) are women headed households and they are the least endowed in terms of household assets, communal resource-based income, and capacity to save. See Tables 2.2 and 2.3 for details.

Table 2.1: Summary of the data

Variables	Means	Standard deviation	Minimum	Maximum
Panel A: Human capital				
Household size	6.88	2.77	2	19
Human dependence ratio	2.12	1.64	0	9
Age of the household head	49.74	13.79	21	90
Education of household head (years)	2.00	4.28	0	16
Gender of the household head	1.29	0.45	1	2
Experience in farming	22.04	14.34	2	80
Years lived in the village	18.05	12.70	1	65
Hired labour (Dummy: 1= yes, 0=No)	0.23	0.46	0	1
Panel B: Natural capital				
Cultivable farm area (ha)	0.10	0.50	0	7.84
Natural resource constraints	0.60	0.14	0.33	0.83
Frequency of access	0.81	0.18	0.17	1
Panel C: Financial capital				
Access to credit (Dummy: 1= yes, 0=No)	1.86	0.34	1	2
Financial savings (Dummy: 1= yes, 0=No)	0.08	0.27	0	1
Total crop income (KSh)	16193.57	52871.54	0	593757
Total livestock income (KSh)	22534.20	53797.34	0	622990
Communal based income (KSh)	4235.38	12214.36	0	120000
Total livestock wealth (TLU)	11.12	12.16	0	99.50
Panel D: Physical capital				
Total household asset index	33.75	63.11	2	1026
Panel E: Social capital				
Membership to community group	0.57	0.63	0	2
Degree of trust	0.26	0.47	0	1
Degree of participation in group meeting	1.50	1.53	0	4
Participation in group activities	0.29	0.34	0	1
Panel F: Market access variables				
Distance to the motorable road (km)	1.06	1.22	0.00	8.00
Distance to the tarmac road (km)	109.33	29.87	40.00	190.00
Distance to the local market (km)	10.14	11.46	0.01	70.00
Distance to the livestock market (km)	12.29	11.88	0.01	74.00
Distance to the urban market (km)	39.11	19.02	0.00	73.81
Panel G: Climate variables				
Mean rainfall (mm)	634.70	93.31	481.00	845.00

S*ource*: authors survey 2012; n=500

Table 2.2: Comparison for means of the main aggregating variables at a rescaled distance (RD) of 18 with three household groups (HGs)

Panel A: Variables	Wealthy household (HG1)	Poor households (HG2)	Financially integrated households (HG3)
Human capital			
Household size	7.01[a]	6.68[ab]	6.71[abc]
Age of the household head (Years)*	47.1[a]	50.2[b]	54.7[bc]
Education of the household head*	4.25[a]	1.08[b]	3.12[ac]
Gender of the household head*	1.20[a]	1.33[b]	1.18[abc]
Farming experience	22[a]	23[ab]	25[abc]
Human dependence ratio	2.27[a]	2.00[ab]	2.37[abc]
Years lived in village*	20[a]	17[b]	22[ac]
Hired labour*	0.87[a]	0.02[b]	0.06[bc]
Natural capital			
Cultivable farm size (ha)*	2.12[a]	0.12[b]	0.09[bc]
Natural resource use constraint*	0.65[a]	0.72[b]	0.80[c]
Natural resource use frequency*	0.73[a]	0.83[b]	0.93[c]
Financial capital			
Access to credit*	0.11[a]	0.31[ab]	0.96[c]
Financial savings*	0.01[a]	0.00[ab]	1.00[c]
Total crop income (KSh)*	54,817[a]	3,381[b]	2,648[bc]
Communal incomes (KSh)*	10,187[a]	2,118[b]	3,678[bc]
Physical capital			
Total household assets index*	71[a]	21[b]	27[ac]
Risk minimizing strategies**			
Storage of food crops	0	90[†]	3.2
Cash for work (farm work or livestock grazing	0	90[†]	3.2
Engage in trade (i.e., groceries items)	13	90[†]	6.4
Borrow food and pay in kind	0.2	97[†]	0
Reliance on natural food (i.e., berries from the forest)[†]	0.5	10[†]	3.2
Wait for relief	0.5	5[†]	0

Table 2.2: Comparison for means of the main aggregating variables at a rescaled distance (RD) of 18 with three household groups (HGs) (cont'd**)**

Panel B: Sampling block			
Block V	5	87	8
Block IV	5	81	14
Block III	78	20	2
Block I	17	76	7
Block II	20	79	1
Panel C: Dry and wet areas			
North (block IV & V): Dry	10	168	22
South (block I, II & III): Wet	115	175	10
(Percent of households)	(25%)	(68%)	(7%)

NB: Means with the same superscript were not significantly different at $p<0.05$ level. HG stands for household group. A symbol (*) indicates means of aggregating variable(s) among the HGs was significantly different at $p<0.05$ level of significance. Panel B and C shows the distribution of households in the three HGs by sampling blocks and as we move from dry to wet areas. **indicate proportion of households in each of the three HGs who use short range insurance strategies. † indicate that the proportion (based on total households per HG) of households in each of the three groups are significantly different (at $p<0.05$) from the rest. *Source*: authors survey 2012

Table 2.3: The description of the three household groups in terms of endowment and main characteristics

Household groups	Resource endowment† and production orientation	Main characteristics††
Wealthy household (HG1)	These group of households are highly endowed in terms of assets, they are commercially oriented	Have the highest crop income, income from communal resources and have the highest assets in value terms. Lack family labour compensated by hiring. Have young mid-aged household heads (in years)
Poor households (HG2)	These are the least endowed group of households in terms of assets, communal resource, ability to save and education.	They mainly rely on short terms insurance (i.e., selling out labour locally, working for payment in kind) strategies to maintain their household livelihood. Produce mainly for household consumption. Majority are female headed households, are self-subsistence and rely on petty trade
Financially integrated households (HG3)	Financially integrated to the credit and finance markets. Have moderate household assets	Have lived the longest in the village and mostly comprise of older household heads.

†Refers to assets representing wealth indicators and †† refers to the family structure, the main constraints to agricultural production and to their main source of income. *Source*: authors survey 2012

2.3.1 Dependent variables

We seek to explore the impact of rain (and market access) on insurance behaviour of households, manifested in their choices with respect to livestock wealth and social capital. We deal with both types of dependent variables in turn.

Livestock wealth

We compute livestock wealth by converting recorded herd and flock size into total livestock units (TLU), following the method of Schwartz et al. (1991). One livestock unit = 10 sheep or goats = 0.7 head of cattle = 1.0 camels. The TLUs were aggregated for each household to constitute our measure of livestock wealth

Social capital

While the exact definition of social capital is subject to debate, it is often treated as a characteristic of communities and described in terms of trust, norms and network (Bowles and Gintis, 2002), and is enhanced as the number of ties between individual and other people increase (Hagan, 1998). In this study, we use two proxies for social capital – a measure of trust or 'cognitive social capital' (CSC) and a measure of 'structural social capital (SSC). This is based on membership to community groups and on the assumption that community members likely have a large social networks on which to draw from during difficult times (Mutenje et al., 2010).

To measure CSC, we used World Value Survey-style trust questions (see appendix 2.3 for details) and asked respondents to rate their level of trust in fellow household members, extended kin, and fellow village members. We then created a dummy variable to capture households indicating to have a "high trust" in all three groups of people. The standardized scale shows an alpha reliability of 0.651.

To measure SSC we asked households whether they were members of any community groups. To those answering affirmatively, we asked how many groups they had joined and their degree of participation in group meetings and activities. The degree of participation in meetings was estimated using a 0 – 4 (low to high) point scale. We also created a dummy variable to capture participation in elections, campaigns and conflict resolutions. These dummies were averaged for each household and normalized, so that a value of 1 indicates full participation in all group activities, and 0 indicates no participation at all. The standardized scale shows a Cronbach's alpha reliability of 0.753. These three sub-indices (group membership, degree of participation in meetings and participations in activities) were aggregated to construct one overall SSC index.

2.3.2 Identification

As mentioned above, we first use a general linear model (GLM) to capture potential heterogeneity in household responses. The GLM approach is based on an agglomerative hierarchical analysis that reduces the dimensionality of the SLF capital variables by clustering households into more or less homogenous groups. The clusters seek to maximize between-cluster variances and to minimize within-cluster variances, as shown in Fig. 2.3. We use the classification in three groups or types in a regression framework (Eq. 2.1).

$$Y_i = \propto + \delta_1 D_1 + \delta_2 D_2 + \delta_3 R_i D_1 + \delta_4 R_i D_2 + \delta_5 X_i + \delta_6 R_i + \varepsilon_i \quad (2.1)$$

Where Y_i represents the dependent variables (LW, CSC, SSC and aggregate social capital SC) for household i, $\delta_1 to\ \delta_6$ are the parameter estimates, D_1 is the dummy variable equal to 1 for wealthy households, and 0 otherwise, D_2 is the dummy variable equal to 1 for poor households, and 0 otherwise (so that financially-integrated households are the omitted category), $R_i D_1$ is the interaction term for rain and wealthy households, $R_i D_2$ is the interaction term for rain and poor households, X_i represents a vector of market access control variables, R_i is the mean annual rain for the area where household i resides, while ε_i stands for the error term. Besides estimating (Eq. 2.1), we also estimate more parsimonious specifications that do not include interaction terms.

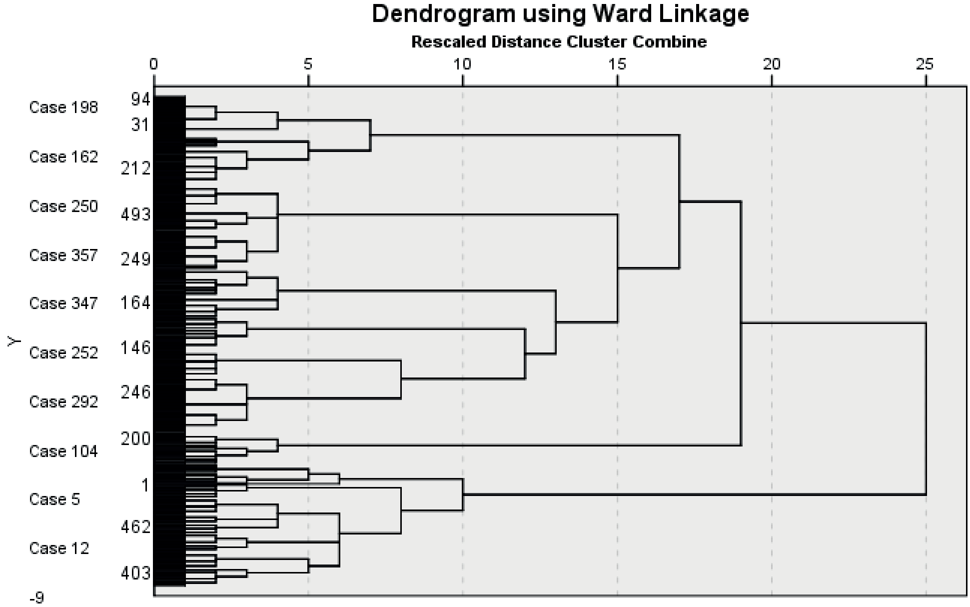


Figure 2.3: The agglomerative hierarchical clustering of households into relatively homogeneous groups (HGs). At a rescaled distance (RD) of 11, we had seven HGs. At RD of 14 we had five HGs and RD of 18 we had three HGs.

Before we embark on the analysis, we test for the joint significance of household groups and the interaction terms with rain. We reject the hypothesis of no structural heteroskedasticity (*see* appendix 2.4). There are rainfall and group specific influences on livestock wealth, and on the size of the variance of the unobserved term. Since multicollinearity among explanatory variables can affect the results, we applied a variance inflation factor (VIF) to test for multicollinearity. Across all independent variables, VIF values ranged from 1.42 to 3.84, not exceeding threshold (minimum) values (10). So multicollinearity does not appear to be a problem in our model.

2.4 Results

2.4.1 Parsimonious specification

We test the hypotheses that as we move from wetter to drier areas, households accumulate livestock wealth, SSC and CSC as insurance against climatic shocks. We start by estimating a parsimonious specification that does not include the above-mentioned interaction terms. Results are reported in Table 2.4. The results in column (1) show that, on average, there is no significant effect of rainfall on livestock wealth. There is some heterogeneity in the sample. Poor individuals in group 2 have lower livestock wealth. Column (1) also shows that the distance to motorable roads is positively and significantly ($p<0.1$) associated with livestock wealth.

Table 2.4: Relationship between rain, households groups (HGs) with livestock wealth, CSC, SSC and overarching measure of SC across the households

	Livestock wealth (TLU)	Cognitive social capital (CSC)	Structural Social Capital (SSC)	Membership to organizations	Participation in group meetings	Participation in group activities	Aggregate Social capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain	-0.011 (1.48)	0.000 (0.02)	0.000 (0.44)	0.000 (0.60)	-0.004** (2.72)	-0.000 (0.02)	0.000 (0.32)
Wealthy household (HG1)	-3.102 (1.23)	0.233*** (3.62)	0.013 (0.23)	0.104 (0.82)	0.080 (0.34)	-0.032 (0.45)	0.523*** (3.33)
Poor households (HG2)	-4.120* (1.83)	0.205*** (3.57)	-0.147*** (2.80)	-0.288** (2.54)	-0.299 (1.41)	-0.221*** (3.48)	0.168 (1.20)
Distance to motorable roads (km)	0.704*** (3.63)	0.013*** (2.59)	-0.010** (2.29)	-0.018* (1.87)	-0.040*** (3.20)	-0.012** (2.15)	0.013 (1.08)
Distance to local market (km)	0.092* (1.81)	-0.001 (0.96)	-0.001 (0.75)	-0.002 (0.96)	-0.003 (0.56)	-0.001 (0.53)	-0.004 (1.17)
Distance to livestock market (km)	0.002 (0.04)	-0.001 (0.95)	0.000 (0.15)	0.000 (0.13)	0.001 (0.19)	0.000 (0.11)	-0.002 (0.60)
Distance to urban market (km)	-0.010 (0.26)	0.000 (0.04)	0.004*** (4.17)	0.010*** (4.88)	0.013*** (3.81)	0.003*** (2.93)	0.005** (2.12)
Constant	19.758*** (4.52)	0.568*** (5.09)	0.211** (2.07)	0.301 (1.37)	0.514 (1.25)	0.353*** (2.87)	2.464*** (9.04)
N	496	496	496	496	496	496	496
R squared	0.06	0.05	0.09	0.11	0.06	0.07	0.06
F-Statistics	4.12***	3.92***	6.78***	8.48***	5.28***	5.48***	4.47***

NB: ***, **and * shows significance at P<0.001, P<0.05 and P<0.01 level respectively. Absolute value of t statistics in parentheses. n=500 households. Column (1), (2), (3) and (7) shows results of the association of livestock wealth, CSC, SSC and overarching measure of SC for the three groups of households (HG1 is the wealthy, HG2 is the poor, and HG3 is the financially-integrated households) with rain when controlling for market access. Column (4) (5) and (6) shows results for variables that constitute structural social capital ('membership to organizations', 'participation in group meetings' and 'participation in group activities'). km stands for kilometer. TLU stands for tropical livestock unit. S*ource*: authors survey 2012

The results in column (2) show that, on average, trust among households does not increase as we move from dry to wet areas. Rainfall is not correlated with cognitive social capital. Trust among the wealthy and poor households is significantly higher (at $p<0.01$) than among financially-integrated households. When rainfall increases by one standard deviation, trust by the wealthy and poor households increase by 0.34 and 0.31 respectively (or 69% of one standard deviation of this variable).

When we consider the relation between rain and structural social capital in columns (3) to (6) in Table 2.4, our results also do not support the hypothesis that SSC increases as the environment becomes drier (column 3). The results in column (3) also show that SSC was lower among the poor households, compared with the other groups. Other variables that explain structural social capital are distance to motorable roads and distance to the urban market. When we consider components of SSC ('membership in organisations', 'participation in group meetings' and 'participation in group activities') social capital does not vary with rain. However, an exception to this rule is provided in column (5): households in all three social groups have lower 'participation in group meetings' as the environment becomes wetter. The regression results (column (5) in Table 2.4) show that when rain increases by one standard deviation (93 mm), then the degree of participation in community meetings decrease by 0.37, which equals about a quarter of the standard deviation of the degree of participation. This suggests that households consider meetings an important avenue to minimize risks associated with climate.

We also explore variation in an overarching measure of social capital in Column 7. This measure is a linear combination of CSC and SSC. The results show that after controlling for market access, social capital does not increase as the environment gets drier. Based on the parsimonious regression results in Table 2.4, we conclude that on average there are no significant effect of rain on livestock wealth and social capital.

2.4.2 Group-specific responses

We include in the estimation interactions between household groups with rain. Column (1) in Table 2.5 shows that households have less livestock wealth when the environment is wetter, and especially individuals in the "Poor households" group have less livestock wealth than the "Financially-integrated households". However, we observe heterogeneity in the coping responses. The interaction term (of Poor household × rain) enters significantly. Because the magnitude of this interaction term is of the same magnitude as the coefficient of the rain variable (i.e., - 0.05 + 0.05 equals zero), the net effect of rain on livestock wealth for poor households is zero. Only for financially-integrated and wealthy households' livestock wealth decreases with increasing rainfall: when rainfall decreases by one standard deviation (93 mm), livestock holdings increase by approximately 0.5 TLU. This is a significant effect because average livestock holding is only 11 TLUs and given that livelihood depend mainly on livestock keeping. Two mechanisms might explain the increase in livestock wealth in response to drier conditions. First, increase in livestock wealth may serve as an insurance mechanism. Second, cropping is riskier in drier conditions and much of the land is rangeland.

There is no difference in livestock wealth between wealthy and financially-integrated households. However, when we move from wet to dry environment poor households have less livestock wealth. The results in Table 2.2 show that poor households had higher involvement in risk minimizing strategies (such as borrowing food for payment in kind, cash for work and petty trade), but indeed little livestock wealth (column (1) of Table 2.5) compared to financially-integrated households ($p<0.05$), suggesting poor households had alternative strategies for dealing with climate risks. The use of various risk minimizing strategies (as shown in Table 2.2) has been observed in other dry areas among pastoralist and agro-pastoralists (e.g., Ouma et al., 2011).

Column (1) also shows that the distance to motorable roads is positively and significantly ($p<0.1$) associated with livestock wealth. Close proximity to motorable roads enhances household's access to services such as credit, health and education. The access to these resources may enable households to pursue specific livelihood and coping strategies (Notenbaert et al., 2012), such as working in specialized trade (i.e., vehicle repair, blacksmithing, teachers, health workers) and have fewer animals for that reason. Households clustered close to motorable roads may also be people who have lost their livestock (e.g., due to drought) and are now destitute. Households close to motorable roads may also constitute majority of people who often receive emergency aid, and long term emergency aid has been shown to lower households' ability to put in place self-protection measures (Barrett, 2006; Harvey and Lind, 2005). Moreover, these results may reflect differences in local population density. In ASALs far from motorable roads, population densities are lower, land fragmentation is lower, and transhumance is more common – allowing easier accumulation of livestock wealth. In contrast, people around areas with good motorable roads have less access to land or have smaller land areas, and may be better qualified to obtain relief by the government or NGOs[2].

[2] Some evidence suggests such households usually have lower motivation for accumulating capital resources (i.e., livestock wealth) that would make them less vulnerable to climate risks.

Table 2.5: Relationship between rain, households groups (HGs) and interaction effects (HGs x Rain) with livestock wealth, CSC, SSC and overarching measure of SC across the households

	Livestock wealth (TLU)	Cognitive social capital (CSC)	Structural Social Capital (SSC)	Membership to organizations	Participation in group meetings	Participation in group activities	Aggregate Social capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rain	-0.050** (1.91)	-0.001** (2.14)	-0.001 (0.30)	-0.0046 (0.76)	-0.0040** (1.88)	-0.0010 (0.52)	-0.004** (2.39)
Wealthy household (HG1)	-17.67 (0.99)	-0.795* (1.74)	-0.337 (0.81)	-0.358 (0.40)	-1.3975 (0.90)	-0.4852 (0.95)	-1.838* (1.69)
Poor households (HG2)	-32.59** (2.11)	-0.637 (1.62)	-0. 272 (0.75)	-0. 021 (0.03)	-1. 1911 (0.92)	0. 2979 (0.95)	-1.339 (1.42)
HG1 × Rain	0.025 (0.88)	0.001** (2.29)	-0.001 (0.84)	0.0007 (0.49)	0.0020 (0.79)	0.0006 (0.88)	0.004** (2.09)
HG2 × Rain	0.046** (1.83)	0.001** (2.17)	-0.0002 (0.36)	-0.0043 (0.34)	-0.0014 (0.68)	-0.00015 (0.45)	0.003* (1.61)
Distance to motorable roads (km)	0.711*** (3.66)	0.012** (2.48)	-0.011** (2.37)	-0.019** (1.99)	-0.0325** (2.01)	-0.0092* (2.23)	0.014 (1.22)
Distance to local market (km)	0.097** (1.91)	-0.001 (0.89)	-0.001 (0.75)	-0.0025 (0.99)	-0.0029 (0.72)	-0.0007 (0.52)	-0.003 (1.23)
Distance to livestock market (km)	-0.001 (0.02)	-0.001 (1.01)	0.000 (0.13)	0.0002 (0.12)	0.0046 (1.18)	0.0009 (0.09)	-0.000 (0.05)
Distance to urban market (km)	-0.012 (0.32)	-0.000 (0.04)	0.004*** (4.41)	0.0095*** (4.87)	0.1002 (1.92)	0.0866** (2.91)	0.004** (2.06)
Constant	37.187*** (16.50)	1.387*** (4.95)	0.361 (1.04)	1.559 (0.21)	6.6629*** (4.74)	1.7574*** (1.35)	6.221*** (6.19)
N	496	496	496	500	500	500	496
R-squared R-adjusted	0.06 0.05	0.06 (0.05)	0.09 0.07	0.11 0.09	0.17 0.16	0.17 0.16	0.11 (0.20)
F-Statistics	3.73***	3.68***	10.44***	6.80***	10.46***	10.46***	11.86***
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance	chi2(1) = 46.85 Prob > chi2 = 0.71	chi2(1) = 0.03 Prob > chi2 = 0.87	chi2(1) = 2.35 Prob > chi2 = 0.12	chi2(1) = 13.80 Prob > chi2=0.02	chi2(1) = 0.99 Prob > chi2 = 0.31	chi2(1) = 17.24 Prob > chi2 =0.02	chi2(1) =0.20 Prob > chi2=0.981

NB: ***, **and * shows significance at P<0.001, P<0.05 and P<0.01 level respectively. Absolute value of t statistics in parentheses. n=500 households. Column (1), (2), (3) and (7) shows results of the association of livestock wealth, CSC, SSC and overarching measure of SC for the three groups of households (HG1 is the wealthy, HG2 is the poor, and HG3 is the financially-integrated households) with rainfall when controlling for market access. Column (4) (5) and (6) shows results for variables that constitute structural social capital ('membership to organizations', 'participation in group meetings' and 'participation in group activities'). km stands for kilometer. TLU stands for tropical livestock unit. S*ource*: authors survey 2012

Column (2) of Table 2.5 explains variation in cognitive social capital (trust) across respondents. We observe that, on average, people in wetter environments have lower trust. However, we also observe heterogeneity in the coping response. Specifically, both interaction terms of social groups and rainfall are significantly. Because the magnitude of the interaction terms (wealthy households × rain and poor households × rain) is of the same magnitude as the coefficient of the rain variable, the net effect of rain on the accumulation of trust is zero for wealthy and poor households. Only for financially-integrated households is trust affected by the environment. If rainfall decreases by one standard deviation (93 mm), then trust scores increase by 0.093, which is considerable in light of average trust scores in our sample (0.26, see Table 2.1).

Wealthy households display less trust towards their peers than financially-integrated households. There is no difference between poor and financially-integrated households. Table 2.2 shows that wealthy households had higher income from crops and communal resources and assets, but lower CSC (column (2) of Table 2.5) than financially-integrated households (at $p<0.1$). This suggests that wealthy households use alternative strategies to deal with climatic risk. The use of crop income as a risk management strategy has been observed elsewhere among pastoralists (Rufino et al., 2013; Silvestri et al., 2012). Our findings are consistent with the notion that wealthier members are less dependent on social capital as they have alternative options for self-insurance.

Among the financially-integrated households, we expected that trust would not vary with rainfall – as these households can borrow in times of crisis, so that social capital matters less for them. However, we find the contrary: one standard deviation increase in rain among financially-integrated households' leads to a 0.40 standard deviation decrease in predicted trust, with other variables held constant. Based on this result two questions arise; i) why do financially-integrated households respond to differences in rainfall? and ii) how is the group of poor households – if not via banks or trust or crops – insured? We explored whether these findings can be explained by access to credit in the study region. According to information from focus group discussions, for borrowers without collateral, credit providing institutions[3] require that at least two people act as guarantors before credit applications can be processed. Land without a title deed and livestock have no collateral value, hence most of our respondents need other villagers to act as guarantors – they are dependent on a specific form of social capital. In wet areas (such as close to Maralal) farm owners have title deeds (Government of Kenya, 2014), which they could use as collateral. This does not hold in dry areas, where access to communal land is a vital component of livelihood strategies to accommodate erratic rainfall. The finding that financially-integrated households accumulate trust (Column 2 in Table 2.5) could thus be explained by the fact that trust is an asset which financially-integrated households tap into to be able to access to credit.

Panel A, Table 2.2, shows that poor households mainly use short-term risk minimization strategies as insurance against risk. Table 2.2 shows that wealthy households are labour constrained and rely more on hired labour. This creates an opportunity for poor households to sell their labour for income generation. The data in panel A in Table 2.2 also show that poor households borrow food, which they pay for in kind (either by working on the farms of the wealthy households or grazing their livestock). Other strategies poor households use to self-insure include producing and storing crop products for own consumption (e.g., Rufino et al., 2013), involvement in petty trade (i.e., selling of groceries items), and diversification (e.g., Ouma et al., 2011). The positive and significant ($p<0.001$) association between distance to motorable roads and trust, in column (2) in Table 2.5, shows that trust is more embedded in social dealings and engagement among households living far from motorable roads.

We explored the relation between rainfall and structural social capital in columns (3-6) in Table 2.5. First, when considering an aggregate measure of structural social capital (column 3), our regression results do not support the hypothesis that SSC

[3] The main credit providing institutions that households reported to had accessed credit from during the 12 months in terms of importance were community groups (71%), banks (13%), money lenders (10%), micro-finance institutions (4%) and cooperative societies (1%).

increases as the environment becomes drier. Structural social capital does not vary across the ecological gradient, nor does it vary across homogenous groups. The only significant variables are distance to motorable roads and distance to an urban market.

When we break down the structural social capital variable into its constituent components ('membership in organisations', 'participation in group meetings' and 'participation in group activities') then similar patterns emerge from the data. Social capital does not vary with rainfall or across social groups. The one exception to this rule is that households have lower 'participation in group meetings' as rainfall levels increase (see column (5). This result holds for all social groups. The increase in participation in group meetings as the environment gets drier could reflect an increase in the perceived importance of such meetings to coordinate community responses. Addressing challenges such as those associated with climate variability requires more collective action in drier areas than in wetter areas.

The regression results show that when rain increases by one standard deviation (93 mm), then the degree of participation in community meetings decease by 0.34, which equals approximately a quarter of the mean participation or a quarter of the standard deviation of the degree of participation. The increase in meeting attendance when rain decrease may demonstrate a realization across households of the need to pull resources together to address the challenges of covariant risk. For institutions and organization aiming to provide information for targeted interventions (such as introduction of new technologies, training of new mitigation and adaptation practices) to pastoral and agro-pastoral households, these results suggest that community meetings might provide an avenue for spreading information across households as we move from wet to dry areas.

The results show that, after controlling for market access, households in wetter areas have low social capital. Compared to financially-integrated households, we also find that wealthy households have lower social capital. There is no difference in social capital between poor and financially-integrated households. Since the coefficient of the interaction terms for poor and wealthy households is of similar magnitude but opposite sign than the coefficient of the rainfall variable, we conclude that the variation in social capital along the ecological gradient exists only for financially-integrated households. These results echo those for the case of trust (CSC).

2.4.3 Robustness analysis

We probed the robustness of our result by estimating a series of related models replacing rainfall by NDVI (Table A2.6). When we introduce group-specific responses to variation in NDVI (i.e., by interacting groups and the NDVI), our results in Table 2.5 remain qualitatively similar (Table A2.7)

2.5 Discussion and conclusions

How do pastoralists respond to a changing climate? To answer this question, we considered variation in coping strategies along an ecological gradient in Northern Kenya. We first demonstrate that in ASALs, as we move from wetter to drier environments, there is variation in accumulation of livestock wealth across groups although this effect is not very robust. Specifically, in drier environment financially-integrated and wealthy households are associated with more livestock wealth. We speculate this is useful for addressing (production) risks associated with unpredictable climate conditions. Evidence from the published literature shows that accumulation of livestock wealth is a risk reducing strategy for households in variable environment such as ASALs (e.g., Barth, 1964; Fratkin and Roth, 1990; Hjort, 1981; McPeak, 2005; Næss and Bårdsen, 2010). This is expected in areas with low human population densities. High population density leads to limited and declining access for example due to land fragmentation and/or fencing to grazing areas (cf. Bailey et al., 1999). A decline in population pressure likely enhances access to dry season grazing for livestock holders. We interpret this as mixed support for the hypothesis that household accumulates livestock wealth under environmentally adverse conditions – which does not deny that households invest in livestock for many other reasons. The hypothesis that households accumulate (more) livestock wealth as we move from wet to dry areas as an insurance against risks and shocks is not supported across all households (Table 2.5), and thus not generalizable.

We find variation in cognitive social capital (trust) for one specific social group. Specifically, in drier environments, financially-integrated households are associated with more trust. There appears to be little variation in terms of structural social capital, but we do observe that across social groups the participation in group meetings increase in drier environments. Overall, we interpret this as weak support for the hypothesis that households accumulate social capital under dry conditions. Again, this does not deny that households invest in maintaining and deepening social relations for many other reasons as well. We also find significant correlations between livestock holdings and social capital on the one hand, and distance to motorable road and livestock market on the other hand. Livestock wealth increases as distances to motorable roads and local markets increases.

The finding that some specific households tend to accumulate livestock in response to drier conditions could be important for some programs aiming to enhance household livelihoods in ASALs. For example, consider the Index Based Livestock Insurance program (IBLI), run by International Livestock Research Institute (ILRI) in Northern Kenya. Results suggest that improving the asset base, such as livestock wealth, expands the range of income sources that households have access to, and provides risk diversification benefits (Chantarat et al., 2009; Chantarat et al., 2013; Mude et al., 2007). However, the provision of livestock insurance will – for some households – undermine incentives to invest in livestock accumulation or in social relationships. The consequences of such altered incentives for livelihoods may be difficult to predict. The IBLI program also found that the idiosyncratic risk faced by some pastoralists is unlikely to be resolved with index insurance (Chantarat et al., 2013; Jensen et al., 2015). One implication of the findings in this study is that there is need for multi-faceted intervention rather than singular approach of improving assets base for expanding risks diversification options to enhance adaptation potential. This is particularly relevant for pastoralist (e.g., in Marsabit) that face great deal of idiosyncratic risk that may not be covered well by index insurance (Chantarat et al., 2013; Miranda and Stutley, 2012).

Our results also suggest that it may be sensible to select livestock tolerant to dry environments, as this ensures that livestock wealth is sustained during droughts. Despite the downside of livestock keeping recorded in the past (e.g., collapse of livestock prices during droughts, deteriorating relative terms of trade between livestock and grain, (e.g., McPeak and Doss, 2006), accumulation of livestock remains a strategy for households to protect themselves against climatic risks (Behnke and Scoones, 1992; Ellis and Swift, 1988).

The positive associations between livestock wealth and distance to local markets suggest that households consider livestock wealth an acceptable risk management strategy in the absence of market mediated risk reduction strategies. Our result shows that poor households have lower livestock wealth compared to their peers as the environment becomes drier. Lack of insurance from livestock wealth might also explain why some households seek alternative insurance options (e.g., petty trade, whose income streams are much lower).

The hypothesis that households invest in trust as we move from wet to dry areas as an insurance to risks and shocks is not supported across all households (Table 2.5), and thus not generalizable. Surprisingly, we find that the environment matters for trust among financially-integrated only, but not for the wealthy. When faced by risks the wealthy could turn to natural resource harvesting or crop products for food and income generation. This result suggests that resource endowment plays an important role in determining the mechanisms that households' use for self-protection. It appears as if wealthy households prefer to use other strategies, such as accumulating stocks of livestock. This may be because of economies of scale associated with livestock wealth up to a certain level (Delgado, 1979). Other studies (e.g., Bac, 2009; Jones, 2004) also show that the wealthy rely less on trust than the poor to protect against risk. Trust especially matters for the financially-integrated households in dry conditions. We speculate this finding may be explained by the lack of collateral among financially-integrated household – since land is not scarce and cultivation on own land limit access to credit since livestock do not have collateral value (Binswanger and Rosenzweig, 1986) – and hence the need to develop trust relations (enabling peers to act as guarantor in case credit is needed). The guarantor in this case is considered as 'social collateral' through which the borrowers' reputation among the financial integrated group of households takes the place of physical or financial collateral. The use of social collateral is common among many poor communities where trust is high (e.g., Stiglitz and Weiss, 1981). Trust facilitates economic exchange and responsibility among trading people (Tabellini, 2010) and provide financially-integrated households a strategy for protecting against financial distress caused by risks and shocks.

The main implication of these studies to other ASALs areas of Kenya and sub-Saharan Africa is that farm households use various strategies as insurance against risks. These emanates from assets, social relations, the economy, prevailing institutions and the environment. Farm households sometimes rely on conservative or opportunistic strategies to be able to self-protect. The reliance on conservative measures to respond to challenges brought about by a change in socio-economics conditions is largely based on resources at their immediate disposal. This finding has important implications for development planners, programs and policy makers seeking to determine the priority target areas for implementing strategies for improving adaptive capacity. This is because they need to incorporate information on socio-economic condition, differential access to infrastructures, dynamism and differentiated responses that farm households use.

Appendices: Chapter 2

Appendix 2.1: Household level data

Human capital

To measure household size, respondents were asked to list household members who sleep in the same home, share production and consumption activities (i.e., eat from the same food pot). Household size was used to compute a human dependence ratio. That is the proportion of household members aged below 15 and above 65 years of age. Household size was converted into an adult equivalent scale following Martin (1985)[4]. Respondents were also asked to declare their age (or year of birth), level of education (number of years spent on education). We include a dummy variable for gender (value 1 if household head is male). Experience in farming was estimated by asking the number of years that household heads had been involved in farming. We also include a dummy variable to indicate whether the household used hired labour during the last 12 months.

Natural capital

Arable land was measured by pacing each of the households' fields (e.g., length and width for the rectangular plots, or the radii for the circular plots). The paces were converted into meters which were then used to compute the plot area. Natural capital includes access to land, water and wildlife from which households engage in resource collections or agricultural activities for both sustenance and income generation (Pereira et al., 2006). To assess 'resource use constraints' we constructed two dummies: i) whether households pay to access water, forest and pastures, and ii) whether there are rules regulating resources access and use (Table A2.2). Responses were averaged into a single value for 'natural resource use constraint'. We include the 'natural resources constraint' because drought and low livestock prices may induce households to pursue alternative coping strategies such as charcoal burning (Casse et al., 2004). The variable 'resource use frequency' was computed by summing the number of times households

[4] The adult equivalent weighing scheme used in this study assigns a value of one to individual of both sexes older than 15 and younger than 65 years, a value of 0.6 to individuals 6-14 years old and those older than 65 years, a value of 0.3 to children ages 2-5, a value of 0.1 for children under 2.

use the specific resource per week. The frequency totals were then normalised to a 0-1 scale using Eq. A2.1 below

$$\left(RUF_i = \frac{F_i - F_{min}}{F_{max} - F_{min}}\right) \quad \text{(A2.1)}$$

Where RUF_i stand for normalised resource use frequency for household i, F_i is the resource use frequency for household i, and F_{min} and F_{max} are the minimum and maximum values for the resource use frequency for all households. That way a higher value for natural resource regulation would lead to a greater flow of harvestable output than unmanaged open access resource. Hence, for the purpose of this study, constrained resource is better than unconstrained resource.

Financial capital

Access to credit was measured by assigning a dummy variable of 1 to those who reported to have had access to credit during the last 12 months. We use a dummy variable to identify households who saved any money during the past 12 months. Crop income, communal product income and livestock income were calculated using revenues from crop sales, products collected from communal areas, livestock (and livestock products) and the value of consumed products, accounting for annual direct production costs.

Physical capital

Based on asset index analysis (Bill and Melinda Gates Foundation, 2010), domestic, transport and productive assets were calculated. Each of the assets was assigned weight (w) – as shown in Table A2.3, which were then adjusted for age (Njuki and Sanginga, 2013). The total asset index was then summed for each household (Eq. A2.2).

$$\text{Household asset index } = \sum_{g=1}^{G}\left[\sum_{i}^{N}\left(w_{gi} \times a\right)\right] \quad \text{(A2.2)}$$

Where: $i=1,2,...N$; $g=1,2,...G$; w_g = weight of the i^{th} item of asset g; N is the number of assets g owned by a household; a is the age adjustment to the weight; G is the number of assets owned by a household. In addition, because assets weight can be context specific, we also used principal component analysis (PCA) (Henson and Roberts, 2006) to ascertain the asset weights used as a robustness check (Appendix 2.2 and Table A2.4).

Market access and information access variables

The distances from each homestead to a motorable road, livestock market and urban market were all measured in kilometres. Motorable road as used in this study refers to a road suitable for use by motor vehicle. Our defining criteria for a livestock market is a central place where people meet to buy or sell livestock at least twice a week, while urban market refers to a major town where people meet to buy or sell commodities (including livestock) and also the county capital. The distances from homestead to the livestock market were calculated using GIS. The distance to the motorable road was considered important because it affects the distribution of food aid and other relief supplies from government agencies and NGO's, especially in times of drought - which research suggest may affect strategies that households use for self-protection (Barrett, 2006; Harvey and Lind, 2005). Distances to livestock and urban market were considered important because in ASAL most of household income is generated from livestock sales, and often livestock prices are better at the main urban markets compared to livestock market (Bailey et al., 1999). The extent to which the different distances variables capture different dimensions of market access was examined using a pairwise correlation. We found that the correlation of distances to: motorable road, livestock market and main market ranged between $\rho = 0.03$ and $\rho = 0.20$, suggesting that each variable picks something that is "distinct". Finally, we compared in prices (spatially) for different livestock species, which shows that further away from the main urban market livestock were cheaper (Table A2.5). To estimate access to information we asked respondents for mobile phone ownership. A dummy variable 1 was assigned to households with mobile phones, and 0 otherwise.

Environmental variables

We used annual rain as a proxy describing the environment. Past research has shown that as rain decreases; the variability in output increases, the number of possible activities that households can engage into decreases, and covariate risks in those activities increase (Binswanger and McIntire, 1987). We used average rain data covering a period of 50 years (1950-2000)[5] for 1×1 km pixel for the sampled households. Rainfall data was extracted from the WorldClim – Global climate data (WC-GCD)[6] database (Hijmans et al., 2005). The Normalized Difference Vegetation Index (NDVI) data expresses the abundance of the green photosynthetically-active vegetation and is derived from reflectance measurement in the red and near-infrared part of the electro-magnetic spectrum (Tucker, 1979). We used the existing eMODIS NDVI of between 2001 and 2011 (since the present study was done during 2012) as a proxy of spatio-temporal environmental condition across the five study sites. In this study we used cumulative NDVI as a proxy of season net primary productivity (Vrieling et al., 2011) and evaluate the temporal coefficient of variation to be able to extract relevant information on vegetation variability (i.e., likelihood of an environmental shock to the farming systems).

[5] We used average rainfall data for 50 years because such data is more accurate and have more power by virtue of it being able to exclude time-invariant unobserved areas differences.

[6]The WC-GCD data are computed from monthly temperature and rainfall from local rain station gauge measures and then corroborated against satellite data of cloud cover and precipitation to generate more biologically meaningful variables. WC-GCD provides set of climate layers on global scales with a spatial resolution of about a km.

Appendix 2.2: Ascertaining the weights of physical asset using principal component analysis

The estimated principal component analysis (PCA) coefficient (Table A2.4) for physical assets rise with the increasing weight of each asset, and a greater number (either positive or negative) means that the variable provides more "information" on household physical assets stock. For instance, the largest negative coefficient is on having a hand hoe. This means that a household that has a hand hoe is likely to fall into the lowest categories of the other types of asset: animal, domestic assets transport or productive. Therefore, values with large negative value are indicative of an asset with lower weight. Similarly, a household with a car or a motorcycle was likely to have scored high on other types of assets. These results confirm that the asset weights assigned based on index analysis of Bill and Melinda Gates Foundation is a good representation the weights assigned to the physical assets among the studied households.

Appendix 2.3: **The world value trust question**

The World Value Trust question asked to the respondents was as follows. On a 3-point scale, (where 1 = no trust, 2 = moderate trust and 3 = a lot of trust) please rate:

i) the level of trust between your household members themselves [___],

ii) the level of trust between your household members and extended kin [___], and

iii) the level of trust between your household members and fellow village members [___].

Appendix 2.4: Test for heteroskedasticity

To ensure we avoid the problem of biased variance for the estimated parameters and to get reliable estimates and their significance, we tested for heteroskedasticity using Breusch-Pagan/Cook-Weisberg tests for the null hypothesis that the error variances are all equal versus the alternative that the error variances are a multiplicative function of one or more variable (Breusch and Pagan, 1979). The result shows that the chi-square value for all the three independent models (column (1) to (3)) in Table 2.5 (in the main results Tables) was small, and their associated p-values were large indicating heteroskedasticity was not a problem.

Table A2.1: A summary of the main shocks reported to be the most important (in terms of amount of loss caused to their livelihood) by households during the last 12 months (prior to field survey)

Blocks	Ecological gradient	Climate change and variability related shocks (Drought and/or flood)	Livestock Diseases	Fire outbreak	Ethno political violence
1	Wet	87%	12%	15%	0%
2	↓	91%	1%	7%	0%
3	to	93%	7%	0%	0%
4	↓	94%	3%	3%	0%
5	Dry	98%	2%	0%	0%

Table A2.2: Frequencies of household responses to the question posed in relation to resource use constraint

		Resource name		
Question posed in relation to resource use		Rangeland	Forest	River
Which the recognized form of ownership?	Private	0	0	0
	Communal	100	100	100
	Total responses	100	100	100
Do pay to access the resource?	No	99	88	100
	Yes	1	12	0
	Total responses	100	100	100
Are there rules§ regulating the resource use?				
	No	65	58	78
	Yes	35	42	22
	Total responses	100	100	100
What is the frequency of use per resource				
	Once a week	0	12	9
	Once a month	2	7	0
	Everyday	95	49	91
	Twice a year	3	32	0
	Once a year	0	0	0
	Total responses	100	100	100

The number in the table represents the percentage (%) of households that gave a specific response to the question posed.

§The main rule regulating the use of forest was: prohibition of felling of green trees for firewood, fencing post or charcoal. The main rules regulation around the use of rangeland were: prohibition of livestock grazing in areas close to the village – as this was reserved for young calves and weak animals, and prohibition of grazing on areas set aside (by the community) for grazing only during the dry season. The main regulation around the use of river was that no one was to cultivate very close to the river course to prevent soil erosion.

Table A2.3: Household domestic asset index

Asset (g)	Weight of assets (w_g)	Age (adjustment for age shown in the cell)		
		<3 years old	3-7 years old	>7 years old
Animal		Calves	Immature male/Heifer	Bull/cow
Cattle	10	× 0.4	× 0.8	× 1
Horses	10	No adjustment		
Sheep/goats	3			
Poultry	1			
Pigs	2			
Domestic assets		<3 years old	3-7 years old	>7 years old
Cooker	2	× 1	× 0.8	× 0.5
Kitchen cupboard	2			
Refrigerator	4			
Radio	2			
Cell phone	3			
Chairs	1			
Mosquito net	1			
Transport		<3 years old	3-7 years old	>7 years old
Car/ truck	160	× 1	× 0.8	× 0.5
Motorcycle	48			
Bicycle	6			
Cart (animal drawn)	12			
Productive				
Hoes	1	× 1	× 0.8	× 0.5
Machete	1			
Spade/shovel	1			
Plow	4			
Sewing machine	4			

Source: Adapted from Women, Livestock Ownership and Markets (Njuki and Sanginga, 2013)

Table A2.4: A summary of physical assets principle component analysis (PCA) coefficients

Animal	Coefficient	Transport	Coefficient
Cattle	0.4433	Car/ truck	0.7306
Goats	0.4365	Motorcycle	0.5734
Sheep	0.4381	Bicycle	0.3788
		Cart (animal drawn)	0.4688
Domestic		*Productive*	
Gas cooker	0.3068	Hand hoes	-0.5681
Cupboard	0.3122	Spade	-0.4217
Radio	0.3213	Axe	-0.3264
Cell phone	0.3219	Machete	-0.4688
Chair	-0.3886		
Mosquito net	-0.4157		

Table A2.5: Summary data on average price of cattle, sheep and goats as we move from site 1 to site 5 (i.e., wet to dry areas)

Animal type	Blocks	Distance (in km) to the main urban market	Price (in KSh) per animal	Standard deviation
Cattle	1	13.36±8.30	21,321.43	10,435.89
	2	43.25±7.98	17,520.00	6,102.39
	3	67.51±4.60	13,442.11	8,951.55
	4	87.73±6.85	12,846.15	3,242.84
	5	103.41±7.43	13,214.29	3,550.26
Goats				
	1	13.36±8.30	2,922.72	1,309.84
	2	43.25±7.98	2,800.00	1,417.35
	3	67.51±4.60	2,563.15	1,440.37
	4	87.73±6.85	2,340.00	850.09
	5	103.41±7.43	2,110.00	1,055.96
Sheep				
	1	13.36±8.30	2,536.36	1,860.82
	2	43.25±7.98	2,268.96	1,315.05
	3	67.51±4.60	2,194.82	1,132.66
	4	87.73±6.85	2,104.76	1,285.32
	5	103.41±7.43	1,691.17	786.00

Table A2.6: Relationship between NDVI, households groups (HGs) and interaction effects (HGs x Rain) with livestock wealth, CSC, SSC and overarching measure of SC across the households

	Livestock wealth (TLU)	Cognitive social capital (CSC)	Structural Social Capital (SSC)	Membership to organizations	Participation in group meetings	Participation in group activities	Aggregate Social capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
NDVI	-0.243 (0.11)	0.043 (2.25)	-0.012 (0.70)	-0.026 (0.77)	-0.028** (2.57)	-0.017 (1.30)	-0.100 (0.87)
Wealthy household (HG1)	-4.56 (1.24)	0.287*** (6.25)	0.038 (0.67)	0.168 (1.33)	0.062 (0.28)	-0.011 (0.19)	0.450*** (4.04)
Poor households (HG2)	-4.965* (2.50)	0.224*** (5.09)	-0.137* (2.83)	-0.261** (2.89)	-0.304 (1.59)	-0.212*** (3.67)	0.188 (1.16)
Distance to motorable roads (km)	0.794*** (3.07)	0.012 (2.11)	-0.011 (2.02)	-0.020 (1.77)	-0.029* (1.78)	-0.012* (2.43)	0.011 (0.64)
Distance to urban market (km)	-0.045 (0.99)	-0.002*** (2.47)	0.003** (2.32)	0.009*** (2.97)	0.018*** (3.44)	0.003 (1.70)	0.005** (3.59)
Distance to the livestock market (Km)	0.027 (0.60)	0.002 (2.47)	-8.8e-05 (0.06)	-3.9e-05 (0.13)	-0.003 (0.99)	-4.9e-05 (0.03)	-0.002 (0.75_
Constant	16.631 (2.08)	0.516*** (5.14)	0.290** (2.71)	0.491* (2.24)	4.87*** (7.65)	0.417** (3.18)	2.397*** (11.40)
N	499	499	499	499	499	499	499
R squared	0.05	0.05	0.09	0.10	0.16	0.07	0.06
F-Statistics	3.88***	5.07***	7.83***	9.74***	5.07***	6.37***	5.04***

NB ***, **and * shows significance at P<0.01, P<0.05 and P<0.1 level respectively. Standard errors are clustered at village levels. Absolute value of t statistics in parentheses. Sample size (n) = 500 households. Column (1), (2), (3) and (4) shows results of the association of for livestock wealth, CSC, SSC and overarching measure of SC for the three groups of households (HG1 is the wealthy, HG2 is the poor, and HG3 is the financially-integrated households) with rain when controlling for market access. Column (4) (5) and (6) shows results for variables that constitute structural social capital ('membership to organizations', 'participation in group meetings' and 'participation in group activities'). km stands for kilometre. TLU stands for tropical livestock unit. S*ource*: authors survey 2012

Table A2.7: Relationship between NDVI, households groups (HGs) and interaction effects (HGs x NDVI) with livestock wealth, CSC, SSC and overarching measure of SC across the households

	Livestock wealth (TLU)	Cognitive social capital (CSC)	Structural Social Capital (SSC)	Membership to organizations	Participation in group meetings	Participation in group activities	Aggregate Social capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
NDVI	-6.04** (1.69)	-0.112** (2.48)	-0.0914 (1.10)	-0.132 (0.74)	-0.168** (1.69)	-0.158 (0.49)	-0.092** (3.22)
Wealthy household (HG1)	-14.15 (1.27)	-0.664* (2.90)	-0.168 (0.65)	0.067 (0.12)	-0.385 (1. 18)	-0.611 (0.60)	-1.202* (2.26)
Poor households (HG2)	-13.75** (6.29)	-0.725 (1.62)	-0. 382 (1.55)	-0. 670 (1.26)	0.692 (1.24)	-0.482 (0.50)	0.799 (0.84)
HG1 × NDVI	6.47 (1.09)	0.001** (2.26)	0.074 (0.87)	0.058 (0.32)	0.137 (1.36)	0.227 (0.68)	0.199** (1.94)
HG2 × NDVI	6.03** (1.80)	0.001** (4.44)	8.6e-05 (1.02)	0.142 (0.78)	-0.168 (0.68)	0.075 (0.23)	0.209** (2.26)
Distance to motorable roads (km)	0.785** (4.11)	0.011** (2.46)	-0.011*** (2.50)	-0.021** (2.23)	-0.012*** (2.73)	-0.041** (2.37)	-0.005 (1.46)
Distance to urban market (km)	-0.047 (1.11)	0.0001 (0.23)	0.003*** (3.52)	0.008*** (4.13)	0.025*** (1.99)	0.014** (3.60)	0.001** (1.80)
Distance to the livestock market (km)	0.037 (0.81)	-0.001 (1.15)	-2.3e04 (0.21)	-6.66e-04 (0.28)	-3.33e-04 (0.27)	-1.19e-04 (0.03)	-0.0027 (0.95)
Constant	1.29 (0.12)	0.28 (1.05)	0.515** (2.05)	0.080 (1.48)	0.850*** 2.81)	1.17 (1.18)	2.36*** (3.52)
N	498	499	499	500	500	500	499
R-squared	0.05	0.06	0.09	0.11	0.16	0.06	0.11
R-adjusted	0.03	(0.05)	0.8	0.10	0.05	0.05	(0.20)
F-Statistics	3.33***	4.36***	6.00***	7.57***	5.15**	4.08***	4.23***

NB ***, **and * shows significance at $P<0.01$, $P<0.05$ and $P<0.1$ level respectively. Standard errors are clustered at village levels. Absolute value of t statistics in parentheses. n=500 households. Column (1), (2), (3) and (4) shows results of the association of for livestock wealth, CSC, SSC and overarching measure of SC for the three groups of households (HG1 is the wealthy, HG2 is the poor, and HG3 is the financially-integrated households) with rainfall when controlling for market access. Column (4) (5) and (6) shows results for variables that constitute structural social capital ('membership to organizations', 'participation in group meetings' and 'participation in group activities'). km stands for kilometer. TLU stands for tropical livestock unit. S*ource*: authors survey 2012

CHAPTER 3

Migration and self-protection against climate change: A case study of Samburu County in Kenya

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Abstract:

Climate change will affect the livelihoods of pastoralists in arid and semi-arid lands. Using data on agro-pastoral households from Northern Kenya, we explore whether migration of household members enhances adoption of agricultural innovations that aim to provide protection against weather shocks. Specifically, we seek to test whether migration and adaptation are complementary mechanisms to protect the household against adverse shocks, or whether they are substitutes. Do remittances relax capital constraints and facilitate the uptake of adaptive measures, or do they render adaptation superfluous? Our data provide suggestive evidence that remittances from migrant household members may relax capital constraints, and that remittances are an important mechanism linking migration to adoption, enabling the uptake of new technologies that involve change in activities or high costs. Specifically, migrant households adopt more adaptive measures (promoting self-protection), and we document some support for the hypothesis that this is especially the case for high cost adaptations such as the purchasing of drought tolerant livestock. These findings suggest that migration and local innovation are complementary rather than substitutive mechanisms of self-protection for pastoral households in the semi-arid lands of Northern Kenya. Households who have at least one member who has migrated are able to overcome barriers to employ high cost agricultural innovations - through using remittances received - thus enhancing their self-protection against climate change related shocks.

Keywords: Adaptation, climate change, insurance, remittance, migration

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3.1 Introduction

Weather shocks affect rural livelihoods, especially for pastoral and agro-pastoral households living in so-called arid and semi-arid lands (ASALs) (Coppock et al., 2011). Vulnerability mapping identified Northern Kenya as highly vulnerable to climate change and associated weather shocks (Little et al., 2008; McPeak et al., 2011; Thornton 2006). This region has historically experienced frequent droughts and floods, causing the loss of human lives, decimating livestock herds, and reducing farm outputs (McPeak et al., 2011).[7] While Northern Kenya, like other ASALs, has limited capacity to respond to such weather shocks (Scoones 1992), coping and adaptation do occur.

How do pastoral households cope with the risks that threaten their livelihoods? Well-known responses include the incorporation of crop farming to enhance food security (Bryan et al., 2011; Rufino et al., 2013), especially the adoption of drought-tolerant crop species, and changing the composition of livestock herds. Focusing on Northern Kenya and Southern Ethiopia, where capital and insurance markets are very imperfect, the Pastoral Risk Management (PARIMA) project identified various alternative and complementary strategies. Herd mobility, accumulation of livestock and opportunistic marketing helps to support pastoralists in managing risks (Lybbert et al., 2004; Barrett et al., 2001). Investment in security increases access to natural resources and hence favours restoration of livestock wealth (Barrett et al., 2001). In terms of the interaction between risks and policies, the PARIMA project found that poorly targeted food aid distribution can be detrimental to pastoral welfare (Barrett 2006). Public investments in marketing infrastructures and institutions are needed for the population residing in remote locations (Barrett et al., 2003), and investments in non-pastoral economic activities that expand employment opportunities tend to affect household welfare favourably (Coppock 1994; Fratkin and Smith 1995; Little 1992; Little 2001). Ethnographic work also emphasizes the importance of collective action and risk-sharing via social networks (e.g., Coppock et al., 2011). Such risk-sharing provides a safety net

[7] During the last 100 years, Kenya experienced 28 major droughts—three of which occurred during the last decade (Maitima et al., 2009).

and insurance for the poor and unlucky, especially when the government is unable to provide such services (Santos and Barrett 2006).

However, not all coping and adaptive behaviour of households needs to take place "on site", or in areas of origin. Spatial diversification represents an alternative opportunity. Many households respond to climate shocks by migrating or by sending household members elsewhere (Bohra-Mishra et al., 2014).[8] In particular, households may send members to urban centres in search of jobs (Ramin and McMichael 2009), and pool income to cope with shocks (see below). It has been shown that investment in primary education has a positive impact on livelihoods with salaried income, and facilitates migration into urban areas (Coppock 1994; Fratkin and Smith 1995). The interaction between migration and adaptive behaviour in areas of origin is the focus of the current paper. We study adoption behaviour of migrant households and non-migrant households to test whether migration enhances the adoption of adaptive measures in areas of origin. Our main finding is that migration is associated with enhanced adoption of adaptive measures, especially when adoption requires cash outlay (is "financially costly"). Remittance flows are likely to be a key channel linking migration to adaptation.

In recent years, migration from rural to urban areas has become an important research topic in development studies. The economic literature distinguishes different motives for migration (see Mendola 2012 for a recent review). The traditional model by Todaro (1980) focuses on labour market imperfections, or the existence of wage differentials. The model explains migration as an arbitrage strategy by individuals who vote with their feet in an effort to maximize expected income (see also seminal contributions by Lewis 1954; Todaro 1969; Harris and Todaro 1970; Stark 1978). While intuitive, this traditional perspective has proven incomplete because it does not consider other market imperfections (Katz and Stark 1986; Massey et al., 1993). The so-called New Economics of Labour Migration (NELM) provides for a broader set of motives, and also considers imperfections in capital and insurance markets. The importance of

[8] Few papers explore how climate change may affect migration (e.g., McLeman and Smit 2006). Migration could trigger conflicts over scarce resources in areas of destination (e.g., Reuveny 2007).

imperfect capital and insurance markets is demonstrated in Bryan et al. (2011). In that study, the authors incentivize a random subsample of Bangladeshi villagers to migrate (seasonally) to urban areas to reduce seasonal poverty. The intervention consisted of covering the round-trip cost of moving, which effectively insured the treated households against the worst outcome of engaging in migration i.e., incurring the cost of moving but not finding a job. The "insurance" treatment resulted in a large increase in migration rates in the treatment areas, translating into substantial welfare gains. The average returns to seasonal migration, measured in terms of enhanced consumption in areas or origin, were high and far outweighed the costs associated with migration (Bryan et al., 2011).

Bryan et al. (2011) found that capital or insurance market imperfections matter and that gains from migration are shared within the family. Indeed, the NELM perspective proposes that migration decisions are typically not taken by individuals but by members of extended households jointly (cf. Stark and Lucas 1988). Migration represents an opportunity for income diversification so that families can reduce exposure to risk and relax financial constraints via remittances and parental income pooling (Katz and Stark 1986; Lucas and Stark 1985; Stark 1991; Stark and Levhari 1982; Taylor 1999).[9] The NELM paradigm highlights the informal insurance role of migration, so that households in source areas are better able to smooth consumption or engage in high-risk, high-profit activities (such as the adoption of HYV rice – see Mendola 2008).[10] If intra-household income flows relax financial constraints imposed by imperfect capital markets, they may also facilitate investment in human capital (Adams et al., 2005), or productive capital (e.g., Lucas 1987; Rozelle et al., 1999; Woodruff and Zenteno 2007). In other contexts, it has been observed that remittances may also translate into additional consumption (e.g., De Brauw and Rozelle 2008), perhaps even of the "socially wasteful" kind associated with social spending and local races for status (e.g., Brown et al., 2011).

[9] There may be other motives for migration. For example, the relative deprivation thesis predicts that people move to improve their (relative) rank in local society (Stark 1991).
[10] While Mendola (2008) found that migration enables households in source areas to take risks associated with certain productive investments. Thornton et al. (2007) indicate that the adaptation strategy chosen depends largely on the costs of investment and less dependent on risk.

This study seeks to contribute to two theoretical strands of literature. The first, introduced above, focuses on the economic consequences of migration for households in areas of origin. The second is the literature on incomplete adoption of agricultural innovations, which has a long tradition, initially emphasizing the role of financial and non-financial returns, schooling, credit constraints, risk and the absence of or limitation in insurance markets to finance adoption of new technology (Feder et al., 1985). In recent years, this field has received an impetus from the work focusing on social learning (Bandiera and Rasul 2006; Conley and Udry 2010) and departures from standard models of rationality (e.g., Duflo et al., 2011).[11] In this paper we focus on the interaction between social networks and a specific form of agricultural innovations, namely activities or investments that facilitate adaptation to droughts, reducing household exposure to climate change-induced risks.

The theories on migration and adoption of innovations are linked through multiple channels, and the net effect of migration on adoption is unclear. Mendola (2012p. 157) writes "the real challenge of research on migration (…) is to answer how the 'development' impact of migration affects farm households' ability to achieve sustainable living standards and a better management of agricultural resources at origin." The NELM literature distinguishes between two ways through which migration may affect household decisions. On the one hand, migration typically implies an inflow of remittances relaxing capital or liquidity constraints and this may facilitate investments in adaptive measures (as well as smoothen consumption, and so on) or may enable households to engage in risky projects. On the other hand, migration may imply a loss of labour available for working on the farm (and possibly other resources used up in the migration process), which may limit the household's ability to adopt labour-intensive adaptive measures. Moreover, if income diversification (via spatial diversification) provides insurance for households, this attenuates incentives to (further) engage in self-protection via alternative mechanisms. Indeed, this could constitute a wasteful form of

[11] For a recent overview, see Foster and Rosenzweig (2010).

double-insurance. Morten (2013) demonstrates that migration and risk-sharing are jointly determined, and that engaging in one activity typically lowers the net returns from engaging in the other.

The main objective of this paper is to analyse whether migration and adaptive measures are substitutes or complements to farm household self-protection measures. We analyse this by using data from a survey on 500 rural households from Samburu County, Northern Kenya, and relating household's adaptive behaviour to a measure of household migration. There are obvious endogeneity concerns – adaptive measures may obviate the need to migrate, and omitted variables are likely to drive both adoption and migration. Among the solutions proposed to estimate credibly causal effects of migration are econometric approaches[12] as well as (quasi) experimental approaches (McKenzie 2015) leveraging exogenous variation in, for example, immigration policies. We use an instrumental variable approach to identify exogenous variation in migration. Our study tests the hypothesis that migration and adaptive measures are complements, consistent with the hypothesis that costs of innovation are a key factor impeding the adoption of adaptive measures. We find that migration facilitates adoption of high cost adaptive measures. Our results speak to policies for rural development through migration and financial sector development.

This paper is organized as follows. In Section 2 we introduce the study area and explain the measures reported by households to reduce exposure to drought. In Section 3 we summarize the data and identification strategy. Section 4 contains main results explaining the determinants of migration and the consequences of migration for the adoption of adaptive measures. Section 5 presents a series of robustness analyses in which we vary the dependent variable, and the instruments we use. Section 6 concludes on our findings.

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[12] Examples, as summarized by Bryan et al. (2011) include selection correction models (Barham and Boucher 1998), matching models (Gibson and McKenzie 2010), instrumental variable models (Macours and Vakis 2010), panel data models (Beegle et al., 2011) and natural policy experiments (Gibson et al., 2013).

3.1.1 Farming and migration among households in Samburu

The study was conducted in the Samburu County, located in the Rift Valley of Kenya. This county lies between 00º 36 and 02º 40 N and 36º 20 and 38º 10 E, covering an area of 21,000 km^2 with a population density of 11 inhabitants per km^2 (Government of Kenya 2009). The climate is hot and dry, with mean monthly temperatures ranging between 24ºC (July) and 33ºC (December). Rainfall is highly variable, ranging between 250 and 700 mm in the plains, and between 750 and 1250 mm in highland areas. The distribution of rainfall is bimodal, with long rains occurring between March and May, and short rains between July and August in the north and October and November in the East. The altitude ranges between 1,000 m on the plains to 2,752 m in the highlands.

Pastoralism is the main economic activity in Samburu, with about 80% of the households keeping livestock. The most important livestock species are goats, sheep, cattle and camels. Cash for buying maize – the main staple food – is derived from livestock sales, but wage labour (mainly from livestock herding) is a frequent supplement to household income. Some cropping also occurs. Rain-fed maize cropping is the most common practice in our study region. Samburu County is classified as the 5th poorest county in Kenya, with 77 percent of household considered poor (Kenya National Bureau of Statistics 2013).

We try to explain variation in the adoption of adaptive practices by households, such as switching to drought-tolerant animal and crop species, or switching to alternative management practices (clarified further below). We believe that a major reason for adopting these strategies is adaptation to climate change and self-protection against weather shocks (e.g., Barrett et al., 2001). Droughts in Samburu County very often lead to livestock mortality and smaller herd size. While some evidence shows that droughts and occasional flooding are the most severe risks facing pastoralists (Ouma et al., 2011), other studies identified additional risks for pastoral households, including disease, risks of market exclusion, deteriorating terms of trade (livestock products relative to grains), and policy shocks (McPeak and Barrett 2001; Mude et al., 2007; Ouma et al., 2008).

(Changing) exposure to such risks may also invite behavioural responses of the type we study.[13] The bottom line is that most pastoral households are likely to adopt innovative practices for a variety of reasons, of which enhanced exposure to weather shocks is only one (albeit presumably a prominent one). For our analysis, however, a better understanding of the underlying motives of pastoralists is of secondary importance. We are primarily interested in the reduced form effect of migration on adoption, and on the mechanism linking migration to adoption.

As in many semi-arid regions, migration in Samburu can take two forms: seasonal and (quasi) permanent migration. Seasonal migration captures off-farm employment for up to three months, typically involving farm work in the highlands of Kenya – where there is more cropping – or the movement of livestock. Occasionally it may also involve short-term contracts for government agencies or non-governmental organisations (NGO's). Our main analysis focuses on (quasi) permanent migration to urban areas, and looks at households of which at least one household member has moved out of Samburu County for a period of at least one year. In robustness analyses we probe the implications of alternative thresholds for migration. The results are qualitatively similar. According to our data, most migrants live and work in seven urban centres, namely Meru, Isiolo, Nanyuki, Nyeri, Karatina, Thika and Nakuru. The remainder moved to Nairobi (38%) and a small group to Mombasa city (2%). The great majority of these migrants work as watchmen (80%). Other migrants work as drivers (10%), private school teachers (7%), or are engaged in the cultural or tourism sector (3%).

3.2 Data and identification

We collected household data between February and May 2012, interviewing 500 households randomly sampled from five locations: Maralal (an urban centre), Londunokwe, Wamba, Swari, and Barsaloi. These five locations capture the variability in especially rainfall and market access in the area. The first three locations, roughly

[13] Indeed, there are even more reasons to engage in asset and activity diversification, including responding to diminishing factor productivity or the realization of complementarities between activities.

placed on a West-East gradient, capture differences in market integration and distance to an urban area, keeping rainfall roughly constant. The other two locations are further North, where the environment is drier (and are also further away from the urban centre).

From each of the five locations we sampled randomly three sub-locations, from which we selected randomly 50 villages. With the aid of the village chiefs we constructed a village list and we then randomly selected 10 households from each village. Hence, our sample size is 500 households. We collected information on a range of variables, including migration status at the household level and the adoption of adaptive measures listed in Table 3.2. In total, 139 of the households in our sample were 'migrant households'[14], where at least one household member moved to an area outside Samburu County for formal or informal employment for a period of more than one year. The remaining 361 households are called 'non-migrant households'.[15] Only nine households had more than one migrant member and only one out of 139 migrant households reported it had not received remittances during the last 12 months. About half of the households who regularly received remittances indicated the amounts involved, which ranged between 720 and 360,000 Kenya Shillings (or between USD 8 and USD 4010) per annum.

Explanatory variables are summarized in Table 3.1, where we distinguish between migrant and non-migrant households. Household size is measured as the number of household members sleeping in the same home, excluding the migrant worker, sharing production and consumption activities ("eating from the same pot"). Arable farm area was measured by pacing the boundaries of each of the households' fields. Access to credit was measured by a dummy variable, taking the value 1 if the household had used credit during the last 12 months. We also used dummies to indicate financial savings (taking a value of 1 if the household had saved any money during the

[14] Migrant households in our sample come from 43 villages (7 villages had no migrants). Aggregating seasonal and permanent migrants, we find that migrant families are spread across all five locations (9, 12, 18, 38 and 62 migrant households). The location with most migrant families (block 5) is the block nearest to Maralal.
[15] Some members of such non-migrant households may actually be engaged in seasonal migration. This introduces some measurement error in our key explanatory variable, which implies our estimation results may be affected by attenuation bias (biasing our estimation results towards zero).

last 12 months), and when the household had participated in NGO activities during the same period (e.g. cash or food for work programs).

Table 3.1 also introduces our two excluded instruments. In our main analyses we use one instrument, namely the number of family members (not household members) working outside Samburu County for a period of more than 10 years in formal employment. We believe such family members are an important source of information and assistance when households decide to engage in migration themselves. As a robustness analysis, and to probe the exclusion restriction via Hansen's J test, we also estimate models using a second instrument. We consider the local density of kinship networks, or the number of (extended) family members in the village that the household can access to facilitate migration – for example by jointly paying for transport costs. Since the exclusion restriction is possibly violated for this instrument (kinship might also affect adoption of adaptive measures via alternative channels than facilitating migration), we believe our models based on the first instrument represent our core specification. Our kinship variable is defined as the reported number of relatives of the household living in the same village, but not staying in the same household (e.g., cousins, nephew and nieces).

Table 3.1: Key variables for migrant and non-migrant households

Variables	Migrant				Non-migrant			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
Household characteristics								
Gender of the household head***	0.85	0.36	0	1	0.66	0.48	0	1
Age of the household head**	47.14	12.47	23	84	50.75	14.16	21	90
Cultivable farm size (in hectares)**	1.02	2.13	0	15	0.47	1.69	0	16
Household size*	6.61	2.62	2	19	6.99	2.82	2	19
Financial saving	0.06	0.23	0	1	0.07	0.25	0	1
Access to credit	0.15	0.36	0	1	0.13	0.34	0	1
Years in education***	3.88	5.53	0	16	1.29	3.44	0	16
Activities of NGOs***	0.48	0.50	0	1	0.30	0.45	0	1
Market access variables								
Distance to the motorable road (km)***	1.03	1.38	0.003	9	1.91	3.30	0	24
Distance to the tarmac road (km)***	114.35	22.03	50	155	107.39	32.20	40	190
Distance to the local market (km)***	7.40	8.22	0.03	45	11.18	12.33	0.01	70
Distance to the livestock market (km)	11.68	12.27	8	70	12.53	11.73	0.01	70
Instrumental variables								
Density of local kinship network***	6.13	3.89	1	16	2.37	2.47	0	13
Number of family members employed outside Samburu for more than 10 years	2.14	0.89	1	5	1.31	0.82	0	4
Adaptation strategies								
Total adaptation strategies***	2.65	0.67	1	4	1.71	0.76	0	4
N	139				361			

***, **and * shows significance at P<0.01, P<0.05 and P<0.1 level respectively; NGOs = non-governmental organizations; N = number of observations; km = kilometres. For the Gender of household head "1" means Male and "0" Female. The observed minimum value one, for adaptation strategies index for migrant households, means that all migrant households had adopted at least one adaptive strategy.

Table 3.1 also contains our dependent variable, the total number of adaptive practices adopted by the household. This variable is introduced in more detail in Table 3.2. We included the use of introduced varieties and fast-maturing variety of maize and changing livestock types, and use of feed conservation measures as adaptation strategies that contribute to reducing risk and exposure to weather shocks. Strategic mobility was excluded from computation of adaptive practices adopted by households. This is because although the conceptual difference between strategic mobility as a coping strategy and mobility for livestock production is clear among pastoralists, it often becomes confused (or lost) during translation. We only consider full and sustained adoption of practices, and collected data via an open-ended question (but respondents were provided with a checklist of potential practices). We distinguish between practices adopted by the household for the last 12 months (resp. 5 years). We implicitly assume all households are equally likely to correctly report the number of practices adopted, or that any propensity to under- or over-report does not correlate with migration status of the household. We believe this is plausible. Our main dependent variable is an index, summing the adaptation strategies adopted by the household. Less than 3% of the households indicated they did not adopt any of the practices (scoring “0” on the adoption index), attenuating concerns that the usual assumptions with respect to distribution are violated.

Table 3.2: Adaptation strategies in response to climate change during the last 5 years

Adaptation strategies	Number of households	Percentage (%)
(1) Changed livestock type		
Increased camel and reduced cattle	20	4
Increased herd of goats and reduced cattle	300	60
(2) Introduced feed conservation measures		
Cut and carry of pastures introduced	258	51.6
Fencing patches with grass for use during dry period introduced	57	11.4
Growing of fodder/improved pastures (Napier grass) introduced	9	1.8
(3) Introduced varieties of cereal crop		
Drought tolerant (millet and sorghum)	384	76.8
(4) Introduced fast maturing variety		
Fast maturing (short season variety of maize) variety introduced	205	41

NB: the percentage need not to add up to 100% because households may adopt more than one strategy.

From Table 3.1 it is clear that the two sub-samples are not balanced. In general, migrant households are headed by male who are relatively young and more educated when compared with non-migrant households. These households are also smaller reflecting that one household member has moved out. In addition, they are more likely to participate in NGO activities. On average, migrant households have adopted more adaptive strategies than non-migrant households. However, in light of the many observable and testable differences between migrant and non-migrant households, it is not obvious whether we can attribute these differences in adaptation to differences in migration status.

3.2.1 Adopted adaptation strategies

This section elaborates on the adopted adaptation strategies summarized in Table 3.2. One key strategy used by pastoralists to deal with the vagaries of climate is to change the mix of livestock species and/or breeds (Blench and Marriage 1999; Sperling 1987; Thornton 2010). We also asked respondents how changes in livestock types were achieved. Farmers reported these changes were achieved slowly over time, through selling few cattle and using the realized income (plus income from other sources) to buy camels or goats. Camels are more expensive than cattle. Three reasons were most often cited for switching to camels and goats; (i) the greater ability to trek long distances without water, (ii) the ability to survive on less pasture (as they have varied diets which includes shrubs and trees) and (iii) more uniform milk production (Guliye 2010; Kagunyu and Wanjohi 2014). Changing of livestock species is considered a financially costly adaptation strategy, because pastoralists in our study areas are reluctant to sell their cattle. Cattle herds are structured to provide supplies of milk so, unless forced by economic and social stress, animals are rarely sold and cash constraints place clear bounds on the ability of households to change the composition of their herds.

The second category of adaptation strategies involves introducing feed conservation measures. For example, '*cut and carry of pasture*' refers to the cutting of dry grass in the hilly areas (or close to the forest), especially in the period following rains. Grass is transported and conserved close to the household. During times of pasture scarcity, this grass is used to feed animals that are weak and unable to trek distances in search of pastures. Movement of feed resources for livestock are an effective adaptation strategy utilised by many households in dry areas (Little et al., 2001). These feed conservation measures are not costly activities, at least not financially, because they don't require investment in terms of cash. Of course they can be economically costly, in the sense that they draw on (potentially scarce) household labour. But in the absence of well-functioning labour markets, migration and the associated flow of remittances are unlikely to relax such non-financial constraints.

'*Introduced variety of cereal crop*' refers to the use of purchased improved varieties of millet and sorghum, rather than the locally harvested varieties. '*Introduced fast maturing varieties*' describes the use of purchased maize seeds, and specifically of fast maturing varieties like SC403, Katumani and Pioneer. Although local seeds systems can be resilient to climate stresses (Sperling et al., 2004), improving access to superior varieties is typically considered helpful for coping with climatic change (Barrett et al., 2001). Introduction of these new crops varieties is considered financially costly as it involves the outlay of cash.

For all adaptive practices included in our study, we only measure whether the household has adopted the new practice, or not, and treat adoption of specific adaptive measures as a binary variable. We did not collect data on the "intensity of adoption" or the degree to which, say, modern millet and sorghum varieties have replaced traditional varieties. This implies we should be careful when interpreting the results – adoption need not imply full abandonment of traditional practices, and protection against weather shocks may be less complete than expected.

3.2.2 Empirical strategy

Since we are interested in examining the effect of migration on the adoption of adaptive measures, we first estimate ordinary least square (OLS) and Tobit models (as the dependent variable is censored at zero):

$$Y_{ij} = \beta_j + \beta_1 X_{ij} + \beta_2 M_{ij} + \varepsilon_{ij}, \quad (3.1)$$

where Y_{ij} represents the innovation (i.e., adoption of adaptation measures) index for household i, in village j, X_{ij} is a vector of household characteristics, M_{ij} is a dummy taking the value of 1 if the i^{th} household is a migration household (and 0 otherwise), β_j are village fixed effects, and ε_{ij} is the random error variable of the equation. In all models we cluster standard errors at the village level. If migration facilitates the adoption of adaptive measures, then $\beta_2 > 0$. If, in contrast, engaging in migration discourages self-protection, then we would expect $\beta_2 < 0$.

Migration status is an endogenous variable in the adoption model (Eq. 3.1). The idea of migration and adaptive measure being substitutes may work both ways (why engage in migration if you can self-protect on the farm?), and omitted variables such as entrepreneurship and curiosity may drive both adoption and migration. To establish causality, we need to identify exogenous variation in our migration variable, and estimate a two-stage model. We use a 2SLS model that explains both the determinants of migration and the causal impact of migration on adoption of adaptive strategies (Angrist and Krueger 2001). The challenge is to identify suitable instrumental variables Z_i – variables that affect the migration decision of households, but do not affect the adoption decision via any alternative channel (that are not correlated with the error term of the adoption model):

$$Y_{ij} = \beta_j + \beta_1 X_{ij} + \beta_2 M^*_{ij} + \varepsilon_{ij}, \text{ and} \quad (3.2)$$

$$M_{ij} = \beta_j + \beta_1 X_{ij} + \beta_2 Z_{ij} + u_{ij}, \quad (3.3)$$

Where M* documents predicted migration. As our main instrumental variable we use the number of family members who have been working outside Samburu County for more than 10 years in formal employment. The assumption is that households with such family members are more likely to migrate because they have access to superior information about where to go, where to stay, or where to find a job (Massey et al., 1993; Massey and Espinosa 1997; Munshi 2003). As a second excluded instrument, in additional regressions, we use the number of kinship members in the village. The reason is that the density of kinship networks is an important factor enabling households to accumulate the resources needed to finance the transaction costs associated with migration.

To probe the strength of our instruments we estimate a probit model explaining migration at the household level, and check whether the instruments correlate significantly with migration. We also estimate OLS and Tobit models explaining variation in our adoption index and check that the instrument does not enter significantly (when controlling for migration). Finally, we estimate 2SLS models and inspect the test statistics. We realize that the over-identification assumption cannot be properly tested so that reservations with respect to the validity of our instrument are likely to remain. Our evidence can only suggest causal inference. Follow up work could include exogenous variation in migration, for example by subsidizing transport to urban areas for a random subsample of the population – as suggested by Bryan et al. (2011).

To probe the welfare effects of migration, we also consider how migration affects food consumption. Our reduced form approach overcomes problems associated with measuring the full costs (or benefits) of adopting a technology. We collected (recall) data on food consumption by the household for a period of one week for frequently consumed items, and two or four weeks for less-frequently purchased items, and computed a caloric intake[16] – based on World Health Organization standards. (FAO/WHO/UNU 2007) – per adult equivalent per household, C_{ij}. Household size was converted into an adult equivalent scale following Martin (1985).[17] We then estimate:

$$C_{ij} = \beta_j + \beta_1 M_{ij} + \beta_2 X_{ij} + \varepsilon_{ij} \tag{3.4}$$

In addition, we perform a number of robustness analyses, including analyses in which we vary the length of the migration interval (from 1 to 5 years), focus on seasonal migration, or use remittances as an explanatory variable. We also explain variation in different types of adaptive practices. Specifically, we distinguish between financially costly and not-so costly practices, as discussed above. This enables us to ask whether any (reduced-form) association between migration and enhanced adoption is most likely due to flows of remittances or information. If the money sent back by migrants matters most, we would expect that migration is correlated with increased adoption of costly practices (but not necessarily of not-so costly practices, as cash does not relax a binding constraint in this case). Conversely, when flows of information from the outside world matter most, then we have no a-priori reason to expect differential results for costly and not-so costly practices.

3.3 Main results

Table 3.3 contains the estimation results of a series of "naïve" OLS and Tobit models, relating our adoption index to the migration dummy (and covariates). The most parsimonious OLS model in column (1) indicates a positive and significant association between migration and adoption of adaptation strategies -- on average, migrant households adopt 0.72 more adaptive measures. In column (2) we control for distance to infrastructure variables. The coefficient of the migration variable is almost unaffected

[16] The per capita food consumption is the sum of total energy consumed in the household divided by the total family size in adult equivalent.

[17] The adult equivalent weighing scheme used in this study assigns a value of one to individual of both sexes older than 15, a value of 0.6 to individuals 6-14 years old, a value of 0.3 to children ages 2-5, a value of 0.1 for children under 2.

(0.67), and remains significant at the 1% level. When controlling for additional household variables (columns 3 and 4) the migration coefficient shrinks but remains significant at the 1% level.

According to the most elaborate OLS model (column 3), other variables that are positively associated with the adoption of adaptive measures are gender (male-headed households are more likely to adopt, perhaps reflecting easier access to complementary inputs including household labour), plot size (capturing a wealth effect, perhaps, but also reflecting economies of scale associated with certain investments), and access to credit (arguably providing the household with additional resources to facilitate self-protection or to engage in adoption of costly innovations).

Note that the number of family members formally employed outside Samburu does not enter significantly in the regression models, when we control for migration. Qualitatively similar results are in column (4) based on the tobit model that takes the censored nature of our adoption data into account. In columns (5-6) we focus on sub-sets of adaptive strategies (financially costly versus not-so costly innovations) and find qualitatively similar results for financially costly innovations.[18] Costly innovations correspond to change in livestock type, introduction of new varieties of cereal crops and introduction of fast maturing variety of seeds in Table 3.2. In contrast, less costly innovations correspond with introduction of feed conservation measures. We find that migration is only correlated with adoption of high cost measures, for which cash is required. The coefficient for the migration variable is much smaller and enters insignificantly in the model explaining variation in the adoption of low-cost adaptive measures.

[18] We have also explored whether engaging in farming, as a coping strategy, is associated with migration. When estimating a probit model that explains the adoption of cropping, we do not obtain a significant association between farming and migration (the same is true when estimating an iv-probit model).

Table 3.3: Migration and the adoption of adaptation strategies

	Adaptation Strategy (OLS) (1)	Adaptation Strategy (OLS) (2)	Adaptation Strategy (OLS) (3)	Adaptation Strategy (Tobit) (4)	Costly Adaptation Strategy (OLS)-(5)	Less costly adaptation Strategy (OLS)-(6)
Migrant	0.717*** [0.122]	0.670*** [0.119]	0.495*** [0.128]	0.494*** [0.118]	0.100*** [0.039]	0.103 [0.057]
Gender of the household head			0.114** [0.045]	0.114*** [0.042]	-0.003 [0.043]	-0.049 [0.063]
Age of the household head			-0.003** [0.002]	-0.003** [0.001]	0.001 [0.001]	8.0e-05 [0.001]
Household size			0.047 [0.036]	0.046 [0.033]	0.026* [0.012]	-0.006 [0.008]
Farm size (ha)			0.047 [0.036]	0.046 [0.033]	0.026** [0.012]	0.006 [0.009]
Farm size (ha) squared			-0.129* [0.066]	-0.129** [0.061]	-0.077** [0.034]	-0.011 [0.020]
Total value of livestock			5.84e-07*** [1.98e-07]	5.85e-07 *** [1.83e-07]	2.14e-07** [9.56e-08]	4.75e-07*** [1.40e-07]
Total value of livestock squared			-6.12e-12** [2.45e-12]	-6.12e-12*** [2.27e-12]	-1.84e-12 [1.27e-12]	-4.86e-12*** [1.56e-12]
Years in education			-0.011 [0.009]	-0.011 [0.008]	0.002 [0.002]	0.001 [0.005]
Financial saving			0.033 [0.013]	0.034 [0.012]	0.060 [0.066]	0.045 [0.072]
Access to credit			0.530*** [0.120]	0.531*** [0.111]	0.319** [0.150]	0.073 [0.066]
Activities of NGO			0.061 [0.090]	0.061 [0.083]	0.005 [0.026]	0.043 [0.066]
Risk perception			-0.082 [0.069]	-0.082 [0.064]	-0.022 [0.023]	-0.009 [0.049]
Own a mobile			0.097 [0.077]	0.097 [0.071]	0.032 [0.034]	-0.041 [0.046]
Trust (CSC)			0.002 [0.088]	0.001 [0.082]	-0.010 [0.027]	-0.011 [0.061]
Structural social capital (SSC)			-0.114 [0.131]	-0.114 [0.121]	0.007 [0.055]	0.175** [0.076]
Social capital (CSC +SSC)			-0.008 [0.055]	-0.008 [0.052]	-0.047 [0.034]	-0.018 [0.028]
Distance to Motorable road (km)		0.009 [0.013]	0.008 [0.013]	0.008 [0.012]	-0.002 [0.006]	-0.003 [0.007]
Distance to tarmac road (km)		0.004 [0.005]	-0.001 [0.005]	-0.001 [0.004]	-0.001 [0.002]	0.001 [0.004]
Distance to local market (km)		0.004 [0.005]	-0.001 [0.005]	-0.001 [0.004]	-0.001 [0.001]	0.001 [0.002]
Distance to livestock market (km)		-0.004* [0.002]	0.002 [0.003]	0.002 [0.002]	0.001 [0.001]	-0.002 [0.001]

Table 3.3: Migration and the adoption of adaptation strategies (cont'd)

	Adaptation Strategy (OLS) (1)	Adaptation Strategy (OLS) (2)	Adaptation Strategy (OLS) (3)	Adaptation Strategy (Tobit) (4)	Costly Adaptation Strategy (OLS)- (5)	Less costly adaptation Strategy (OLS)-(6)
Households working outside Samburu for more than 10 years	0.0707 [0.042]	0.073 [0.063]	0.063 [0.044]	0.063 [0.042]	-0.001 [0.031]	-0.011 [0.030]]
Village dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant/Sigma				1.963*** [0.307]		
Constant	2.028*** [0.012]	1.678*** [0.259]	1.963*** [0.332]	0.557*** [0.019]	1.203 [0.128]	0.644*** [0.230]
R Squared	0.50	0.50	0.56		0.45	0.25
Log likelihood				-227.07		
N	500	500	500	500	500	500

Robust standard errors clustered by village level are reported in parentheses, *p<0.10, **p<0.05, ***p<0.01. Columns 1, 2 and 3 represent stepwise regression results to enable us see the effect of migration on adoption of adaptation strategies (column 1), the effect of migration on adoption of adaptation strategies when controlling for spatial variables (column 2) and the effect of migration on adoption of adaptation strategies when controlling for spatial variables, household characteristics and social capital.

Because of simultaneity bias and omitted variables, we cannot interpret the associations in Table 3.3 as causal effects. We estimate a Probit model explaining migrant household status to identify whether our instruments are correlated with migration (Table 3.4). The results support our assumption that the presence of family members working outside Samburu and the density of local kinship networks are determinants of household migration decisions. Other variables correlated with migration corroborate results from the literature. Households with high social capital and those with mobile phones are more likely to have a migrant member.

Table 3.4: The correlates of migration (Probit analysis)

	Migration	Margins
Gender of the household head	-0.063 [0.231]	-0.013 [0.049
Age of the household head	-0.001 [0.006]	-0.0003 [0.001]
Household size	-0.040 [0.034]	-0.001 [0.007]
Farm size (ha)	0.164** [0.076]	0.035** [0.016]
Farm size (ha) squared	-0.189 [0.134]	-0.040 [0.029]
Total value of livestock	- 2.23e-06 *** [7.94e-06]	-4.82e-07** [1.65e-07]
Total value of livestock squared	2.80e-11 [1.99e-11]	6.05-12 [4.32e-12]
Years in education	0.056** [0.029]	0.012** [0.006]
Financial saving	-0.544 [0.335]	-0.117 [0.070]
Access to credit	1.355*** [0.327]	0.293*** [0.062]
Activities of NGO	-0.309 [0.234]	-0.067 [0.051]
Risk perception	0.362* [0.212]	0.078** [0.044]
Own a mobile	0.356* [0.215]	0.077* [0.046]
Trust (CSC)	0.212 [0.272]	0.046 [0.058]
Structural social capital (SSC)	0.482 [0.417]	0.104 [0.090]
Social capital (CSC +SSC)	0.332** [0.150]	0.071** [0.032]
Kinship	-0.012 [0.023]	-0.002 [0.004]
Distance to Motorable road (km)	-0.096* [0.042]	-0.020* [0.008]
Distance to tarmac road (km)	-0.011 [0.012]	-0.002 [0.002]
Distance to local market (km)	-0.007 [0.007]	-0.001 [0.001]

Table 3.4: The correlates of migration (Probit analysis) (cont'd)

	Migration	Margins
Distance to livestock market (km)	0.009 [0.007]	0.002 [0.001]
Family members working outside Samburu for more than 10 years	0.439*** [0.110]	0.094*** [0.022]
Density of local kinship network	0.198*** [0.034]	0.042*** [0.006]
Village dummies	Yes	Yes
Constant	-1.637** [1.644]	
Log likelihood	-183.31	
LR (chi2) *P value*	126.10 0.0000	
Join sign. Plot size[a]: $\chi^2(2)$ Probability> $\chi^2(2)$	5.87 0.05	
Join sign. Liv Value: $\chi^2(2)$ Probability> $\chi^2(2)$	5.39 0.0202	
N	500	500

Robust standard errors clustered by village are reported in parentheses, **p*<0.10, ***p*<0.05, ****p*<0.01.[a] Joint significance of plot size per household and plot size owned squared
The results in column 2 (the margins) display the marginal effects of the estimates of the responses for each of the specified value of covariates.

Table 3.5 summarizes our 2SLS results. We report only coefficients of interest, however all models have been estimated using a full vector of household and village controls. The first two columns present the results of an analysis of the full dataset. First consider column (1b), which contains the first stage of the model -- explaining migration status of households now using a linear model, instead of the non-linear model presented in Table 3.4. The excluded instrument enters significantly and the partial F-value associated with the instrument is 26.16. We therefore start from the premise that our instrument is strong.

Table 3.5: The impact of migration on the adoption of adaptation strategies (2SLS results)

	Adaptation Strategy (pooled) (1a)	Migrant (pooled) (1b)	Adaptation Strategy (costly) (2a)	Migrant (costly) (2b)	Adaptation Strategy (costless) (3a)	Migrant (costless) (3b)
Migrant	1.011*** [0.269]		0.311*** [0.102		0.096 [0.205	
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Village control dummies	Yes	Yes	Yes	Yes	Yes	Yes
Family members working outside Samburu for more than 10 years		0.123** [0.019]		0.122*** [0.019]		0.112*** [0.019]
Constant	2.128*** [0.383]	0.062 [0.198]	1.139*** [0.147	0.051 [0.201]	0.641 [0.228	0.052** [0.200]
First stage (F) p-value		*(1, 49) 26.16 0.000*		*(1, 49) 24.99 0.000*		*(1.49) 24.99 0.000*
R^2	0.54	0.52	0.47	0.53	0.22	0.53
N	500	500	500	500	500	500

Robust standard errors clustered by village are reported in parentheses, *p<0.10, **p<0.05, ***p<0.01.

Results of the second stage are reported in column (1a). Predicted migration status enters significantly at the 1% level, and again with a positive sign. As before, the coefficient is large (a Wald test confirms that the coefficient of the 2SLS model is indistinguishable from the OLS coefficient presented in Table 3.3). Assuming our instrument identifies exogenous variation in migration status, our interpretation of column (1a and b) is that migration is a key determinant of adoption.

To further probe this result and to learn about the mechanism linking migration to adaptation, we next distinguish between financially costly and not-so costly practices. We again report first and second stage results. Evidence in columns (2) and (3) supports the assumption that migration matters via remittances. While the uptake of costly activities is encouraged by migration, the same is not true for not-so costly practices. This suggests migration enables households in areas of origin to relax a binding financial constraint. There is ample anecdotal evidence of capital market imperfections in the study region, primarily because of high transaction costs (e.g., Little et al., 2001).[19]

3.4 Robustness analysis

To probe the robustness of our results, we estimate a series of related models. Results are summarized in Table 3.6, reporting only the main coefficients but all models were estimated with a full set of controls. We estimate these models with two excluded instruments so that we can report whether the exclusion restriction is violated, but similar results are obtained when we estimate these models using only the preferred instrument (or the number of family members who have been working outside Samburu for more than 10 years).

[19] In an auxiliary analysis – not reported – we look at the relation between credit markets and the effect of migration. If remittances help to relax a binding cash constraint, then remittances should be especially important, and have the largest impact, for credit-constrained households. If we split the sample in two subsamples of villages, based on the availability of credit for our respondents, we indeed find that migration explains adoption only in villages without access to credit. However, access to credit is presumably an endogenous variable in these models, and therefore we regard the regression results as illustrative only (details available on request).

First, we provide additional support for the hypothesis that remittances are a channel linking migration to adoption. We replace the binary migration variable in (2) by a continuous remittances variable (defined as *ln* (remittances+1)). Many migrant households were unwilling (or unable) to provide us with an estimate of the remittances, and these enter as missing observations. Second and first stage results are reported in columns (1a, b) of Table 3.6, respectively. Supporting our earlier results, predicted remittances enter significantly at the 1% level, and the coefficient again has a positive sign.

Table 3.6: Two stage least squares (2SLS) estimate of the impact of remittance and migration on adoption of adaptation strategies to climate change

	Whole sample (2SLS)		Whole sample (2SLS)		Whole sample (IV-probit model)		Seasonal migration (2SLS)		Whole sample (5 years) (2SLS)	Whole sample	Whole sample
	Adaptation strategy (1a)	Remittances (1b)	Energy consumed (2a)	Migrant (2b)	Any innovation adopted (3a)	Migrant (3b)	Adaptation strategy (4a)	Migrant (4b)	Adaptation measures adopted (5)	Non-pastoral innovations (6)	Pastoral innovation (7)
Remittances	0.083*** [0.033]										
Migrant			23.85*** [4.740]		1.586*** [0.403]		0.870*** [0.163]		1.000*** [0.060]	0.441*** [0.186]	0.299*** [0.076]
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Family members working outside Samburu for more than 10 years		0.436*** [0.177]		0.800*** [0.015]		0.117*** [0.005]		0.080*** [0.016]			
Density of local kinship network		0.133*** [0.026]		0.027*** [0.003]		0.008*** [0.005]		0.027*** [0.002]			
Village dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.496*** [0.369]	0.047*** [1.556]	15.161** [7.891]	0.173 [0.130]	1.111 [0.857]	-0.309*** [0.227]	0.294 [0.242]	0.177 [0.147]	0.288 [0.220]	1.632*** [0.411]	0.574** [0.463]
Hansen's J Chi2 p-value		2.910 {0.267]		1.263 [0.260]				0.429 [0.512]			
First stage F p-value		17.13 0.000		39.63 0.000				69.44 0.000			
/athrho						-1.092 [0.378]					
/lsigma						-0.887 [0.041]					
Log likelihood					-203.51						
R2	0.50	0.43	0.55	0.40			0.14	0.55	0.39	0.74	0.43
N	500	500	500	500	500	500	466	466	466	500	500

Robust standard errors clustered by village are reported in parentheses, *p<0.10, **p<0.05, ***p<0.01.

Next, we report the results of a series of models where we vary the dependent variable. First, since we are also interested in welfare effects of migration (and adoption), we regress our measure of per capita food consumption on migration status (and controls). Second and first stage results are presented in columns (2a, b). These results, given the nature of the data (cross-sectional and not longitudinal) suggest that migrant households consume more calories than non-migrant households, all else being equal. Migration affects consumption for both households with high cost and low cost adaptations (results not shown), so that results for consumption are different than the results for investment in new practices. As a follow-up analysis we examined the channels via which migration might affect consumption. Specifically, we have estimated a system where our instrumental variable identifies exogenous variation in migration. Next, we regress adoption on predicted migration. Finally, we regress consumption on predicted migration and predicted adoption (and controls). We find that both variables enter significantly – see Appendix Table A3.1. These findings suggest that migration affects consumption via two channels: directly and indirectly (via adoption of costly innovations).

In columns (3a, b) we replace the number of adaptive strategies adopted by a simple binary variable capturing whether *any* innovation was adopted. The reason is that there may be economies of scale in adoption of multiple innovations (via learning, cost-saving complementarities etc.) so that the relation between migration and adoption could be non-linear. Reflecting the binary nature of the dependent variable, we now estimate an IV probit model (and report marginal effects). The associated first stage of the model is contained in column (3b). As is evident, there is, again, a strong relationship between (predicted) migration and any adopted adaptation strategies (column 3a).

In column (4a, b) we focus on seasonal migration, and omit permanent migrants from the sample. We again use our standard dependent variable. First stage results are reported in column (4b), as are key test statistics. The second stage results in column (4a) are comparable to the earlier results that included permanent migrants – the quantitative effect of seasonal migration on the adoption of innovations is nearly identical to the effect of permanent migration. Perhaps this implies seasonal migrants send back a larger share of their income during the shorter time they are away.

We estimated three more 2SLS models, of which we only report second stage results in Table 3.6 (in columns 5, 6 and 7). Appendix Table A3.2 reports the matching first stage results. We examine what happens when we change the one-year threshold to define permanent migration, and instead focus on the subsample of households of which a member has migrated out at least five years ago. For this analysis we also adjust the dependent variable to indicate all adaptive measures adopted within the past five years (and still being used today). Results are reported in column (5), and are qualitatively similar as results for the one-year threshold. Next, we split the set of adaptive measures into pastoral and non-pastoral innovations, and consider the impact on the sub-categories separately. We find that migration affects both types, and the coefficients are statistically indistinguishable (see columns 6 and 7).

3.5 Conclusions

Climate change may threaten the livelihoods of herders and farmers in Africa's arid and semi-arid lands. While various innovations are available that reduce household exposure to weather risk, the uptake of such innovations is still low. Enhancing our understanding of factors encouraging or impeding adoption has emerged as a research priority.

Recent empirical work suggests that family ties may affect adoption decisions. In addition to learning effects, family membership may affect adoption through risk-sharing. For example, focusing on farmers in Ethiopia, Di Falco and Bulte (2013) find an adverse effect of kinship on adoption. More extensive kinship networks are characterised by relatively low investment levels. The reason why family ties may discourage adoption is sharing norms within the network that invite free riding, causing under-investment in self-protection.[20] The evidence in this paper points to another,

[20] For related theory, refer to Alger and Weibull (2010). For other empirical evidence focusing on free riding and compulsory sharing within kinship networks, refer to Baland et al. (2011).

complementary perspective. We provide tentative evidence that remittances from migrant household members may relax local capital constraints, and that remittances are an important mechanism linking migration to adoption, enabling the uptake of new technologies that involve change in activities or high investment costs. Specifically, migrant households adopt more adaptive measures (promoting self-protection), and we document some support for the hypothesis that this is especially the case for high cost adaptations such as the purchasing of drought tolerant livestock.

These findings suggest that migration and local innovation are complementary, rather than substitutive mechanisms of self-protection, at least for pastoral households in the semi-arid lands of Northern Kenya. Households who have at least one member who has migrated are able to overcome barriers to employ high cost agricultural innovations – including through using remittances received – thus enhancing their self-protection against climate change related shocks. The link between capital and labour markets may be relevant from an academic as well as a policy perspective. Insofar as remittances substitute for lack of access to capital, interventions that seek to promote financial development (i.e., provision of cash) in rural areas may affect the demand for insurance via income-pooling (i.e., via migration), and will thereby affect the flows of labour across the African continent (and perhaps beyond). Similarly, by contributing to the availability of cash in areas of origin and promoting local investments in various forms of capital, remittances may affect the dynamics of local capital markets. Probing these complex interrelations between capital and labour, mediated via family membership and other local institutions, is an urgent priority for future research.

Appendix: Chapter 3

Appendix 3.1: Heterogeneity

To control for heterogeneity, a standard open-ended interview was conducted by the researcher by first preparing a set of open ended question which were carefully worded and arranged for the purpose of minimizing variation in the questions posed to the interviewee. The survey had three components. The first component contained question that helped to clarify whether households understand what climate change meant. The second component of the survey dealt with understanding what measures the households has put in place to cope or adapt to climate change, while the third component included questions pertaining to the adaptation measure that the household had put in place five years ago and are still practicing to date. To ensure that the interviewer understood the questions well, the questionnaire was pre-tested among twenty households by five different interviewers in two different locations, after which the responses were compared and discussed. This exercise facilitated further polishing of the research question to remove any ambiguity and to enable the interviewee to understand the question well and easily.

Table A3.1: The direct and indirect effects of migration on consumption

	Energy consumed	Adaptation strategies	Migrant
Migrant	46.477*** [8.306]	0.961*** [0.078]	
Adaptation strategies	21.064*** [8.41]		
Household controls	Yes	Yes	Yes
Village control	Yes	Yes	Yes
Households working outside Samburu for than 10 years			0.0405*** [0.011]
Kinship			0.0603*** [0.001]
Constant	51.377*** [18.433]	2.000*** [0.241]	0.059 [0.073]
N	500	500	500

Table A3.2: First stage results for 2SLS models (Table 3.6)

	Migrant (1b)	Migrant (2b)	Migrant (3b)	Migrant (4b)	Migrant (5b)	Migrant (6b)
Gender of the household head	-0101 [0.037]	-0.101 [0.037]	-0.101 [0.037]	-0.113 [0.039]	-0.025 [0.039]	0.025 [0.039]
Age of the household head	-0.001 [0.003]	-0.001 [0.003]	-0.001 [0.003]	-0.003 [0.003]	-0.003 [0.003]	-0.003 [0.003]
Household size	-0.009 [0.006]	-0.009 [0.006]	-0.009 [0.006]	-0.007 [0.006]	-0.007 [0.006]	-0.007 [0.006]
Farm size (ha)	-0.009 [0.017]	-0.009 [0.017]	0.009 [0.017]	0.007 [0.018]	0.012 [0.018]	0.012 [0.018]
Farm size (ha) squared	-0.006 [0.028]	-0.006 [0.028]	-0.006 [0.028]	-0.043 [0.035]	-0.046 [0.036]	-0.046 [0.036]
Total value of livestock	-1.73e-07** [9.78e-08]	-1.17e-07 ** [1.10e-08]	-5.08e-07** [6.52e-08]	-2.08e-07** [4.72e-08]	-2.06e-07** [8.63e-08]	-2.06e-07** [8.63e-08]
Total value of livestock squared	-2.84e-12 [1.67e-12]	-1.67e-10 [2.19e-10]	-3.21e-11 [4.89e-11]	-3.21e-11 [4.89e-11]	-3.21e-11 [4.89e-11]	-3.21e-11 [4.89e-11]
Years in education	0.015*** [0.004]	0.015*** [0.004]	0.015*** [0.004]	0.013*** [0.004]	0.013*** [0.004]	0.013*** [0.004]
Financial saving	-0.070 [0.065]	-0.077 [0.076]	-0.077 [0.076]	-0.054 [0.071]	-0.046 [0.071]	-0.046 [0.071]
Access to credit	0.472*** [0.046]	0.467*** [0.053]	0.467*** [0.053]	0.476*** [0.054]	0.481*** [0.054]	0.481*** [0.053]
Activities of NGO	0.011 [0.062]	0.011 [0.062]	0.011 [0.062]	0.018 [0.065]	0.019 [0.065]	0.019 [0.065]
Risk perception	0.057 [0.035]	0.056 [0.034]	0.056 [0.034]	0.049 [0.041]	0.050 [0.041]	0.049 [0.041]
Own a mobile	0.043 [0.039]	0.043 [0.040]	0.043 [0.040]	0.093 [0.035]	0.050 [0.041]	0.093 [0.035]
Trust (CSC)	0.031 [0.040]	0.033 [0.037]	0.033 [0.037]	0.037 [0.037]	0.035 [0.036]	0.035 [0.036]
Structural social capital (SSC)	0.005 [0.074]	0.0002 [0.082]	0.0002 [0.082]	0.0002 [0.082]	0.0716 [0.082]	0.0716 [0.082]
Social capital (CSC +SSC)	-0.043* [0.026]	-0.046* [0.027]	-0.046* [0.027]	-0.050* [0.028]	-0.047* [0.027]	-0.047* [0.027]
Distance to Motorable road (km)	0.003 [0.006]	0.001 [0.004]	0.001 [0.004]	0.001 [0.004]	0.001 [0.004]	0.001 [0.004]
Distance to tarmac road (km)	-0.001 [0.002]	-0.001 [0.001]	-0.001 [0.001]	-0.001 [0.004]	-0.0005 [0.001]	-0.001 [0.001]

Table A3.2: First stage results for 2SLS models (Table 3.6) (cont'd)

	Migrant (1b)	Migrant (2b)	Migrant (3b)	Migrant (4b)	Migrant (5b)	Migrant (6b)
Distance to local market (km)	-0.002 [0.001]	-0.002 [0.001]	-0.002 [0.001]	-0.002 [0.001]	-0.001 [0.001]	-0.002 [0.001]
Distance to livestock market (km)	0.001 [0.001]	0.001 [0.002]	0.001 [0.002]	0.001 [0.002]	0.001 [0.002]	0.001 [0.002]
Village dummies	Yes	Yes	Yes	Yes	Yes	Yes
Households working outside Samburu for than 10 years	0.123*** [0.019]	0.123*** [0.019]	0.154*** [0.078]			
Kinship				0.008*** [0.001]	0.008*** [0.001]	0.008*** [0.001]
Constant	0.062 [0.198]	0.051 [0.201]	0.052** [0.200]	0.158 [0.195]	0.143 [0.199]	0.143 [0.195]
First stage (F) *p-value*	(1, 49) 26.16 0.000	(1, 49) 24.99 0.000	(1.49) 24.99 0.000	(1.49) 33.63 0.000	(1.49) 33.64 0.000	(1.49) 33.64 0.000
Sargan test: χ2 (2) *Sargan test: p-value*	Exact Identification	Exact Identification	Exact Identification	Exact Identification	Exact Identification	Exact Identification
R^2	0.53	0.54	0.54	0.53	0.54	0.54
N	500	500	500	500	500	500

CHAPTER 4

Adaptation of agriculture to climate change in semi-arid Borena, Ethiopia

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Abstract

Livestock production is very risky due to climate variability in semi-arid sub-Saharan Africa (SSA). Using data collected from 400 households in the Borena zone of the Oromia Region, we explored what drives adoption of agricultural practices that can decrease the vulnerability of agro-pastoralists to climate change. Households with more adaptive capacity adopted a larger number of practices. The households' adaptive capacity was stronger when the quality of local institutions was high. However, adaptive capacity had less explanatory power in explaining adoption of adaptation options than household socio-economic characteristics, suggesting that aggregating information into one indicator of adaptive capacity for site-specific studies may not help to explain the adoption behaviour of households. Strong local institutions lead to changes in key household level characteristics (like membership to community groups, years lived a village, access to credit, financial savings and crop income) which positively affect adoption of agricultural practices. In addition, better local institutions were also positively related to adoption of livestock-related adaptation practices. Poor access to a tarmac road was positively related to intensification and diversification of crop production, whereas it was negatively related to the intensification of livestock production, an important activity for generating cash in the region. Our findings suggest that better local institutions lead to changes in household characteristics, which positively affect adoption of adaptation practices, suggesting that policies should aim to strengthen local institutions.

Keywords: Adoption, adaptation, agro-pastoralists, Borena, adaptive capacity, institutions**.**

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4.1 Introduction

Livestock and crop production risks due to climate variability are widespread in the arid and semi-arid lands (ASALs) of sub-Saharan Africa. In such dry regions of East Africa most agricultural households are pastoralists or agro-pastoralists who struggle to cope with current climate variability (cf. Cooper et al., 2008). Climate change will most likely exacerbate this situation. Although rainfall is likely to decrease only in a few places in East Africa, the anticipated increase in rainfall will not increase agricultural productivity due to unfavourable timing and distribution of precipitation (Thornton et al., 2010). Thus the livelihoods of many low-income households are likely to suffer from declining food production (Jones and Thornton 2009). Adaptation is an urgent priority for farm households to reduce the negative effects of climate change, and effective policies are needed to support farm households to adapt (Kurukulasuriya et al., 2006).

The ability of pastoral and agro-pastoral households to adapt is constrained by many factors including land degradation, limited education, poor access to financial resources and markets to diversify their livelihoods, gender inequalities and marginalization (Njuki and Sanginga 2013). How the negative effects associated with climate change can be reduced depends on a favourable institutional environment to alleviate these constraints, thereby increasing the capacity of farm households to adopt effective adaptation practices (Di Falco et al., 2011; Jones et al., 2010; Thornton et al., 2007). Many householders in ASALs are unable to test new adaptation practices such as new crop varieties, drought tolerant livestock and reducing soil degradation due to their low capacity to invest, lack of inputs and access to information (Bryan et al., 2013). Adaptive capacity as used in this thesis refers to "the ability of the (human) system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (Field et al., 2012). The implication is that capacity to adapt varies among households and that the forces that influence the ability of the system to adapt are the drivers or determinants of adaptive capacity (Adger 2003; Adger 2006). Low adaptive capacity is mostly attributed to a deteriorating ecological base, widespread poverty, high dependence on natural resources and poor access to these resources (Hulme et al., 2001; Intergovernmental Panel on Climate Change (IPCC) 2013; Kelly and Adger 2000; Smit et al., 2001).

We define vulnerability as the "the level of exposure and defencelessness against risks" (Dercon 2006). In ASALs of East Africa four main risk categories have been identified: climate variability, disease outbreaks, market imperfections and risks of policy shocks (Ouma et al., 2011). Of these, risks associated with climate extremes, primarily drought with occasional flooding, are the most severe and constraining for pastoralists or agro-pastoralists (Ouma et al., 2011). Scoones (2009) and Babulo et al. (2009) suggest that the ability of households to pursue different livelihood strategies and thereby adapt to climate change depends on ownership of assets.

In Ethiopia, research suggests that adoption of adaptation practices increases food production per unit land area and households net income (Di Falco et al., 2011). Adaptation can be supported by policy makers through provision of credit, information, inputs, and extension (Hisali et al., 2011; Tambo and Abdoulaye 2012). Below et al. (2010) shows that improving rural transportation, infrastructure, weather forecasts, investment in public health care, and policies that improve local governance and coordinate donor activities can increase adaptive capacity for African farmers. Recent literature on farmers' behaviour in relation to climate change and variability shows that age, education, household size and income are important determinants of adaptation (Bryan et al., 2013; Deressa et al., 2009; Hisali et al., 2011). The importance of institutions and entitlements (such as access to common property resources) enabling households to adapt has received less attention (Jones et al., 2010). Despite the large body of literature on adaptation, and the increasing importance of promotion of agricultural technologies for climate adaptation, little empirical research has explored the link between adoption of agricultural adaptation practices and determinants of adaptive capacity. A better understanding of this link is needed to inform policies that aim to promote adaptation to climate change in the ASALs.

We focus on autonomous adaptation and investigated the relationship between adoption of agricultural options that can decrease the vulnerability to climate change and adaptive capacity among pastoralists in Borena, Ethiopia. The Borena region is one of the 13 administrative zones within Ethiopia's Oromia state. The region is semi-arid savannah, marked by flood plains vegetated predominantly with grass and bush land and frequently exposed to droughts. Borena was chosen as a case study because it is typical for the agro-pastoral areas in the horn of Africa where biophysical constraints and social rules and institutions may limit the space for adaptation. We hypothesized that: i) the quality of local institutions is a key driver of adaptation at household level influencing overall adoption by governing access to resources; and ii) adoption of specific adaptation options is determined by household assets, farming experience, financial resources, household age and gender, membership to community groups.

4.2 Methods

4.2.1 Study area

This study was conducted in Southern Ethiopia in the Borena zone of Oromia regional state in the districts (or *woredas*) of Yabelo and Arero which lies between $4^0$41'-$5^0$03'N and $38^0$17'-$38^0$33'E (Fig. 4.1). The zone covers an area of approximately 95,000 km^2 with an overall population density of six inhabitants per km^2. The climate is hot and dry, with mean monthly temperature ranging between 15^0C (July) and 24^0C (January) with little variation between seasons. The area is semi-arid with highly variable rainfall ranging between 500 to 900 mm per annum. The rainfall is bi-modally distributed with long rain occurring between March and June, and short rains between August and October (Solomon and Coppock 2004). The elevation ranges between 1000 m above sea level on the plains to 1500 m in the highlands (Solomon et al., 2007).

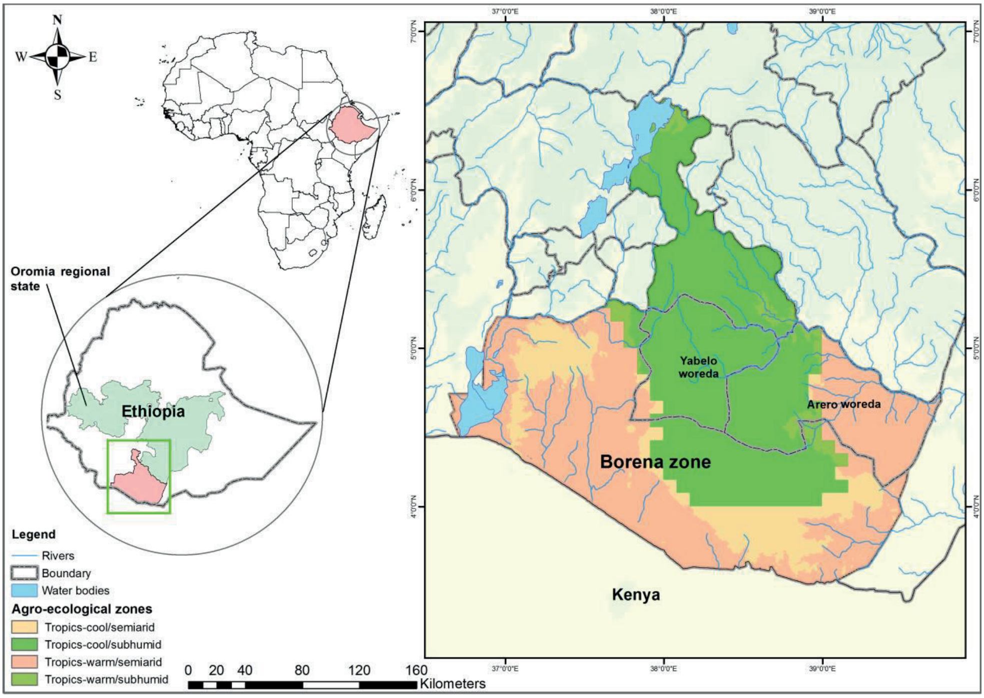

Figure 4.1: Map of Ethiopia showing Oromia regional state, Borena zone and the two woredas (Yabello and Arero) from which our sample households were selected

The predominant form of livelihood is semi–nomadic pastoralism, but current estimates indicate that less than 15% of households in Borena rely on livestock production alone (Angassa and Oba 2008). The majority of households rely on both arable farming and livestock production (Ibid). Rain-fed cropping of maize, sorghum, teff and barley is the common practice. Fences are often erected to protect crops from damage by livestock and wildlife. Cash for buying maize – the main staple food – is derived from the sale of livestock and livestock products. The common livestock species are goat, sheep and cattle, with an increasing population of camels. Areas with good quality pastures are reserved as enclosures for use in dry periods by calves and to a lesser extent milking cows. Croplands, pastures and watering points are communally owned and access to them is regulated through local institutions (Solomon et al., 2007).

The behaviour of households in Borena zone are regulated by local institutions, which are part of the Borena-wide (Appendix 4.1), generation[21] grading '*Gada'* system (Watson 2003). In the *Gada* system, rights to water use are organised and regulated by the well owners locally known as '*Abba hirega'*. The management of pasture including migration of livestock is under a territorial unit leader locally known as '*Abba dheeda'*. The village leader or *'Abba olla'* is the person who started a village and is in charge of resolving conflicts. Several villages make up an '*olla'*. The '*olla'* leader locally known as '*Abba eela'* is in charge of organisation of all villages encompassed in their *'olla'* as defined by the *Gada* system. Conflicts relating to land, water, pastures and social issues in villages are mediated by the local judiciary known as *'Ayyu'*.

4.2.2 Data

Data were collected between August and September 2013, interviewing 400 households from 40 villages randomly selected from six pastoral associations (PAs), the administrative level encompassing several villages: *Gada, Hallona, Dambala-Saden, Dikale, Harboro* and *Abunu.* These PAs constitute Yabelo and Arero *woredas.* Thus,

[21] One generation rules for eight years and then succeeded by the next one.

data were collected in the two *woredas* (i.e., Yabelo and Arero) that were selected as representative of climate, soil, geography and household socio-economic conditions encountered in Northern Borena. From the two *woredas* six PAs were randomly selected from a PAs list. Then using a list of village names in each of the PA that had been developed with the help of key persons, 40 villages (locally referred to as *olla*) were randomly selected. A key person was somebody with good insight about the area such as village boundaries and on social dynamics. Finally, using household lists for each of the selected villages in an *olla* developed with the help of village leader, 10 households were randomly selected so that the total sample size was 400 households. Data were collected with the help of six local enumerators who were trained for five days in both English and the Oromifa language spoken by the largest ethnic group in Borena to ensure a good understanding of the research questions. To maintain consistency during the interviews, each enumerator was provided with an Oromifa version of the questionnaire to serve as a reference point throughout the survey period, although data were recorded in English. We collected information on a range of households' characteristics to estimate human, natural, financial, physical, and social capital as summarized in Table A4.1. In this paper households' socio-economic characteristics are considered as availability of resources for household and access to them (i.e., they constitute five capitals).

Human capital

Education is an important measure of human capital due to its importance to secure employment and skills for managing scarce resources (Saenz and Morales 2005). We measure education as the number of years spent in school. Large household size provides labour, thus enabling households to accomplish various tasks in a short time (Croppenstedt et al., 2003). To estimate household size, the age and gender of household members who share shelter, production and consumption activities (i.e. "eat from the same food pot") were recorded and converted into adult equivalents (AE) following the method by Martin (1985). Then we computed a human dependence ratio (HDR) as the proportion of households' members aged below 15 and above 65 years of age to AE. Experience increases the ability to adopt adaptation measures (Nhemachena and Hassan

2007). In this thesis, experience was estimated by the number of years the households head practiced farming. To estimate 'hired labour' we assigned a dummy variable 1 to households that hired labour during the last 12 months, and zero otherwise.

Natural capital

Natural capital was estimated as access to land, water and wildlife products. Arable land was measured using a geographical positioning system (GPS). To measure 'natural resources constraint' the households were asked: i) whether they pay to access water, forest, shrub land, and pastures and assigned a value of 1 if the answer was yes and 0 if otherwise, and ii) whether there are rules[22] regulating access and use of water, forest, shrub land, and pastures (Table A4.2) and assigned a value of 1 if the answer was yes and 0 if otherwise. These values were summed and averaged to constitute 'the natural resource constraint'. We used equal weighing as we lacked field data to indicate preferential weights. Our standardized scale shows a Cronbach's alpha reliability of 0.507. A larger value for natural resource constraint would minimise unsustainable use of resources.

Financial capital

Financial capital represents the financial resources (e.g., credit, saving and income) available to a household (Nawrotzki et al., 2012). Principal components analysis (PCA) was used to identify non-correlated financial resources (Appendix 4.2) available to households and used as proxies for financial capital. We estimated access to credit and financial saving by asking the households: i) whether they had accessed credit in the last 12 months and assigned a value of 1 if the answer was affirmative and 0 otherwise, and ii) whether they had saved money in the last 12 months and assigned a value of 1 if the answer was affirmative and 0 otherwise. Crop and livestock income were obtained by subtracting direct production costs from estimated revenues and self-consumption.

[22] Rules represents a 'real' resource constraint in Borena since those who break them are punished (Coppock, 1994).

Physical capital

An asset index analysis (Bill and Melinda Gates Foundation 2010) was adapted. The asset index for domestic, transport and productive assets were calculated. Each of the assets was assigned a weight *(w)* as shown in Table A4.3 were then adjusted for age (Njuki and Sanginga 2013). The total asset index was then summed for each household (Eq. 4.1).

$$\text{Household asset index } = \sum_{g=1}^{G}\left[\sum_{i=1}^{N}\left(w_{gi} \times a\right)\right] \qquad (4.1)$$

Where: $i=1, 2,...N$; $g=1, 2,...G$; w_g = weight of the i^{th} item of asset g; N is the number of assets g owned by a household; a is the age adjustment to the weight; G is the number of assets owned by a household.

Social capital

We assumed that social capital is characterised by a strong social network and rural reciprocity (Binswanger and McIntire 1987; Bowles and Gintis 2002; Fafchamps and Minten 2001). We use five proxies for social capital: sharing during hard times[23], group membership, degree of participation in group meetings and participation in group activities (including donations). To estimate sharing we asked respondents to rate their degree of sharing among household members, extended kin and fellow village members, where 0 indicated no sharing and 1 indicated sharing. These variables were then averaged so that a value of 1 indicated sharing in all the three groups. We asked households whether they were members of any community groups. To those answering affirmatively, we asked how many groups they had joined and their degree of participation in group meetings and activities. Participation in meetings was estimated using a 0 – 4 (low to high) point scale. We also created a dummy variable to estimate participation in group activities such as elections, campaigns and conflict resolutions. These dummies were then averaged for each household, so that a value of 1 indicated full participation in group activities and 0 indicates no participation.

[23] Our computation of social capital excludes trust, because it was significantly correlated (at $p<0.001$) with sharing during hard times.

Local institutions

We collected data on three dimensions of local institutions following (Acemoglu and Johnson 2005): tenure security, rule of law, governance and accountability (Table A4.1). We used payment of taxes for cropland and livestock grazing as a proxy for tenure security. To estimate tenure security, we asked households how much tax they had paid for their crop plot(s) and livestock during the last 12 months. These values were then converted into an index. In Borena, land use right to households is accredited by the village leaders in consultation with the PAs. However, payment of taxes to the PAs is a sign of '*de facto*' ownership and right to use the land by householders as perceived by the village leaders. Since the *olla* leader has the right to allocate land to other uses or to other householders, payment of the tax serves as a constraint for land re-allocation.

To estimate rule of law, the respondents rated (on a five-point scale (low to high) the quality of the rule of law as applied by (i) local judiciary ('*Ayyu'*), ii) the territorial leader ('*Abba dheeda'*), iii) the well keepers (*'Abba hirega'*), iv) the leader of several villages ('*Abba eela'*) and v) the village leader ('*Abba olla'*). The responses were averaged into an index for 'rule of law'. To estimate governance and accountability we asked respondents to rate – on a five point scale (low to high) – the *Ayyu, Abba dheeda, Abba hirega, Abba eela and Abba olla,* on; i) degree to which they involve householders in their decision making, ii) degree of transparency in their decision making, iii) degree they represent the interest of the householders in the community and iv) degree of transparency in coordinating activities such as food aid and communicating important information from *Gada* leaders to the householders. These responses were averaged and then converted into the governance and accountability index. In this chapter quality of institutions means the degree to which local institutions are free from poor management and corruption (Voors et al., 2011).

Spatial and information variables

Market access was estimated by quantifying the distances from each homestead to roads (i.e., tarmac and motorable) and markets (i.e., local, urban and livestock markets) as summarised in Table A4.1. All distances were measured in kilometres using a GPS by driving those paths. To estimate access to information we collected information on ownership of mobile phones (dummy variable 1 or 0).

Adopted adaptation options

Data on adopted practices was gathered by posing an open-ended question on whether there were any agricultural practices they had adopted to minimise risks associated with climate variability during the 7 years prior to the field survey. Those who responded ‘yes’ were asked to list the practices they had adopted (Table 4.1). The practices analysed in this study should increase the capacity of the farm household to cope with and adapt to climate related risks, and we call them ‘adaptation options’. The listed adaptation options compare well with options for dry lands found in literature (Bryan et al., 2013; Fratkin 1991; Little et al., 2001; Rufino et al., 2013; Thornton et al., 2007). Before eliciting households’ responses on adaptation options, we sought to know what household understood by ‘climate change’ through a focus group discussions (FGDs). Most households indicated that climate change meant reduction in rainfall, rainfall becoming more erratic, droughts becoming more frequent and more severe and severe reduction in pastures. The changes perceived by the households are associated with current trends in the region (Debela et al., 2015).

Table 4.1: Percentage of households adopting adaptation practices among households in the last 7-10 years

Acronym	Adopted adaptation practices across household during the last 7-10 years	Households (%) who had adopted a particular practice
	Income diversification	
Off-farm job	At least one household member working off-farm	15
Start trade	Started some form of trade/business	8
	Livestock related	
Migration	Some members migrate with livestock, while others are left to work on croplands	44
Feed conservation	Started conserving feed for livestock (e.g., collecting grass at times of abundance) as hays	48
Drought tolerant animals	Introduced drought tolerant animals such as camel	31
Hired labour	Started using hired labour to graze the livestock	8
	Crop related	
Use manure as fertilizer	Started applying manure on cropland as fertilizer	12
Use hybrid seeds	Started using hybrid varieties of seeds	32
Erosion control	Started putting soil erosion control measures on their croplands i.e., grass strips	48
More crop plots	Opened up new crop plots	72
Intercropped	Started intercropping (i.e., cereals and legume)	4
Crop diversity	A variety of crops	72
	Information related	
Joined information group	Joined information sharing group (i.e., on livestock diseases, new technologies etc.,)	77

The percentages need not add up to 100% since some households had adopted more than one adaptation practice

4.3 Data analysis

4.3.1 Set up of the analysis

First, we examined correlations among household socio-economic variables and excluded variables with correlation coefficients greater than 0.4, and computed the adaptive capacity (AC) (Fig. 4.2). Second, we tested for the association between the AC and adoption using number of adopted practices (Fig. 4.2), and AC and three dimensions of local institutions (Fig. 4.2). Next, we explored the effects of the three dimensions of local institutions and AC on number of adaptation options adopted (Fig. 4.2). Finally, we examined the effects of institutions and household socio-economic characteristics, the five capitals, and the spatial variables on the adoption of the total number adaptation options (Fig. 4.2). A normality test shows that the distributions of the AC, the number of adopted adaptation options, the spatial variables and the three dimensions of local institutions were not significantly different from a normal distribution *(results not presented).*

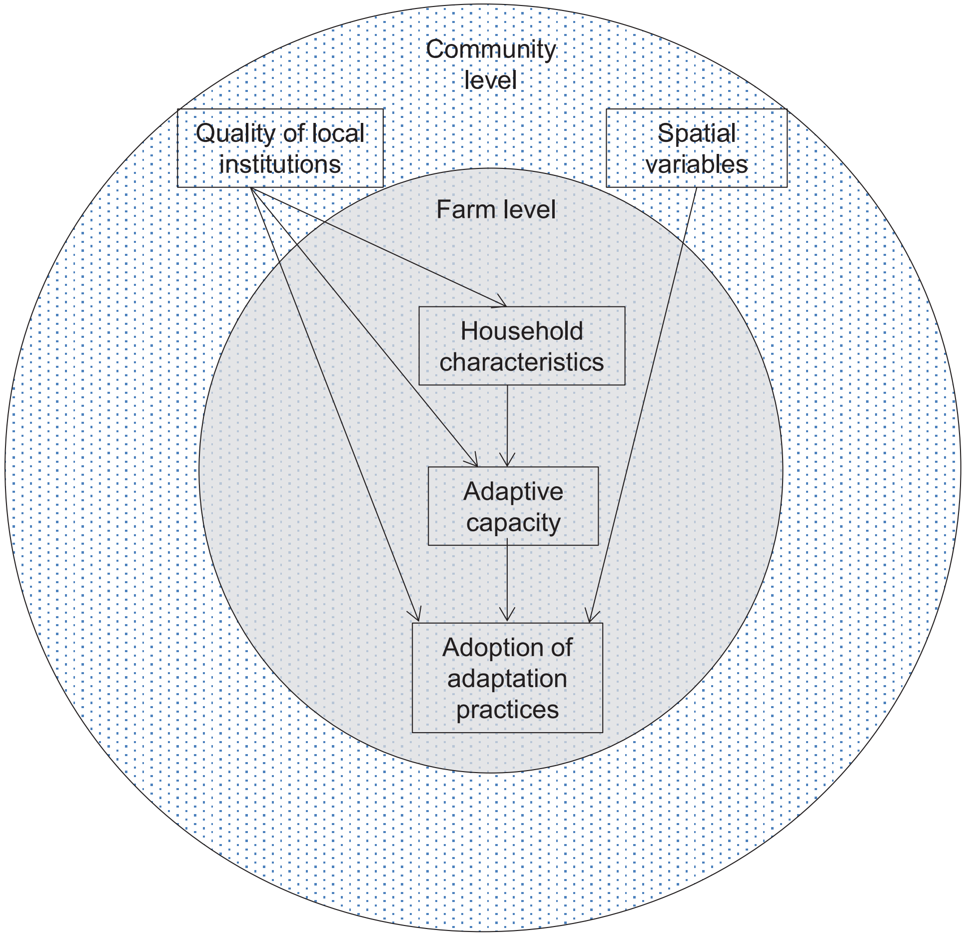

Figure 4.2: A conceptual illustration of the set-up of the analysis

4.3.2 Computing adaptive capacity

Literature on determinants of AC refers to entitlement and command over resources, and shows a positive relationship between access to natural, physical, human, financial and social capital and capacity to adapt (Dulal et al., 2010; Eakin and Bojorquez-Tapia 2008; Tompkins and Adger 2004). Thus households' characteristics (i.e., skills and education) and access to resources are common determinants used in adaption studies. Households with few resources and/or poor access to them seem to have less capacity to adapt to climate change and are more exposed to its negative impacts (Smit and Wandel 2006). Following this empirical evidence, the socio-economic characteristics were normalized by converting them into indices using Eq. 4.2.

$$\left(x_{ij} = \frac{s_{ij} - s_{min}}{s_{max} - s_{min}}\right) \qquad (4.2)$$

where:

x_{ij} = index for each variable i for household j,

s_{ij} = original value for each variable i for household j,

s_{min} and s_{max} = minimum and maximum values for each variable, and

j = 1, 2, …, 400

Subsequently, the indices for the various characteristics were aggregated into their respective capital (Z) type for each household following the framework outlined by Yohe and Tol (2002) (Eq. 4.3). The framework of Yohe and Tol (2002) provides a simple but functional representation of adaptive capacity. The five types of capital were assumed to be equally important in their contribution to the overall AC. Thus, we computed the AC by summing up the five capitals (Z) (Eq. 4.3) and then dividing by five (the total number of capitals) (Eq. 4.4). This approach to the five capitals was tested by comparing the AC values computed with the number of adopted agricultural practices.

$$Z_{kj} = \left(\sum_{i=1}^{n} x_{ij}\right) \Big/ n \quad (4.3)$$

$$AC_j = \left(\sum_{i=1}^{k} Z_{kj}\right) \Big/ 5 \quad (4.4)$$

where; AC_j= Adaptive capacity for household j

n = number of variables constituting each of the five capital for household j

k = 1,…,5 (i.e., five types of capital for household j). But before calculating AC, we tested for normality of our data.

We acknowledge the potential drawback of using equal weight for all capitals. In the absence of field data to indicate preferential weights we conducted a sensitivity analysis by taking five steps between zero and one for each of the five capitals. Then we computed three adaptive capacities indices using a random combination of weights for the five capitals. Finally, we performed a pairwise correlation to see how sensitive the new adaptive capacity (AC) indices were to the different weights when assigned randomly to each capital. The results show that the correlation coefficient of the three new AC indices ranged between ρ=0.577 and ρ=0.9615 and were significantly correlated (at ρ<0.001) to our original AC index. These high correlation coefficients suggest that our AC is not very sensitive to differential weights.

4.3.3 Association between adaptive capacity, adoption and local institutions

We used ordinary least squares (OLS) regression to test whether the number of adopted practices was related to AC (Eq. 4.5). Next, we analysed the association between AC and local institutions variables using Eq. 4.6.

$$AC_j = \delta_1 + \delta_2 S_j + \varepsilon_j \quad (4.5)$$

$$AC_j = \beta_1 + \beta_2 TS_j + \beta_3 RoL_j + \beta_4 GA_j + \varepsilon_j \quad (4.6)$$

Where: AC_j= Adaptive capacity for household j, S_j = number of adopted adaptation options by household j, TS_j = tenure security; RoL_j = rule of law; GA_j = governance and accountability for household j, and ε_j = random error term.

If AC, number of adopted practices and the three dimensions of local institutions are positively related, then we expect δ_2, β_2, β_3 *and* β_4 to be significantly larger than zero. We thereby test the hypothesis that good institutions are likely to facilitate coordination and cooperation reducing social conflicts among households in a community (Bellows and Miguel 2009; Toulmin 2009), and consequently promote private investments thereby increasing household adaptive capacity. If in contrast, good institutions reduce the incentive for investments due to free riding for example, the coefficients will be negative.

4.3.4 Institutions and adoption of adaptation practices

We explored the association between adoption of adaptation practices and the three dimensions of institutions in two steps. First, and for robustness, we use i) number of adopted practices (Eq. 4.7) and ii) adoption as a binary variable (Eq. 4.8) as the dependent variable.

$$S_j = \beta_0 + \beta_1\, TS_j + \beta_2\, RoL_j + \beta_3\, GA_j + \varepsilon_j \qquad (4.7)$$

Where: S_j TS_j, RoL_j, GA_j *and* ε_j are as explained in Eq. 4.5 and Eq. 4.6 above

$$\text{Logit}\left(A_j\right) = \beta_0 + \beta_1\, TS_j + \beta_2\, RoL_j + \beta_3\, GA_j + \varepsilon_j \qquad (4.8)$$

Where: A = adoption of practices as a binary (i.e., Y/N).[24]

In order to estimate the explanatory power of AC on adoption of adaptation practices, we repeated regressions as defined in Eq. 4.7 and 4.8, but included AC as an explanatory variable. Finally, we explored the relationship between adopted adaptation practices and household socio-economic variables, the five capitals and spatial variables by these factors as control in Eq. 4.8.

[24] That is household who had adopted any of the adaptation practice were assigned dummy variable 1, and 0 otherwise.

4.4 Results

4.4.1 Adaptive capacity, adoption and local institutions

There was a positive and significant (p<0.001) association between the number of adopted practices and AC (Fig. 4.3). AC explained about 22% of the total variation in the number of adopted practices. Also in the OLS regression AC and the number of adopted practices were positive and significantly (p<0.001) associated.[25] AC was positively related to the three dimensions of local institutions: tenure security, rule of law and governance and accountability (Table 4.2).

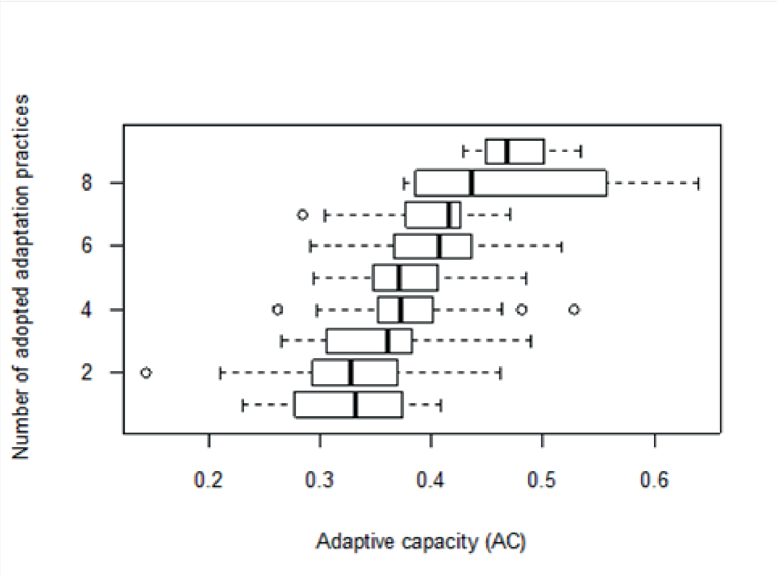

Figure 4.3: The association between number of adopted adaptation practices and adaptive capacity NB: Adjusted r squared = 0.22, p<0.001, adaptive capacity is joint score of the different capitals)

[25] We performed a Logit regression between the AC and the adoption of adaptation practices (as a binary response) for robustness. There was a positive and significant (P<0.001) association between AC and adoption of adaptation practices (results not shown).

Table 4.2: Slope and proportion of explained variance showing the relationship between the three dimensions of institutions (tenure security, rule of law and 'governance and accountability') in explaining adaptive capacity (AC)

Dimension of local institutions	AC (1)	AC (2)	AC (3)	AC (4)
Tenure security	0.087***			0.088***
	(3.94)			(4.49)
Rule of law		0.009***		0.0123***
		(2.17)		(1.98)
Governance and accountability			0.015***	0.077***
			(2.38)	(4.21
Constant	0.341***	0.262***	0.381***	0.237***
	(49.13)	(20.11)	(70.02)	(15.80)
R^2	0.05	0.02	0.02	0.09
N	400	400	400	400

N stands for sample size (apply to all tables). Between parentheses the absolute value of t statistic clustered by village is given. *, ** and *** indicate significant at 10%, 5% and at 1% respectively (applies to all Tables). To increase rigor in our data analysis we perform four independent OLS regressions. First, we perform three independent OLS regression associating AC with the three dimensions of local institutions separately (i.e., columns 1-3) and, secondly associated AC with the three local institutions together (column 4). A blank cell in any of the columns indicates that the respective variables were excluded in the regression (applies to all tables).

The combined model with all three dimensions of local institutions also had a positive and significant ($p<0.001$) association with AC with each of the dimensions, adding significantly to overall model performance, implying that the effects of the three dimensions of local institutions on AC are complementary.

4.4.2 Effects of institutions on adoption

Tenure security and governance and accountability were positively related to the number of adopted practices (Table A4.4). AC and high quality of tenure security and governance and accountability had a positive and significant association with the number of adopted practices, suggesting that the effects of the three variables on adoption are complementary, and that besides AC, other variables determine adoption.

4.4.3 Effects of household socio-economic characteristics and institutions on adoption

High crop income, financial savings, natural resource constraints, years lived in the village, and membership in community groups were positively related to crop related adaptation practices (Table 4.3). Crop income and years lived in the village were positively related with crop related adaptation practices (‘use of hybrid seeds’, ‘use of manure as fertiliser’, ‘erosion control’, ‘more cropping plots’ and ‘crop diversity’). Membership to community groups was positively related with crop related adaptation practices intensification (hybrid seeds, erosion control, and intercropping). High financial saving and natural resource constraints were positively related to the ‘use of hybrid seeds’ and the ‘use of manure as fertiliser’. However, the increase in the age of the household head, household dependency ratio and participation in group activities were negatively related to adoption of crop related adaptation practices.

Table 4.3: The effect of household characteristics (internal factors) and local institutions (external factors) on the likelihood of adopting various adaptation practices among household in Borena region of Ethiopia

	Start trade	Use hybrid seeds	Use manure as fertilizer	Drought tolerant animals	Erosion control	Feed conservation	Joined information group	Inter cropping	More crop plots	Use hired labour	Migration	Off-farm job	Crop diversity
Crop income	-0.00 (0.33)	0.00*** (4.03)	0.00*** (2.81)	0.00 (0.33)	0.00* (1.75)	-0.00 (0.14)	-0.00 (1.11)	-0.00 (0.14)	0.00*** (5.52)	0.00 (1.28)	-0.00 (0.45)	0.00 (0.02)	0.00*** (5.52)
Age of household head	0.03* (1.75)	-0.03*** (2.78)	-0.04 (1.13)	0.01 (0.72)	0.01 (0.15)	-0.00 (1.17)	0.00 (0.49)	-0.01 (0.66)	-0.01 (0.90)	-0.02 (1.40)	0.01 (1.64)	0.03** (2.09)	-0.01 (0.90)
Financial savings	-1.55** (2.08)	0.94*** (2.87)	-1.54 (1.31)	0.09 (0.25)	-0.26 (0.83)	0.04 (0.88)	-0.06 (0.87)	-0.45 (0.52)	0.25 (0.67)	-0.02 (0.02)	0.52* (1.74)	0.49 (1.17)	0.25 (0.67)
Access to credit	0.45 (0.92)	0.09 (0.29)	0.56 (0.60)	0.30 (0.97)	-0.06 (0.22)	-0.00 (0.23)	0.09 (1.50)	-0.49 (0.66)	-0.04 (0.13)	-1.47** (2.05	0.02 (0.06)	1.13*** (3.03)	-0.04 (0.13)
Natural resource constraint	2.79 (1.62)	0.37 (0.32)	5.16* (1.93)	0.60 (0.53)	-0.94 (0.92)	-0.11* (1.95)	0.00 (0.00)	-1.70 (0.62)	-0.84 (0.70)	-4.84** (2.10)	0.11 (0.11)	1.22 (0.91)	-0.84 (0.70)
HH dependent ratio	-2.53 (1.36)	-1.55 (1.58)	-6.62* (1.79)	-0.73 (0.70)	-1.06 (1.21)	0.14*** (2.94)	0.07 (0.36)	1.63 (0.81)	-1.14 (1.20)	0.75 (0.45)	-0.24 (0.32)	-1.40 (1.15)	-1.14 (1.20)
Years in the village	-0.04 (1.42)	0.03* (1.91)	0.08* (1.90)	-0.02 (1.11)	0.04** (2.52)	-0.00 (1.15)	0.002 (0.73)	-0.03 (0.82)	0.03* (1.78)	-0.01 (0.24)	0.00 (0.02)	0.02 (0.99)	0.031* (1.78)
Gender of the HH head	0.55 (0.76)	0.24 (0.68)	1.62 (0.99)	-0.35 (0.95)	0.28 (0.85)	0.01 (0.28)	0.134* (1.79)	1.08 (1.16)	-0.04 (0.12)	-0.46 (0.70)	0.18 (0.58)	0.92* (1.81)	-0.04 (0.12)
Livestock wealth (Eth Birr)	0.00*** (4.01)	0.00 (1.02)	-0.00 (1.00)	0.00*** (5.76)	0.00 (0.50)	-0.00 (0.73)	0.00*** (2.76)	-0.00 (1.13)	0.00 (1.50)	0.00 (0.02)	0.00 (1.31)	0.00 (0.16)	0.00 (1.50)
Community groups member	1.37* (1.87)	0.73** (2.20)	-0.23 (0.24)	-0.32 (0.96)	0.68** (2.16)	-0.01 (0.84)	-0.00 (0.05)	1.6*** (2.87)	0.38 (1.05)	0.19 (0.34)	0.62** (2.04)	-0.80** (2.04)	0.38 (1.05)
Participation in group meeting	0.70 (0.50)	-0.08 (0.14)	-1.71 (1.53)	0.028 (0.05)	0.12 (0.19)	-0.01 (0.33)	-0.00 (0.03)	-0.40 (0.34)	-0.65 (0.91)	-1.60** (2.07)	-0.06 (0.12)	-1.45** (2.30)	-0.65 (0.91)
Participation in group activities	0.071 (1.25)	-0.16 (1.36)	0.06 (0.92)	-0.03 (0.34)	-0.10 (1.01)	-0.00 (0.67)	0.01 (1.44)	-0.06 (0.35)	-0.19* (1.71)	-0.39* (1.81)	-0.09 (0.97)	-0.23 (1.61)	-0.20* (1.71)
Tenure security	-0.64 (0.37)	-0.51 (0.45)	3.36 (0.89)	0.55 (0.44)	1.31 (1.29)	0.28*** (5.15)	0.04 (0.16)	-3.39 (1.48)	0.20 (0.18)	0.05 (0.02)	1.56 (1.60)	-3.19** (2.28)	0.20 (0.18)
Rule of law	-0.14 (0.29)	-0.20 (0.70)	1.19 (1.49)	0.18 (0.67)	-1.3** (4.55)	-0.01 (0.96)	-0.10* (1.70)	0.041 (0.06)	0.27 (0.84)	2.28*** (3.77)	0.44* (1.80)	-0.13 (0.38)	0.27 (0.84)
Governance and accountability	0.60 (0.87)	-1.18*** (2.69)	-0.77 (0.62)	-0.10 (0.25)	0.35 (0.92)	-0.01 (0.29)	0.31*** (3.84)	-0.41 (0.44)	0.45 (1.06)	2.11*** (3.02)	1.52*** (4.00)	-0.06 (0.14)	0.45 (1.06)
Constant	-11.7** (2.05)	-3.36 (1.40)	-4.78 (0.91)	-1.05 (0.44)	1.97 (0.81)	0.99*** (8.46)	1.27** (2.58)	0.41 (0.08)	2.07 (0.74)	-0.37 (0.09)	-4.16* (1.88)	4.36* (1.66)	2.07 (0.74)
Pseudo R	0.28	0.19	0.30	0.21	0.17	0.13	0.16	0.25	0.24	0.28	0.10	0.13	0.24

The coefficients shown (except the constant, pseudo R) present only the direction of the effect of internal and external factors on the likelihood of adoption of the various adaptation practices, but not the actual magnitude of change. Between parentheses, the absolute value of t statistic clustered by village is given (Applies to all subsequent tables). HH stand for household. Results of year of education of HH head is not shown in the table (though it was in the analysis) because it had no effect on the adaptation practices. Sample size is equal to 400

The age of the household head, access to credit, livestock wealth and membership to community groups were positively associated with income diversification practices (‘start trade’ and ‘off-farm income’). Access to credit and gender of the households was positively related with the likelihood of taking ‘off-farm jobs’, while livestock wealth and ‘membership to community groups’ were positively associated with ‘start trade’.

Livestock wealth, membership to community groups, household dependency ratio and financial saving had a positive and significant effect on adoption of livestock related adaptation practices (adoption of drought tolerant animals, feed conservation and migration). Participation in community meetings and activities, access to credit and high ‘natural resource constraints’ were negatively associated with ‘use of hired labour’.

Tenure security was positively related with feed conservation, but was negatively related with income diversification (i.e. ‘off-farm jobs’). Governance and accountability and rule of law were positively related to more livestock related adaptation practices supporting migration and ‘use of hired labour’, but were negatively related to crop intensification (‘erosion control’ and ‘the use of hybrid seeds’).

4.4.4 Effects of capitals on adoption

There was a positive and significant relationship between human capital and migration and use of hired labour (Table A4.5). Natural capital had a positive relationship with adoption of crop intensification practices. More financial capital was positively related to adoption of livestock-related adaptation practices (‘drought tolerant animals’ and migration), income diversification practices and crop related adaptation practices (‘crop diversity’, ‘use of hybrid seeds’ and ‘more crop plots’), but less adoption of intercropping. More physical capital led to more crop and livestock related adaptation practices and income diversification. Higher social capital, led to more adoption of livestock related practices.

4.4.5 Effects of infrastructure on adoption of practices

Distance to the tarmac road was positively associated with an increased ‘use of manure’, ‘more crop plots’, ‘use of hired labour’ and ‘crop diversity’ (Table A4.6). There was a negative effect of the distance to the tarmac road on the adoption of ‘feed conservation’. An increase in the distance to the local markets was positively associated with adoption of ‘drought resistant animals’. An increase in the distance to the local market was negatively associated with the ‘use of hybrid seeds’, ‘erosion control’, ‘use of hired labour’, ‘off-farm jobs’, and ‘crop diversity’ implying that as distance to the local market increases, the adoption of crop intensification and income diversification practices declined.

There was no difference in adopted practices between male (75% of the sample)- and female (25% of the sample)-headed households (Fig. A4.1). Nevertheless, the proportion of households adopting specific practices varied among the low, medium and high income households (Fig. A4.2). About 50% of the high, medium and low income households had adopted seven, five and three practices respectively. Moreover, the results suggest that local institutions have a larger impact on adoption of adaptation practices among male headed households who join information groups and engage in income diversification (Table 4.3).

4.5 Discussion

We explored relationships between adaptive capacity (AC), the quality of local institutions (tenure security, rule of law, and governance and accountability), and the number of adaptation practices adopted by agro-pastoral households. Aggregating household level information into the AC indicator led to a loss of information (Table A4.8): the explanatory power of the statistical models using household level information directly was stronger, both for the total number of adopted practices, as for the adoption of individual practices (Table A4.7). The loss of information when using either characteristics of household or local institutions suggests that better local institutions lead to changes in key household level characteristics (e.g., membership to community groups, years lived a village, access to credit, financial savings and crop income), which positively affect adopted adaptation strategies. This finding suggests that policies that enhance the quality of local institutions have the potential to support households to adapt by enhancing their AC in the short term, and to adapt in the longer term by stimulating change in the household themselves, which then increases AC. These findings also partly confirm our hypothesis that the quality of local institutions is positively related with adaptation at household level, but it is difficult to say whether they are more important than characteristics of the household themselves. The amount of variability in total number of adopted adaptation practices explained by the household level characteristics was larger than the amount of variation explained by the local institutions. However, some household characteristics were correlated with quality of the local institutions, thereby making it difficult to infer their relative importance. For individual practices, household characteristics were the most important factors, sometimes complemented, depending on the specific adaptation option, by the quality of local institutions and / or spatial variables (Table 4.3 and Table A4.6). Thus, policies aimed at supporting the management of local institutions have the potential of stimulating their quality and consequently management of rangeland resources, thereby fostering adaptation. In addition, provision of financial resources for strengthening local institutions may foster internal and external coordination and connections (i.e., feedback loops) that can ensure equity, transparency and the ability to seize adaptation opportunities.

Models using the five capitals as explanatory variables had less explanatory power than those using household characteristics directly (Table A4.5). So whilst AC and the five capitals provides an abstract way of representing the potential of a household to adapt (Adger and Vincent 2005; Dulal et al., 2010; Eakin and Bojorquez-Tapia 2008; Tompkins and Adger 2004), and can used to compare systems (cf. Deressa et al., 2009), for site-specific studies they are perhaps not the best way of analysing the adoption behaviour of households. This is because using the five capitals typically masks the roles of specific household’s characteristics and their functions in supporting adaptive capacity. Our analyses support earlier research that shows positive relationships between access to natural, physical, human, financial and social capital and the capacity to adapt (Adger 1996; Brooks and Adger 2004; Brouwer et al., 2007; Reid et al., 2007). However, other studies suggest that cognitive factors (i.e., risk perception, information management and behaviour) play a critical role (i.e., helping household to make decision on resource use and management) in determining household level AC (Grothmann and Patt 2005; Peacock et al., 2005). The advantage of using the five capitals is the increased transparency as a measure of AC. The drawback of using cognitive factors is that farmers with a high risk perception are likely to adopt measures simply because of their perception, not necessarily because they have intrinsically a high AC (Clayton 2012). So, if the likelihood of adoption is then used as an indicator of AC, the whole analyses will have difficulty to distinguish the driver of the process: was it the chicken (perception) or was it the egg (AC)? We therefore believe it is more appropriate to use an AC indicator based on intrinsic farm household characteristics, supplemented by information on local institutions. The five capital approach then serves as a useful reference that covers several key aspects that characterise households and thereby allows standardization for across site comparisons. This approach to gain insight in AC of households across socio-economic and agro-ecological gradients uses a bottom up approach based on primary data collection at households' level, rather than a top down approach or from anecdotal information about case studies or expert opinion (Adger and Vincent 2005; Gupta et al., 2010; Jones et al. 2010). We see this as an important step in adaptation research because it helps to unmask the roles of the specific household characteristics and their functions as well as local institutions in supporting household adaptive capacity.

4.5.1 The role of adaptive capacity and the three dimensions of local institutions on adaptation

The positive and complementary effect of the three dimensions of local institutions on AC shows that higher quality local institutions affect household level welfare positively, especially through accumulation of assets and other resources that are important determinants of AC (cf. Grootaert and Narayan 2004; Little et al., 2001). The positive relationship between tenure security and governance and accountability and the number and the type of adaptation practices adopted suggests that high quality local institutions increase the ability of households to intensify crop and livestock production. For instance, to reduce the negative impact of drought on livestock wealth, high quality of governance and accountability ensures that enclosures (areas reserved for grazing by calves and cows) are not grazed during non-dry season by imposing strict penalties to errant households, thereby increasing the ability of households to adapt (Chavas et al., 2005; Kabubo-Mariara 2007).

4.5.2 Effects of socio-economic characteristics on adoption of adaptation practices

Crop related adaptation practices

Whether larger crop income is a cause or an effect of adoption crop related adaptation practices is difficult to determine, although previous research has shown that when land is limited farmers are motivated to intensify crop production (Baidu-Forson 1999; Deressa et al., 2009; Di Falco et al., 2011). The numbers of years spent in a village is often a good indicator of the willingness of farmers to invest in improving soil fertility and intensifying crop productivity, as well as a representation of experience gained that enable households to adapt (Deressa et al., 2009; Notenbaert et al., 2012; Odendo 2010). Other factors related to adoption of crop related adaptation practices include membership to community groups, which may enhance adoption of crop related adaptation practices by facilitating sharing of knowledge and ideas (Bryan et al. 2013).

On the other hand, natural resource constraints hinder households' ability to secure food (cf. Marenya and Barrett 2007; Mazzucato et al., 2001; Shiferaw et al., 2009), and the ability to save money to acquire inputs (Di Falco et al., 2011).

Income diversification

Older farmers, owing to their accumulated experience and wealth can diversify their income to safeguard their livelihood (Table 4.3) (Aklilu and Catley 2011; Bayard et al., 2007). The positive relationship between access to credit and income diversification shows the role institutions may play in enabling adaptation (Di Falco et al., 2011). Male headed households engage more easily in income diversification than female headed households, highlighting the need for effective interventions to improve the AC of women (Njuki and Sanginga 2013; Notenbaert et al., 2012). The strong relationship between livestock wealth and income diversification can be explained by a 'banking' effect: selling livestock (products) can provide capital to for example 'start trade' (Ouma et al., 2011), as a diversification strategy (cf. Carter and Barrett 2006; Little et al., 2001). Thus, a policy to support investment in institutions (such as the banks) may stimulate households to save and access credit, and enhance their ability to adapt. The negative relationship between group membership and participation in group activities and income diversification may be explained by the time spent in group meetings and activities which reduces the time required to pursue other activities (Marenya and Barrett 2007). This suggests that, policies aimed at encouraging informal social networks (financially or materially) may facilitate the flow of information and coordination of activities much more efficiently; thereby boosting household AC. High tenure security shows a negative relationship with the adoption of income diversification options.

Livestock related adaptation practices

Livestock wealth is a good indicator of the capacity of households to intensify livestock production (cf. Amsalu and De Graaff 2007; Bekele and Drake 2003; Di Falco et al., 2011; Marenya and Barrett 2007). Financial savings enhance households' capacity to adopt livestock related adaptation practices, for example by enabling them to buy food (or other social amenities) when migrating or looking for pastures (Barrett et al. 2006).

A high household dependency ratio would suggest households' willingness to secure more milk and income through livestock related adaptation practices given the greater family needs (cf. Somda et al., 2005), while membership to community groups enhances livestock related adaptation practices in semi-arid areas as a source of information on water and pasture availability (cf. Deressa et al. 2009; Di Falco et al., 2011). High quality tenure security enhances adoption of livestock related adaptation practices by enabling households to make long term production decisions (Deininger and Jin 2006; Kabubo-Mariara 2007), while high quality local institutions stimulate the choice for enclosures are a source of livestock feed during dry periods.

4.5.3 Effects of infrastructure on adoption of adaptation practices

Poor access to a tarmac road was positively related to the adoption of income diversification and crop intensification practices, but negatively related to livestock related adaptation practices. This could be explained by the fact that crop production in the region is mostly for home consumption (Angassa and Oba 2008). Lack of access to a tarmac road (and therefore to markets) means that to feed the family the farmers need to intensify and diversify food production to obtain a reasonable harvest. In contrast, livestock is the key cash generator for these agro-pastoral households, and lack of access to a tarmac road means that marketing of livestock products is more difficult, and therefore a disincentive to intensify livestock production. Our findings suggest that besides household level characteristics, their geographical location needs to be taken into account to explain adoption of agricultural practices that can reduce vulnerability to climate variability.

4.6 Conclusions

Aggregating household level information into the AC indicator or the five capitals for explaining adoption behaviour leads to loss of information. So whilst AC and the five capitals can be used as an abstract way representing the potentials of a household to adapt and can easily be compared across systems, for site-specific studies they are not the best way of analysing the adoption behaviour of households. We conclude that the best way of analysing behaviour of households for site-specific study is to use household level information directly. Our results suggest that better local institutions lead to changes in key household level characteristics, which positively affect adoption. Thus, policies aimed at supporting the management and strengthening of local institutions can foster adaptation to an increasingly erratic climate.

Appendices: Chapter 4

Appendix 4.1: Gada

Each *Gada* period is named after the elected leader of the generation class (*Abba gada)*. The *Abba gada* lives according to specific rules and taboos, and is the head of each generation-grade. One generation-grade rules for eight years and then succeeded by the next one. The *Abba gada* is appointed by the *Gumi gayo* – the highest authority among Borena for decision making and together with his councils of ministers – presides over all issues affecting pastoral life in Borena. *Gumi gayo* is held once every eight years, and discusses issues such as resource conflicts, renewing of fundamental principles and customs (locally known as *Aada*) and their adoption. The *Abba Gada* and his councils are considered the embodiment of the *Aada.* The *Aada* are laid out in sets of law known as the *Aada seera*, which embody the correct way a Borena person to live.

Appendix 4.2: Principal component analysis on financial resources

A principal component analysis on financial resources available to household indicated that roughly 84% of the households variability was explained by the first three principal components (PC) which had high positive and negative loading with respect to the access to credit, ability to save and farm income (crop and livestock). The first PC was dominated by the proportion of livestock income; the second PC was dominated by the financial saving and access to credit; while the third PC was dominated by the proportion of crop income.

Table A4.1: The basic data description in terms of the five capitals and social institutions

Variables	Mean	Standard deviation	Minimum	Maximum
Panel A: Human capital				
Human dependence ratio (HDR)	0.35	0.17	0	1
Age of the household head (Years)	47.06	16.95	20	96
Education of household head (Y/N)	0.05	0.22	0	1.0
Gender of the household head (0=F and 1=M)	0.76	0.42	0	1.0
Experience in farming (Years)	12.24	8.33	1	50
Years lived in the village (Years)	10.73	9.65	1	60
Hired labour	0.08	0.28	0	1
Panel B: Natural capital				
Cultivable farm area (ha) (90% of the households had a crop farm)	0.87	0.61	0	4
Natural resource constraints (0-1)	0.37	0.13	0	1
Panel C: Financial capital				
Access to credit (Y/N)	0.34	0.47	0	1
Financial savings (Y/N)	0.28	0.45	0	1
Off-farm income (Y/N)	0.10	0.30	0	1
Total crop income (Eth. Birr)	4568.65	4557.80	0	35760
Total livestock income (Eth. Birr)	9293.77	12689.40	0	77810
Livestock wealth (Eth. Birr)	72282.55	76583.58	0	782100
Panel D: Physical capital				
Total household asset index	271	214	28	1636
Panel E: social capital				
Sharing during hard times	0.84	0.11	0	1
Membership to community groups (count)	1.29	0.54	1	4
Participation in community group meetings (degree)	2.88	0.44	2	4
Degree of participation in group activities (Yes/No)	0.33	0.27	0	1
Panel F: Dimension of local institutions				
Tenure security	0.32	0.14	0.21	0.99
Rule of law	0.59	0.12	0	0.8
Governance and accountability	0.37	0.08	0.1	0.7

Table A4.1: The basic data description in terms of the five capitals and social institutions (cont'd)

Variables	Mean	Standard deviation	Minimum	Maximum
Panel G: Spatial variables				
Distance to the motorable road (km)	1.13	1.74	0.001	10
Distance to the tarmac road (km)	25.99	15.86	2	60
Distance to the local market (km)	11.14	7.80	0.5	30
Distance to the livestock market (km)	16.01	14.80	0.5	77
Distance to the urban market (km)	38.52	14.54	0.5	78
Panel H: Dependent variable				
Adaptive capacity	0.37	0.06	0.14	0.63

Source: Author survey 2013 (applies to all tables). Eth. Birr stands for Ethiopia Birr; the legal currency of federal republic of Ethiopia (applies to all tables).

Table A4.2: Frequencies of household responses to the question posed in relation to resource use constraint

		Resource name		
Question posed in relation to resource use		Rangeland	Forest	River
Which is the recognized form of ownership?	Private	0	0	0
	Communal	100	0	100
	Government	0	100	0
	Total responses	100	100	100
Do pay to access the resource?	No	99	100	100
	Yes	1	0	0
	Total responses	100	100	100
Are there rules[§] regulating the resource use?				
	No	2	28	1
	Yes	98	72	99
	Total responses	100	100	100

The number in the table represents the percentage (%) of households that gave a specific response to the question posed.

[§]The main rule regulating the use of forest was prohibition of felling of green trees for firewood, fencing post or charcoal. The main rules regulation around the use of rangeland were: prohibition of livestock grazing in areas close to the village – as this was reserved for young calves and weak animals – and prohibition of grazing on areas set aside *also referred to as enclosures* (by the community) for grazing only during the dry season. The main regulation around the use of river was that no one was to cultivate (for those who had crop land) very close to the river course to prevent soil erosion.

Table A4.3: Household domestic asset index

Asset (g)	Weight of assets (w_g)	Age (adjustment for age shown in the cell)		
		< 3 years old	3-7 years old	>7 years old
Animal		Calves	Immature male/Heifer	Bull/cow
Cattle	10	× 0.4	× 0.8	× 1
Horses	10	No adjustment		
Sheep/goats	3			
Poultry	1			
Pigs	2			
Domestic assets		< 3 years old	3-7 years old	>7 years old
Cooker	2	× 1	× 0.8	× 0.5
Kitchen cupboard	2			
Refrigerator	4			
Radio	2			
Cell phone	3			
Chairs	1			
Mosquito net	1			
Transport		< 3 years old	3-7 years old	>7 years old
Car/ truck	160	× 1	× 0.8	× 0.5
Motorcycle	48			
Bicycle	6			
Cart (animal drawn)	12			
Productive				
Hoes	1	× 1	× 0.8	× 0.5
Machete	1			
Spade/shovel	1			
Plough	4			
Sewing machine	4			

Source: Adapted from Women, Livestock Ownership and Markets (Njuki and Sanginga, 2013)

Table A4.4: The effect of institutions on adoption; the latter represented by either the number of adopted adaptation practices per households" or as a binary variable

	Number of adopted adaptation practices (1)	Adoption Binary (Y/N) (2)	Number of adopted adaptation practices (3)	Adoption Binary (Y/N) (4)
Tenure security	2.68*** (4.70)	3.21*** (3.95)	1.33*** (2.60)	2.24** (2.56)
Rule of law	0.12 (0.93)	0.082 (0.67)	-0.087 (0.72)	-0.19 (0.93)
Governance and accountability	0.78*** (3.78)	1.06*** (3.38)	0.42*** (2.27)	0.64*** (6.95)
AC			15.48*** (11.14)	21.84*** (6.95)
Constant	2.31** (5.35)	0.29 (0.50)	-1.42*** (2.82)	-5.05*** (4.98)
R^2	0.09	0.05	0.29	0.18
N	400	400	400	400

To analyse column 1 and 3 ordinary least squares (OLS) were used. The coefficients in columns 1 and 3 present the slope and the explained variance between adopted adaptation practices and the explanatory variables. To analyse columns 2 and 4 a logit model was used. The coefficient in columns 2 and 4 present only the direction of the effect of independent variable on the likelihood of adoption of adaptation practices, but not the actual magnitude of change.

Table A4.5: The effect of the five capitals on the likelihood of adopting various adaptation practices among household in the Borena region of Ethiopia

The five capitals	Start trade	Use hybrid seeds	Use manure as fertiliser	Drought tolerant animals	Erosion control	Feed conservation	Joined information group	Inter cropping	More crop plots	Use hired labour	Migration	Off-farm job	Crop diversity
Human capital	3.846	-0.878	3.884	0.386	0.495	-2.593	-2.266	-0.853	-0.160	-4.380**	2.290*	2.556	-0.159
	(0.71)	(0.64)	(1.03)	(0.29)	(0.40)	(0.54)	(0.74)	(0.26)	(0.10)	(1.98)	(1.75)	(1.45)	(1.57)
Natural capital	4.388	5.889***	4.741*	2.112*	2.963***	4.573	3.320	-0.133	12.95***	-0.499	1.731	-0.857	12.95***
	(1.14)	(4.82)	(1.85)	(1.86)	(2.72)	(0.89)	(1.16)	(0.05)	(6.99)	(0.25)	(1.58)	(0.57)	(1.85)
Financial capital	3.235	2.920***	-0.811	2.618***	-0.510	2.182	-0.437	-4.362*	1.891*	6.941***	2.339***	4.023***	1.891*
	(1.05)	(3.27)	(0.34)	(2.98)	(0.62)	(0.56)	(0.20)	(1.65)	(1.73)	(4.75)	(2.75)	(3.66)	(1.09)
Physical capital	59.9***	-1.788	0.901	5.080***	0.148	2.770*	-11.760***	1.155	8.712*	-0.329	8.476***	0.825	8.712**
	(4.54)	(1.03)	(0.30)	(2.77)	(0.11)	(1.73)	(3.06)	(0.42)	(1.89)	(0.14)	(3.11)	(0.54)	(4.60)
Social capital	-5.128	-1.250	-0.905	-1.192	3.385***	-1.865	54.076***	3.922	-1.077	0.605	1.736*	-0.759	-1.076
	(1.27)	(1.15)	(0.33)	(1.11)	(3.31)	(0.54)	(6.73)	(1.33)	(0.89)	(0.30)	(1.67)	(0.54)	(1.21)
Constant	-6.626*	-1.838*	-6.63**	-1.597	-3.088***	3.635	-25.319***	-4.493*	-2.306	-1.706	-3.640***	-3.327**	-2.30**
	(1.82)	(1.77)	(2.41)	(1.58)	(3.22)	(0.99)	(5.90)	(1.73)	(1.92)*	(1.00)	(3.61)	(2.52)	(1.19)
Pseudo R	0.77	0.09	0.04	0.05	0.03	0.14	0.77	0.04	0.20	0.13	0.08	0.05	0.20
N	400	400	400	400	400	400	400	400	400	400	400	400	400

Table A4.6: The effect of the spatial and information variables on the likelihood of adopting various adaptation practices among households in the Borena region of Ethiopia

Spatial and information variables	Start trade	Use hybrid seeds	Use manure as fertiliser	Drought tolerant animals	Erosion control	Feed conservation	Joined information group	Inter cropping	More crop plots	Use hired labour	Migration	Off farm job	Crop diversity
Distance to the motorable road (km)	0.025 (0.14)	-0.034 (0.52)	-0.675 (1.28)	0.006 (0.09)	-0.045 (0.75)	0.011 (0.05)	-0.02*** (0.21)	-0.006 (0.04)	0.092 (1.05)	0.111 (1.31)	-0.096 (1.47)	-0.022 (0.26)	0.092 (1.05)
Distance to tarmac road (km)	0.035** (1.74)	0.001 (0.15)	0.016 (1.89)	-0.003 (0.44)	0.003 (0.43)	-0.041 (1.69)	-0.038 (0.54)	0.012 (0.70)	0.029** (3.40)	-0.04*** (3.36)	0.005 (0.74)	0.011 (1.25)	0.029*** (3.40)
Distance to local market(km)	0.016 (0.45)	-0.071*** (3.09)	-0.044 (1.03)	0.047** (2.24)	-0.027* (1.68)	-0.024 (0.47)	-0.001 (1.25)	0.030 (0.86)	-0.040** (2.75)	-0.101*** (2.62)	-0.022 (1.60)	-0.009 (0.47)	-0.040*** (2.75)
Mobile Phone	1.482*** (2.54)	0.462 (2.38)	-2.278 (0.14)	0.280 (1.23)	0.571 (1.68)	1.492 (1.35)	0.001 (1.29)	0.194 (0.34)	0.012 (0.05)	1.277*** (3.03)	0.95** (4.36)	-0.438 (1.20)	-0.012* (0.05)
Constant	-11.38*** (4.04)	-2.19 (1.55)	-2.933 (0.25)	0.695 (0.45)	-0.034 (0.13)	5.176 (1.99)	0.007 (0.90)	0.035 (4.99)	-0.628 (0.64)	0.570 (0.23)	-4.22*** (1.46)	-1.72*** (4.62)	0.628** (2.11)
Pseudo R	0.34	0.19	0.28	0.22	0.12	0.12	0.09	0.19	0.27	0.18	0.09	0.11	0.27
N	400	400	400	400	400	400	400	400	400	400	400	400	400

Household characteristics have been controlled for in the model

Table A4.7: The effect of household characteristics (internal factors) on the likelihood of adopting various adaptation practices among households in the Borena region of Ethiopia

Household characteristics	Start trade	Use hybrid seeds	Use manure as fertiliser	Drought tolerant animals	Erosion control	Feed conservation	Joined information group	Inter cropping	More crop plots	Use hired labour	Migration	Off farm job	Crop diversity
Crop income	-0.000 (0.56)	0.000*** (3.82)	0.000*** (2.88)	0.000 (0.39)	0.000** (2.03)	0.000 (1.00)	-0.000 (0.48)	0.000*** (6.03)	0.000* (1.69)	0.000 (0.32)	-0.000 (0.07)	0.000*** (6.03)	-0.000 (0.48)
Age of household head	0.026* (1.70)	-0.029*** (2.86)	-0.010 (0.32)	0.008 (0.84)	-0.001 (0.10)	-0.001 (1.05)	-0.017 (0.81)	-0.009 (0.88)	-0.010 (0.72)	0.016** (2.01)	0.020* (1.79)	-0.009 (0.88)	-0.017 (0.81)
Financial savings	-1.746** (2.45)	1.048*** (3.34)	-0.809 (0.77)	0.139 (0.43)	-0.447 (1.56)	0.022 (1.35)	-0.486 (0.55)	0.306 (0.87)	-0.079 (0.15)	0.395 (1.44)	0.480 (1.23)	0.306 (0.87)	-0.486 (0.55)
Access to credit	0.412 (0.85)	0.104 (0.36)	0.103 (0.12)	0.300 (0.98)	-0.035 (0.13)	-0.005 (0.3)	-0.596 (0.82)	-0.161 (0.51)	-1.547** (2.32)	-0.016 (0.06)	0.985*** (2.75)	-0.161 (0.51)	-0.596 (0.82)
Natural resource constraint	2.721 (1.64)	0.614 (0.56)	4.088* (1.68)	0.520 (0.47)	-0.620 (0.63)	-0.125** (2.16)	-1.756 (0.56)	-0.714 (0.60)	-5.322** (2.35)	-0.371 (0.38)	1.780 (1.33)	-0.714 (0.60)	-1.756 (0.56)
Household dependent ratio	-2.638 (1.43)	-1.454 (1.51)	-4.340 (1.32)	-0.768 (0.75)	-1.042 (1.24)	0.111** (2.29)	2.448 (1.25)	-1.113 (1.18)	1.201 (0.87)	-0.270 (0.34)	-1.295 (1.04)	-1.113 (1.18)	2.448 (1.25)
Years lived in the village	-0.040 (1.34)	0.029* (1.92)	0.060 (1.58)	-0.017 (1.05)	0.023* (1.68)	-0.001 (1.43)	-0.041 (0.92)	0.029* (1.68)	0.004 (0.17)	-0.001 (0.05)	0.018 (0.98)	0.029* (1.68)	-0.041 (0.92)
Gender of the household head	0.770 (1.07)	0.064 (0.19)	0.028 (0.02)	-0.322 (0.90)	0.140 (0.46)	0.004 (0.25)	0.746 (0.81)	-0.109 (0.31)	0.168 (0.30)	0.388 (1.31)	0.599 (1.24)	-0.109 (0.31)	0.746 (0.81)
Years in education of household head	0.517 (0.99)	0.199 (0.90)	-0.590 (1.34)	-0.279 (1.31)	-0.070 (0.36)	0.002 (0.21)	-0.369 (0.93)	-0.292 (0.94)	0.045 (0.16)	0.288 (1.43)	-0.131 (0.47)	-0.292 (0.94)	-0.369 (0.93)
Livestock wealth (Eth Birr)	0.000*** (4.14)	0.000 (1.15)	-0.000 (0.57)	0.000*** (6.00)	-0.000 (0.09)	0.000 (0.66)	-0.000 (1.41)	0.000 (1.35)	-0.000 (0.00)	0.000 (1.44)	-0.000 (0.71)	0.000 (1.35)	-0.000 (1.41)
Membership in community groups	-0.002 (0.00)	-0.266 (0.94)	0.427 (0.64)	-0.263 (0.89)	1.010*** (3.67)	-0.011 (0.65)	1.336*** (2.76)	0.418 (1.38)	-0.817 (1.29)	0.418* (1.76)	0.639** (2.11)	0.418 (1.38)	1.336*** (2.76)
Participation in group meeting	1.226* (1.75)	0.737** (2.29)	-0.124 (0.14)	-0.360 (1.14)	0.808*** (2.76)	-0.019 (0.65)	-0.304 (0.35)	0.307 (0.88)	-0.609 (1.28)	0.433 (1.57)	-0.847** (2.16)	0.307 (0.88)	-0.304 (0.35)
Participation in group activities	0.058 (1.07)	-0.156 (1.41)	0.080 (1.28)	-0.010 (0.15)	-0.290*** (2.88)	-0.002 (0.92)	-0.093 (0.43)	-0.163 (1.53)	-0.047 (0.39)	-0.061 (0.80)	-0.264* (1.93)	-0.163 (1.53)	-0.093 (0.43)
Constant	-10.663*** (3.01)	-2.886** (1.97)	-3.286 (0.97)	0.201 (0.14)	-2.131 (1.64)	1.092*** (10.03)	-1.028 (0.32)	0.278 (0.16)	1.975 (0.97)	-3.970*** (3.01)	-1.240 (0.71)	0.278 (0.16)	-1.028 (0.32)
Pseudo R	0.27	0.17	0.21	0.20	0.12	0.34	0.34	0.16	0.23	0.12	0.07	0.10	0.23
N	400	400	400	400	400	400	400	400	400	400	400	400	400

Table A4.8: The effect of AC on the likelihood of adopting various adaptation practices among household in the Borena region of Ethiopia

	Start trade	Use hybrid seeds	Use manure as fertiliser	Drought tolerant animals	Erosion control	Feed conservation	Joined information group	Inter cropping	More crop plots	Use hired labour	Migration	Off farm job	Crop diversity
Adaptive capacity (AC)	27.71*** (6.43)	6.35*** (3.06)	5.41 (1.12)	8.72*** (4.03)	5.96*** (2.98)	11.84 (1.46)	23.65*** (6.93)	-1.76 (0.33)	15.26*** (5.59)	7.81** (2.54)	12.79*** (5.61)	6.78*** (2.69)	15.26 (5.59)***
Constant	-11.27*** (7.64)	-2.62*** (4.22)	-5.09** (3.36)	-3.36** (5.16)	-1.82*** (3.09)	0.76 (0.35)	-5.34*** (5.81)	-2.80* (1.83)	-3.34*** (4.40)	-4.75*** (4.90)	-3.96*** (5.89)	-3.74*** (4.83)	-3.34 (4.40)***
Pseudo R	0.26	0.02	0.01	0.04	0.02	0.04	0.15	0.00	0.08	0.03	0.07	0.02	0.08
N	400	400	400	400	400	400	400	400	400	400	400	400	400

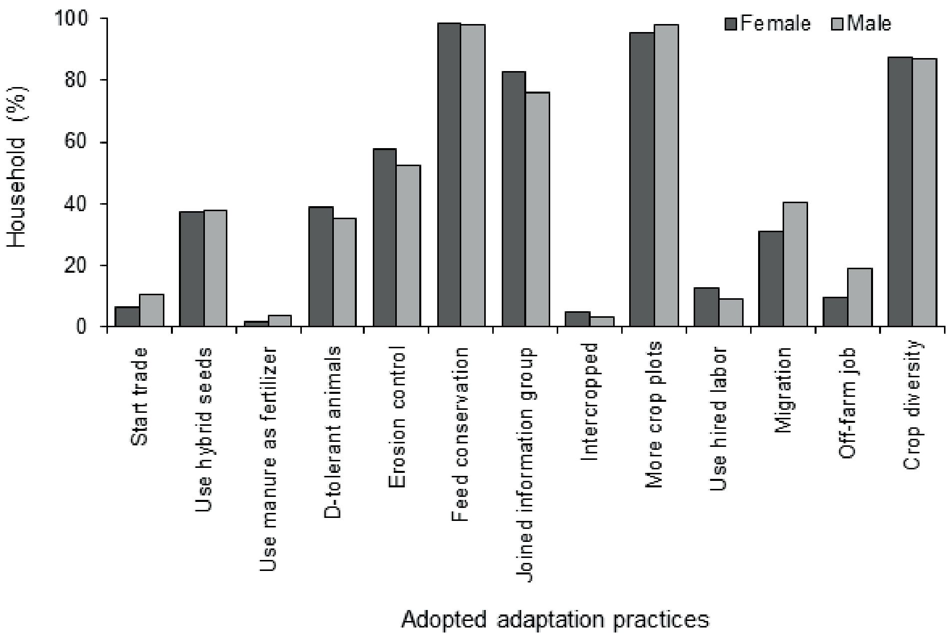

Figure A4.1: Adopted adaptation practices by gender of the household head

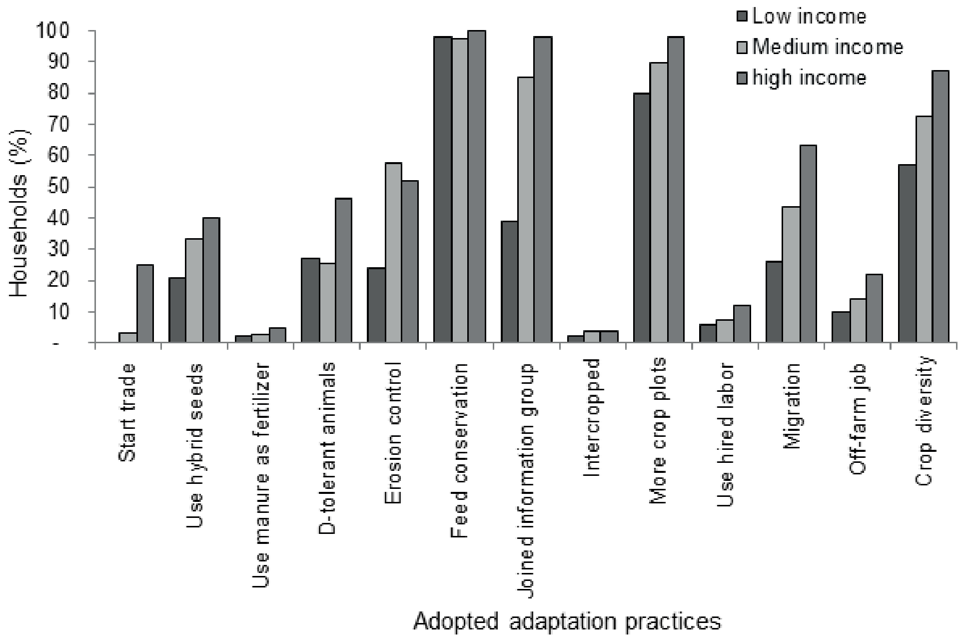

Figure A4.2: Adopted adaptation practices among households grouped by income quartiles (low, medium and high income quartiles)

Chapter 5

Adaptation and food security in agro-pastoralist systems of Northern Kenya

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Abstract

In semi-arid environments, the majority of pastoral and agro-pastoral households suffer from food insecurity and experience low farm income due to climate change-related shocks such as droughts. Using representative households data collected from the Samburu County in Kenya, we explored how improved farm management and livestock intensification coupled with an increase in market prices of farm products affect food security and farm income over a period of 25 years. We also explored the impacts of climate change via an increased probability of drought on food security and farm income. Improved farm management can improve food security by 45% and farm incomes by 31% in places where both cropping and livestock keeping are practiced. Livestock intensification can improve food security by 28% and farm incomes by 20% where only livestock are kept. An increase in price of crop and livestock products by 10% on sites where both cropping and livestock keeping are practiced can improve food security and farm income by 65% and 58%, respectively. In sites where only livestock are kept, an increase in price of livestock and livestock products by 10% can lead to an improvement in food security by 36% and 32%, respectively. In sites where both cropping and livestock are practiced, an increase in the probability of drought by 10% can lower food security by 29% and farm income by 32%. However, adapting farming (intensifying, changing livestock species) in sites where farmers practice crop-livestock farming shows potential to reduce the negative impacts caused by drought. Our findings suggest that use of fertiliser, certified seeds, early planting using the recommended plant spacing, and changing livestock types, improving livestock feeding has the potential of increasing farm income preventing pastoral and agro-pastoral households from falling deeper into food insecurity over time. These findings suggest that policies should aim to support provision of advice through agricultural extension officers or other means on how to improve farm management and livestock intensification. Policies should also aim at improving market prices for farm products by supporting investment on infrastructure such as road and communication.

Keywords: Food security, income, modelling, drought, Samburu, adapted farming, livestock intensification

This chapter is not yet submitted for publication

5.1 Introduction

In Kenya, about 84% of the land is classified as arid and semi-arid and is mainly inhabited by pastoralist and agro-pastoralists (Cynthia, 2009; Omoyo et al., 2015). Agriculture and livestock keeping are their main sources of livelihood. Semi-arid environments are characterised by variable and erratic rainfall ranging between 400-800 mm per year, with evapotranspiration exceeding rainfall most of the time (Thomas, 2011). Variability in food supply in semi-arid systems is mainly driven by environmental effects on agricultural production and fluctuations in prices of cereals and livestock (Falkenmark and Rockström 2008; IPCC, 2014). Following a drought, people in semi-arid regions experience shortages in food and are highly food insecure (Di Falco and Chavas, 2009; Schlenker and Lobell, 2010).

Negative impacts of weather shocks on food security are likely to increase in the future, especially among poor households, who have weak adaptive capacity (Thornton et al., 2011). Food security refers to a "situation that exists when all people, at all times, have physical and economic access to sufficient, safe, nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organisation (FAO), 1996). The definition of food security encompasses four main pillars: food availability, economic and physical access, food utilization, and stability of the three dimensions. Food self-sufficiency refers to being able to meet consumption needs from own production rather than buying or importing (Minot, 2010). Food self-sufficiency and farm income as used in this paper represent the access pillar of food security.

Households at great risk of food insecurity try to adapt to achieve food self-sufficiency (de Sherbinin et al., 2008; De Waal and Whiteside, 2003; Ickowitz et al., 2014). According to IPCC (2013), adaptation is defined as adjustments of human or natural systems in response to actual stimuli with the aim of moderating harm. Evidence shows that households' ability to adapt relates to the quality of the environment where they make a livelihood: adaptive capacity seems to be higher in drier environments

(Speranza et al., 2008; Rufino et al., 2013; Thornton et al., 2011). Kristjanson et al. (2012) shows that a household's ability to adopt new farming practices is positively related to food security. Some of the adaptation practices being adopted by households in semi-arid areas of Kenya include changing crop varieties to drought resistant, changing of livestock types (Bryan et al., 2009), and diversification into off-farm income generating activities (Silvestri et al., 2012).

The prevalence of food insecurity resulting from droughts in semi-arid areas of Kenya has increased tremendously over the past several decades (eNews Channel Africa, 2014; Mwadalu and Mwangi, 2013). Some of the hypothesized drivers of food security are household assets, premised on the idea that what households own (i.e., assets) and access to resources (i.e., how they negotiate grazing areas and ability to acquire credit) could help them to become food secure (Deressa et al., 2009; Lin and Yang, 2000; Molua, 2002; van der Geest and Dietz, 2004 Pp 125). Persistent food insecurity may impede households' ability to invest in assets that are critical for consumption smoothing and store of wealth (Hoddinott, 2006; Sutherland et al., 1999). Farm income enables households to adopt new technologies and farm inputs (i.e., machinery) to boost farm production and revenue (Mabiso et al., 2014). When farmers earn low farm income, they tend to direct most of it toward consumption and this may lower their ability to save (Serra et al., 2004). Inability to save may, in turn, affect households' allocation of income (Dercon, 2002). The empirical evidence shows that long-term goals of food security are not only connected to food self-sufficiency but also to the generation of farm income, and that adaptation options have to be diverse enough for a range of rural household to adopt what fits their needs (Ritzema et al., 2017; Rufino et al., 2013).

Adoption of practices that increase land productivity may increase food self-sufficiency, whereas other practices may generate more farm income and hence improve food security (Deressa et al., 2008, 2009). However, some practices are likely to benefit some households more than others, and that depends on the state of the environment where people grow their crops and keep their livestock, and some specific household characteristics (Ritzema et al., 2017). In some cases, the effectiveness of new practices supported by government policies depends on higher-level determinants, such as market access, and social support networks (Dethier and Effenberger, 2012). Researchers can use models to explore ex-ante the impact of different practices on achieving a goal and given a set of resource constraints households' face. Such analyses are useful to assess different technological and policy interventions and their trade-offs (Thornton and Herrero, 2001). Given the risky environment in which most agro-pastoral households live, exploring the impact of policy interventions and adaptation practices on food security and expected farm incomes can help us to identify what are their likely impacts on food security and income for a diverse population (Herrero et al., 2014).

Food security requires an effective food and economic production system (Yang and Hanson, 2009). Increasing productivity in food systems can improve food security through higher farm income generation (Yang and Hanson, 2009). Higher farm income, in turn, can improve households' livelihood and food security (Burchi and De Muro, 2016). Ex-ante impact assessment can help decision makers in targeting and upscaling the appropriate adaptation practices, and farm household models have often been used for this purpose (Paul et al., 2017), however ex-ante analysis of how different technologies impact food security at the household level are still scarce (van Wijk et al., 2014). The approach used in recent studies is to capture the diversity of farming systems with a limited number of farm types, using resource endowment and/or production goals as a clustering factors. The potential impacts for the different farm types are then quantified and scaled up depending on the relative importance of each farm types (e.g., Tittonell et al., 2010).

The objective of this paper is to advance our understanding of how the adoption of adaptation practices can support food security in diverse agro-pastoralist households. We use household-level data and a dynamic programming household model to assess the impact of adaptation practices and policies by way of scenarios on food security and farm income. The analyses include current farm resources such as cropland, labour, livestock, and search for optimal allocations that maximise household food security and income. Data were collected on household size, livestock and crop yield, quantities of crop and livestock product consumed and sold, market prices for crop yield, livestock and livestock products, the cost of inputs, and household perception on the frequency of occurrence of drought. We used a different sequence of drought, and hence a different possible “futures” to try and quantify how often food security cannot be guaranteed for different policy scenarios.

We find that adapted farming (i.e., use of certified seeds, recommended plant spacing and seeds per hole, planting before the onset of rains, using fertiliser, and soil conservation) and livestock intensification (i.e., change of livestock, grazing livestock on pastures that are well managed, and supplementing with crop residues) has the potential to decrease food insecurity for agro-pastoral households. This is because adapted farming increases crop and livestock yield thereby increasing food for consumption and for sale. We also find that adapted farming and livestock intensification through the increase in yield and increase in households’ income has the potential to boost food security and income among agro-pastoral households, even in cases where the probability of drought occurrence may increase. Our results contribute to the ex-ante impact assessment literature and speak to policies for supporting the implementation of targeted interventions that can help improve food security and income in semi-arid environments.

5.2. Methods

5.2.1 Study site and sampling strategy

The study was carried out in the Samburu County located between 00^{o} 36' - 02^{o} 40' N and 36^{o} 20' - 38^{o} 10' E, in the Rift Valley Province of Kenya. The county consists of vast alluvial inland plains, ranging from an altitude of about 1,000 to 2,752 masl in the highlands. The county covers an area of about 21,000 km^2 with a population density of 11 inhabitants per km^2 (Government of Kenya, 2009a). According to the climatological classification of Peel at al., (2007) the county is part of the arid tropical climate with two short sub-humid seasons. Mean monthly temperature ranges from 24^{o}C (July) to 33^{o}C

(December) (Government of Kenya, 2009b). Rainfall concentrates in two seasons: the long rains from March to May, and short rains from October to December. The county is the fifth poorest in Kenya, with 77% of the households considered living below the poverty line[26] (Kenya National Bureau of Statistics (KNBS) and Society for International Development (SID), 2013). Pastoralism is the main source of livelihood in Samburu County, with goats, sheep, cattle, and camels as the main livestock species (Government of Kenya, 2009b). Cash for buying maize is derived mainly from livestock sales and off-farm income. Wage labour (mainly from herding) and petty trade (mainly for households living close to urban centres) to supplement household income are also common.

Site selection was done purposively to take into account environmental dryness and market access, thereby capturing the variation in agricultural potential, distance to the market for input and produce, and rainfall variability in the region (Fig. 5.1). We first distinguished 3 locations along the "wetter or good market access" gradient: near an urban centre (Cropping/good market access [CG] (Table 5.1)), medium distance from an urban centre (Cropping/moderate market access [CM]) and far away from an urban centre (Mixed farming/moderate market access [MM]). Along the "wetter or good market" access gradient, the geophysical conditions are rather constant (i.e. similar annual rainfall), while the distance to the urban market increased. The three locations are hereby referred to as 'wetter'. Then, using the location at the medium distance (Cropping/moderate market access [CM]) of the "wetter or good market access" gradient as a starting point, we developed a second gradient the "drier or poor market access" gradient that was (orthogonal to the "wetter" gradient) by moving North (i.e., to livestock farming/low market access [LL] and livestock farming/very poor market access [LVL]). Along the "drier or poor market access" gradient the mean rainfall per annum decreases from 600 mm in LL to about 500 mm in LVL and rains become more unpredictable (i.e., the mean of coefficient of variation increases from 0.14 to 0.16), and as distance from the main urban centre increases from 70 to 100 km.

[26] Poverty line is a threshold below which people are deemed poor.

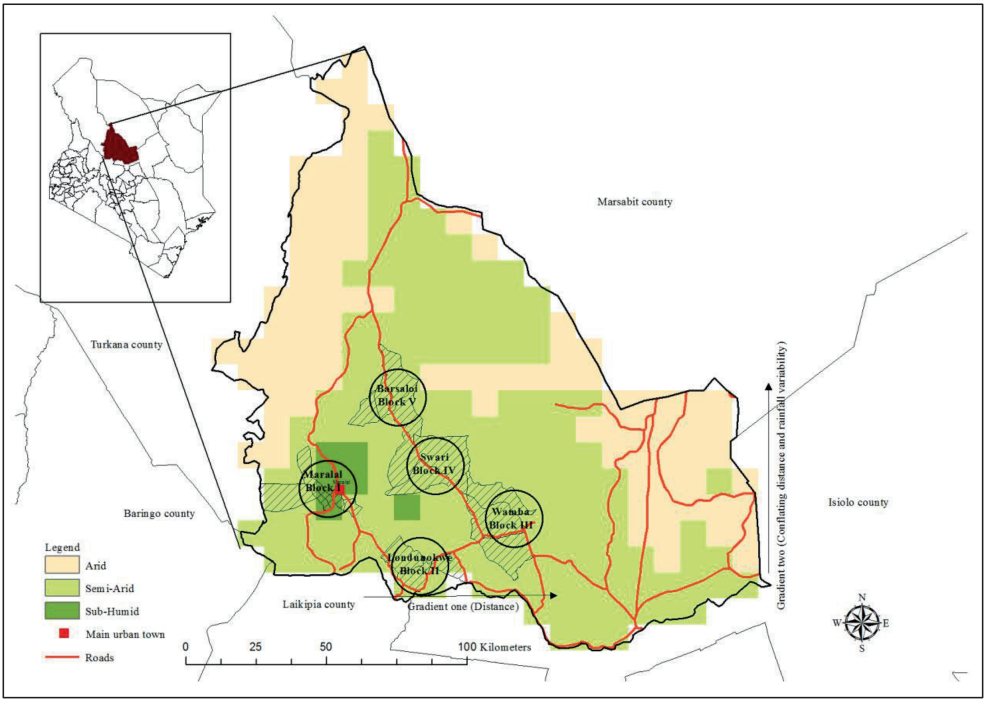

Figure 5.1: Map of Kenya showing Samburu County and the five Locations (Maralal, Londunokwe, Wamba, Swari and Barsaloi) from which our sample households were selected. We refer to Maralal, Londunokwe, Wamba, Swari and Barsaloi as Cropping /good market access [CG], Cropping /moderate market access [CM] Mixed farming /moderate market access [MM) Livestock farming /low market access [LL], and Livestock farming /very low market access [LVL] respectively

Table 5.1: Description of the five study sites from Samburu County in Kenya

Variables	Site 1: Cropping /good market access *[CG]*	Site 2: Cropping /moderate market access *[CM]*	Site 3: Mixed farming /moderate market access *[MM)*	Site 4: Livestock farming /low market access *[LL]*	Site 5: Livestock farming /very low market access *[LVL]*
Agricultural potential	Good	Moderate	Moderate	Low	Very low
Arable land for cropping	Large ($\overline{x}$ = 2.37 ha)	Moderate ($\overline{x}$ = 0.64 ha)	Small ($\overline{x}$ = 0.10 ha)	No cropping	No cropping
Livestock farming	Cattle ($\overline{x}$ = 13±14) Goats ($\overline{x}$ = 37±56) Sheep ($\overline{x}$ = 44±53) Camels ($\overline{x}$ = 1±1)	Cattle ($\overline{x}$ =12±13) Goats ($\overline{x}$ = 50±56) Sheep ($\overline{x}$ = 22±25) Camels ($\overline{x}$ = 1±1)	Cattle ($\overline{x}$ = 10±14) Goat ($\overline{x}$ = 32±33) Sheep ($\overline{x}$ = 14±19) Camels ($\overline{x}$ = 1±3)	Cattle ($\overline{x}$ = 12±13) Goats ($\overline{x}$ = 59±56) Sheep ($\overline{x}$ = 19±28) Camels ($\overline{x}$ = 4±7)	Cattle ($\overline{x}$ = 10±13) Goats ($\overline{x}$ = 45±53) Sheep ($\overline{x}$ = 19±31) Camels ($\overline{x}$ = 3±8)
Forest/shrubs	Forest	Open savannah Woodland	Open savannah Woodland	Open savannah Woodland	Open savannah Woodland
Market access	Good	Moderate	Moderate	Poor	Very poor
Road quality	Good	Moderate	Moderate	Poor	Very poor
Walking time to the main market (hours)	<1	3	5	10	16
Mobile phone network	Good	Moderate	Good	Poor	Very poor
Electricity	Present	Absent	Present	Absent	Absent
Hospitals	County hospital, private medical clinics	One dispensary	One hospital	One dispensary	None
Government officers presence	Several	Chiefs office	Chiefs office	Chiefs office	Chiefs office
Police station	Present	Absent	Present	Absent	Absent
Markets	Main urban market	A road side market	A road side market	A shopping centre	A shopping centre
Schools	Several (primary and secondary)	None	Several (primary and secondary)	None	One primary school
Non-Government organisations (NGO's)	Many NGO's	None	Few NGO's	None	None

We selected households using a multi-stage cluster sampling strategy. From each of the five locations mentioned above we randomly sampled three sub-locations, from which we randomly selected 10 villages. With the aid of local chiefs, we produced a full list of households for each of the 50 villages. All households in a village were eligible to participate. Subsequently, 10 households were randomly selected. Hence, our sample size is 100 households per location and 500 households in total. The surveys were conducted between February and May 2012 during the long rains. The surveys were conducted using structured questionnaires and trained local enumerators to collect detailed information on household composition, livelihood strategies assets, land, livestock ownership, management and social capital. Detailed information on crop harvested, inputs (i.e., seeds and fertilizers), yield and prices were recorded for each household. Information on livestock (species, breeds, number, input and management cost) and other assets such as land (used) were collected. We also collected data on household-reported food items produced on-farm.

5.2.2 Food security indicators

Energy available for each household was calculated based on crop and livestock production data and food consumption. The food self-sufficiency ratio (FSSR) is a measure of ability of the households to satisfy consumption needs through own production (Eq. 5.2), calculated using World Health Organization (WHO) standards. The food security ratio (FSR) is an estimate of energy available based on food items produced on-farm and those reported to have been purchased by the households on a weekly basis, but the indicator is calculated on an annual basis (Eq. 5.1). Although the contribution of the sold farm produce to FSR is likely to reflect the differences in production and consumption among farm households within and across sites, we included food availability ratio (FAR) to access the potential contribution of other sources of income (Frelat et al., 2016). The FAR shows the upper boundary of food availability under the current production levels. Therefore, FAR is a measure of the energy that can potentially be consumed by the household based on annual crop production, livestock production, food sales and consumption, and off-farm income. We used this data to calculate a FAR (Eq. 5.3) as the sum of total available energy in the household divided by total energy requirements for the family. A food availability ratio greater than one implies that the family has access to surplus energy above their requirements.

$$\mathrm{FSR}_h = \frac{\sum_{l=1}^{p}(QtyC_l \times E_l) + (QtyS_l \times P_l \times cKcal)}{\sum_{c=1}^{r} K_c} \quad (5.1)$$

$$\mathrm{FSSR}_h = \frac{\sum_{l=1}^{p}(QtyC_l \times E_l)}{\sum_{c=1}^{r} K_c} \quad (5.2)$$

$$\mathrm{FAR}_h = \frac{\sum_{l=1}^{p}(QtyC_l \times E_l) + (QtyS_l \times P_l \times cKcal) + (offinc_h \times cKcal)}{\sum_{c=1}^{r} K_c} \quad (5.3)$$

Where FSR_h, FSSR_h, FAR_h is the food security, food self-sufficiency and food availability ratio for household h,

$QtyC_l$ represents quantity of food item l produced on-farm that is consumed in the household (kg or litre),

$QtyS_l$ represents quantity if food item l produced on-farm but sold (kg or litre),

$QtyP_l$ represents quantity of food item l purchased that is consumed (kg or litre),

E_l represents energy content of food item l (MJ kg^{-1} or litre),

P_l represents price (in KSh) of food item l (MJ kg^{-1} or litre),

Kcal represents equivalent amount of energy contained in one kilogram of maize in MJ that KSh100 (or US$ 1)[27] can purchase. The price of one kilogram of maize was KSh 40. The energy density in one kilogram of maize used is about 15.24MJ (USDA, 2015)

offinc_h represents off-farm income for household h,

K_c represents energy requirement in MJ per capita for c member, and

r represents the number of members in household h.

The relative contribution of crops sold and consumed, livestock sold and consumed, and off-farm income to the food availability ratio was calculated by first converting crop sold and consumed, livestock sold and consumed and off-farm income into energy, that was then summed up. The total energy was then divided by the total

[27] At the time of the survey the exchange rate for US$ 1 was about KSh 100.

amount of energy that the household needs. Off-farm income is the sum of cash earned from all off-farm activities that the household members engage in.

5.2.3 Model description

A dynamic programming household model was developed to allocate farming activities to maximize expected farm income (Eq. 5.4) subject to a number of constraints.
The objective function is represented as:

$$E(\pi) = \sum_{i=1}^{n}(E(HarvestCrop_i) \times PriceCrop_i) + \sum_{j=1}^{m}\left(E\left(ValAnimalProd_j\right)\right) - \sum_{i=1}^{n}(CropCost_i \times AreaCrop_i) - \sum_{i=1}^{m}\left(E\left(AnimalHerd_j\right) \times AnimalCost_j\right) \quad (5.4)$$

Where $E(\pi)$ represents the expected farm income; $E(HarvestCrop_i)$ represents the expected annual harvest of crops i (i.e., maize and beans); $PriceCrop_i$ represents price per kilogram of crop harvest associated with crop i; $E\left(ValAnimalProd_j\right)$ represents the expected value of an animal product (i.e., milk or head of animal) belonging to jth species (calculated as shown in Eq. 5.9); $E\left(AnimalHerd_j\right)$ represents the expected heads of animals belonging to jth species; $CropCost_i$ represents the annual cost of inputs (e.g., seeds and fertiliser) per hectare associated with production of crop i, $AreaCrop_i$ represents the land area in hectares occupied by crop i; $AnimalCost_j$ represents annual cost of inputs (e.g., veterinary drugs and mineral supplements) associated with producing an animal belonging to j^{th} species; and $PriceCrop_i, CropCost_i, AreaCrop_i, AnimalCost_j, E\left(AnimalHerd_j\right)$, $E(HarvestCrop_i), E\left(ValAnimalProd_j\right) \geq 0$.

A household is assumed to maximize expected farm income, which can be used to purchase food to achieve food security. The most essential components that households in Samburu could spend their farm income on include clothes, medication, school fees, and food. The household is expected to maximize their expected farm income subject to the following constraints (Eq. 5.5 – Eq. 5.9):

i. $E(HarvestCrop_i) = \{A(LabourCrop_i{}^{\beta} AreaCrop_i{}^{1-\beta})\}\omega + (1 - \omega)\{A(LabourCrop_i{}^{\beta} AreaCrop_i{}^{1-\beta})\}\varphi$ (5.5)

where $E(HarvestCrop_i)$ represents the expected annual harvest associated with crop i that is produced using the inputs $LabourCrop_i$ and $AreaCrop_i$; $LabourCrop_i$ represents the amount of annual labour associated with production of crop i; $AreaCrop_i$ represents the physical land area occupied by crop i; A represent the total factor productivity that measures the change in $HarvestCrop_i$ that is not as a result of the inputs; ω represents the probability of a good weather and $\omega \in (0,1)$; $(1-\omega)$ represents the probability of a drought; the superscripts β and $(1-\beta)$ represents output elasticity of inputs (i.e., the change in $E(HarvestCrop_i)$ that results from a change in either $LabourCrop_i$ or $AreaCrop_i$; φ is an index for the loss associated with $E(HarvestCrop_i)$ when drought occurs. We assumed that when a drought occurs, a half of the crop harvest is lost (i.e., $\emptyset = 0.50(i.e., 1 - 0.50)$[28], and $HarvestCrop_i, AreaCrop_i, LabourCrop_i \geq 0$.

ii. $HHlabour \geq LabourCrop_i + LabourAnimal_j$ (5.6)

where $HHlabour$ represents the total available household labour; $LabourCrop_i$ represents annual labour associated with crops production; $LabourAnimal_j$ represents annual labour associated with animal production, $HHlabour, LabourCrop_i$, $LabourAnimal_j \geq 0$.

iii. $Arableland \geq \sum_{i=1}^{n}(AreaCrop_i)$ (5.7)

where $Arableland$ represents the total available arable land for the household; $\sum_{i=1}^{n}(AreaCrop_i)$ represents annual sum of land area occupied by different crops on the farm. We assumed that the soil fertility level was similar across all plots and sites. In Samburu County, except in areas around Maralal town where the county government is responsible for land allocation, land is communally owned. The arable land area for cropping depends on the labour available and other farm assets.

[28] This assumption is based the data from households in which about 60% of households in cropping sites reported that during the 2011 drought they lost about 50% of their harvest.

iv.

$$E(AnimalHerd_{j,t+1}) = \{(1+gr)[Z(LabourAnimal_j{}^{\alpha} AnimalHerd_j{}^{1-\alpha})]\omega\} + \{(1-\omega)[Z(LabourAnimal_j{}^{\alpha} AnimalHerd_j{}^{1-\alpha})]\emptyset\} - \{[HarvestAn_j]\omega\} + \{(1-\omega)[HarvestAn_j]\tau\} \qquad (5.8)$$

where $E(AnimalHerd_{j,t+1})$ represents the expected herd size of livestock of jth species at time $t+1$; gr represents the rate of herd growth (for this study we assumed a herd growth of 7% and 28% for the cattle and shoats respectively)[29]; $LabourAnimal_j$ represents annual labour associated with production of an animal of jth species; $AnimalHerd_{j,t}$ represents the herd size of animal of jth species at time t (where $t = 0$); $HarvestAn_j$ represents the head of animals of jth species disposed annually and it is a choice variable (based on offtake rates from the field survey); τ is an index representing the loss in offtake of animals of jth species, when drought occurs (we assume that harvest decline by 50% when drought occurs); ω represents the probability of a good weather and $\omega \in (0,1)$; $(1-\omega)$ represents the probability of a drought; the superscripts α and $(1-\alpha)$ represents output elasticity of inputs (i.e., the change in $E(AnimalHerd_{j,t+1})$ that results from a change in either $LabourAnimal_j$ or $AnimalHerd_j$; $\emptyset$ represent loss (i.e., through death) of animals in the herd due to drought. We assumed that when a drought occurs, a quarter of the animal herd is lost through death (i.e., $\emptyset = 0.75(i.e., 1-0.25)$; Z represent the total factor productivity that measures the change in $E(AnimalHerd_{j,t+1})$

v.

$$E(ValAnimalProd_j) = \{([HarvestAn_j]\omega) \times PriceAn_j\} + \{((1-\omega)[HarvestAn_j]\tau) \times PriceAn_j\} + \{(\delta_j \times 0.25[AnimalHerd_j])\omega \times PriceMilk_j\} + \{((1-\omega)(\delta_j \times 0.25[AnimalHerd_j]))\theta \times PriceMilk_j\} \qquad (5.9)$$

[29] This assumption is based on the growth rates of 8-11% for cattle and 28-35% for shoats, and based on calving rate of about 45-55% estimated in Samburu district (Spencer, 1973; Dahl and Hjort, 1976).

where $E(ValAnimalProd_j)$ represents expected value of the offtake of animal products (i.e., milk or head of animals) from livestock of jth species; $HarvestAn_j$ represents the head of animals of jth species disposed annually and it is a choice variable (based on data from field survey); $PriceAn_j$ represent the price per head of animal of jth species; δ_j represents annual quantity of milk produced by an animal of jth species (we assume that only a quarter of the herd (i.e., $0.25[AnimalHerd_j]$) is lactating annually; $PriceMilk_j$ represent the price per kilogram of milk of jth species; ω represents the probability of a good weather and $\omega \in (0,1)$; $(1-\omega)$ represents the probability of a drought; θ is an index representing the loss associated to quantity of milk produced by livestock of jth species, when drought occurs (we assume that milk production decline by 50% when drought occurs); and τ is an index representing the loss in milk when drought occurs;

Using the result from the model, we calculate the 'potential'[30] FSR for the household and household income per capita per day as shown in Eq. 5.10 and Eq. 5.11 respectively.

$$PotFSR_{\mathrm{h}} = \frac{\{\pi\} \times Kcal}{\sum_{c=1}^{r} K_c} \tag{5.10}$$

Where $PotFSR_{\mathrm{h}}$ represent the potential food security ratio for household h; $\{(\pi)\}$ represent the realized farm income converted in KSh; $Kcal$ represents equivalent amount of energy in MJ that one US dollar can purchase; K_c represents energy requirement in MJ per capita per year (as per WHO requirement) for c member; and r represents the number of members in household h.

$$PerCapInc = \frac{\{\pi\}}{r \times 365} \tag{5.11}$$

Where $PerCapInc$ represent the income (in KSh) per capita per day for members in a household h; $\{(\pi)\}$ represent the realized farm income converted in KSh; 365 represent the number of days in a year; r represents the number of household members (in adult equivalent) in household h.

[30] Potential because we are assuming that households use the expected farm income mainly for buying food.

5.2.4 Model implementation

We explored the consequences on food security (FSR) and farm income (income capita^{-1} day^{-1}) of crop failure, and livestock mortality due to drought. We assessed the probability distribution of FSR and income per capita over a period of 25 years. Droughts deplete household reserves and assets accumulated in good years.

The Microsoft EXCEL 2007 Solver was used to identify the optimal combination of activities that maximize the expected farm income subject to the constraints (Eq. 5.5 - Eq. 5.9). Once the model was set up using mean crop and livestock yields, harvest prices and input costs extracted from the survey, the optimisation was solved for one year first. This was followed by calibration of the model as explained in Appendix 5.1 until the output results from the model (i.e., the optimal baseline model) were similar to the observed results for the average farm for each site. The baseline model was then used as starting point for subsequent dynamic optimisation over a period of 25 years. Optimisation occurs every year and the herd sizes from the previous year are used as the initial condition for the next period. Once the model was solved for the 25 years, we solved the model again using Monte Carlo simulation (n=5000). For each run, we used a different sequence of drought (the only stochastic variable in the model) and hence a possible future. By using Monte Carlo simulations, we consider 5000 possible futures for a representative household, and estimate the distribution of food security outcomes and expected farm income. We assumed that over that period, crop and livestock production is not affected by other socio-economic changes (i.e., changes in land size, community conflicts etc.). The dynamic optimisation takes into account the yield variability as determined by the occurrence of drought. To represent the stochasticity in production associated with drought, we included loss indices associated with drought (see Eq.5.5, Eq. 5.8 and Eq. 5.9). We assumed that in a year of drought the household loses about 50% of crop harvest, 25% of the herd, and 50% of milk yield. The key assumptions in this approach are: (i) herders are risk neutral and only care about expected income, (ii) households not look into the future but respond to current or perceived risks and/or opportunity, and, (iii) we disregard seasonality in production and only look at an average income and consumption.

5.2.5 Description of the sites

Crop-livestock farming is practiced in three of the five sites (i.e., cropping/good market access (CG), cropping/moderate access (CM), and mixed farming/moderate access (MM)) while solely livestock keeping is practiced in two sites (i.e., livestock/low market access (LL) and livestock/very low market access (LVL)). We performed the modelling exercise using representative farm households from CM and LVL. Site CM was considered as a representative for sites where both crop-livestock farming is practiced while LVL was considered as a representative of sites where households keep livestock only. At the study sites, farmers grow a variety of crops such as maize *(Zea mays)*, common bean (*Phaseolus vulgaris*), potato (*Solanum tuberosum),* pigeonpea (*Cajanus cajan*), cowpea (*Vigna unguiculata*), kale and cabbage (*Brassica* spp.) and onion (*Allium cepa*). In the explorations, we only considered maize and beans because these crops are grown by a majority (over 90%) of the households, while only 20% and 13% of the households grow potatoes and kales. Other crops such as pigeonpea, cowpea, cabbage, and onion are grown by less than 3% of the households. Households keep cattle, shoats (sheep and goats) and camels. Cattle, sheep, and goats were considered in the modelling exploration in both sites. However, camels were only included in the modelling exploration in LVL. Camels were not included in the modelling exploration in CM because less than 10% of the household keep camels.

5.2.6 Scenarios

<u>Baseline scenario (*'Current farming'*)</u>

The allocation of land to crops at each site is that observed on-farm (Table 5.2). Farm income is estimated based on current prices for crops and livestock products. The cost of agricultural inputs for crops and livestock is as reported by households. Livestock (cattle, sheep, goats, and camels) numbers are as observed on-farm. Sales of livestock are based on offtake rates obtained during the field survey. Off-farm income is not taken into account in the model. In this scenario, farmers are maximizing expected farm income given the resources available: land available, local seeds, no fertilizers, no soil conservation measures and no application of livestock manure to crops. We assume households use the crop and livestock harvest for income generation. Household use the income realized to buy food. Calculation of income is based on current cost of livestock inputs and prices for livestock products (Table 5.2). The farm household bears the cost of production (i.e., no subsidies). We assume that farmers use the realized farm income to help meet their consumption needs over time. We assume that drought occurs once every four years.

Table 5.2: Parameters used in the model

Variables	Cropping/Moderate market access (CM)		Livestock farming/Very low market access (LVL)	
Land	Mean	Standard deviation	Mean	Standard deviation
Total cropland (ha)	0.23	±0.65	0	0
Maize area (ha)	0.08	±0.05	0	0
Beans area (ha)	0.14	±0.07	0	0
Crop yield (kg) ha^{-1}				
Maize	115	±280	0	0
Beans	416	±991	0	0
Cost (KSh) of crop production ha^{-1}				
Maize	504	±1504	0	0
Beans	728	±1645	0	0
Herd size (#)				
Cattle(#)	12	±13	10	±13
Goats (#)	50	±56	45	±53
Sheep (#)	22	±25	19	±31
Camels (#)	1	±2	3	±8
Livestock yield (litres) $year^{-1}$				
Cattle	103	±79	95	±104
Goats	11	±15	16	±18
Sheep	18	±23	22	±47
Camels	300	±19	157	±137
Cost (KSh) of livestock production $year^{-1}$				
Cattle	2,840	±317	1,755	±170
Goats	432	±25	468	±11
Sheep	432	±25	468	±11
Camel	612	±22	600	±13
Price (KSh) per litre of milk				
Cattle	32	±39	65	±28
Goats	36	±40	63	±26
Sheep	35	±40	70	±68
Camel	86	±15	82	±23
Price (KSh) per animal				
Cattle	17,250	±6,102	13,214	±3,550
Goats	2,800	±1,417	2,110	±1,056
Sheep	2,269	±1,315	1,691	±786
Camel	28,000	±9,626	22,428	±7,733
Livestock off-take rates $year^{-1}$				
Cattle	0.01	±0.05	0.01	±0.04
Goats	0.08	±0.50	0.07	±0.33
Sheep	0.01	±0.06	0.02	±0.11
Camel	0		0.004	±0.03
n	100		100	

Scenario 1: Improved farm management (*'Adapted farming'*)

In this scenario, we assume higher crop yield due to adapted farming. Crops sold include maize, and beans. However, crops and livestock yield are modified from 'as observed on-farm' to 'the adapted yield'. Adapted yield refers to the crop yield per hectare and livestock yield per animal per year that farmers could obtain under improved farm management (Samburu County, 2013a). Improved management for crop production involves farmers implementing advice offered by the agricultural extension agents, using fertilizer (i.e., 50 kg of triple super phosphate (TSP) fertiliser per hectare), conserving soils and using certified seeds (e.g., fast maturing maize DH04), preparing land early enough, planting at least 2 weeks before onset of the rains, adhering to the recommended spacing of 75 x 60 cm and planting two maize seeds per hole (Biovision, 2014, 2009; National drought management authority, 2015; Wambugu et al., 2012). Improved livestock yield is obtained by grazing livestock on pastures that are well managed through the use of enclosures[31] (fencing patches with grass for use during the dry period), and supplemented with maize stover and beans residues from own farm. This scenario applies to CM where crop farming is practiced. Crop market prices used are those reported by the households but adjusted downward by 5%, assuming that when yield increases local prices adjust downward by 5%. Farmers bear the additional costs for fertilizer (50 kg of TSP at KSh 20 per kg), certified maize beans seeds (20 kg of certified at KSh 110 per kg), better quality beans seeds (20 kg of certified quality seeds at KSh 130 per kg) associated with adapted yield. Farmers also bear the cost of soil conservation measures, harvesting of maize stover and conserving it as feed for livestock. We assume that households spend at least three days per month doing soil cultivation. The wage rate is estimated at KSh 260 per day. We assume that it cost the household about KSh 10,000 to construct a good structure for conserving maize stovers. We assume that drought occurs once every four years.

[31] Enclosures as explained by the experts during focus group discussions, refers to areas that are demarcated by the community elder for livestock grazing only during the dry season. Those farmers found grazing during the wet season are subjected to a penalty (i.e., a bull) as a punishment to ensure adherence to the rules. These enclosures are opened and closed for grazing by the community elders. However, they consult the community widely before making any decision.

Scenario 2: Barriers of access to information are removed and prices for crop and livestock yield increase (*'Price increase'*)

Crops for sale are those reported by households using the adapted yield, costs and prices associated with '*Adapted farming*'. This scenario is an incremental scenario (i.e., improved yield plus better prices). We did not take into account household off-farm income. However, price of crop and livestock yield is increased in steps (i.e., 10% at first, then to 20%) due to an assumed increase of flow of information which helps households to sell their produce at the time when demand is high and prices are good (i.e., during the dry season). Increased information flows could be due to an improvement of mobile phone signal, increased investment in rural areas by telecommunication companies, supported by the government. Good flow of information and business opportunities could also be due to increased investment in roads, such as those earmarked for improvement by Samburu County government (Samburu County, 2013b). For example, the main road from Maralal to Nyahururu is a dirt road which hampers the movement of livestock for sale from Samburu to major towns such as Nyahururu, Nakuru, and Nairobi. Assuming that this road is improved to be an all-weather road as planned by the county (Samburu County, 2013b), it could increase access to markets by farmers and attract livestock traders from other major towns. Improved business opportunities could also be as a result of improvement of livestock holding structures during markets days, rehabilitation of livestock sale yards (including loading ramps), and installation of cattle weighing machines (Samburu County, 2013b).

Scenario 3: Climate change and probability of drought increases (*Drought increases*)

In this scenario, we assume that households could use the realized income to purchase food. Crops sold are those from the survey using current yields, costs and prices. We did not take into account household off-farm income. However, the probability of drought increases from the current drought probability of 25% to about 45% in steps (i.e., 35% at first, then to 45%). This scenario is an incremental scenario (i.e., improved yield plus drought increase). The price of crop and livestock yield increases by 5%, 10% and 15% when weather shocks is at 25%, 35% and 45% respectively. We assume that household livestock numbers change such that when drought occurs the household losses a quarter of the herd (i.e., 25%). Off-farm income is not taken into account in this scenario. We assume that households use farm income realized to purchase food.

Scenario 4 Household adapts by changing livestock types and intensifying livestock production (*'Change livestock & intensify'*)

We assume that households change their livestock type by selling cattle (using reported offtake rate) and buying small ruminants (i.e., shoats) using yield, cost, and prices recorded during the survey. The adaptation by changing livestock types and intensifying livestock production is only in sites LVL where crop farming is not practiced. During the survey, households pointed that changing livestock from cattle to shoats does not require new farm structures. Therefore, we assumed that no new investments are needed. We assume that about 80% of the income realized from the sale of cattle is used in buying shoats, while the remaining 20% is used for improving the livestock management and feeding of lactating cows. We assume there is an improvement in the quality of pastures brought about by introducing enclosures and strict adherence to the rules regulating the use of enclosures. We assume that households spend at least three days per month doing soil conservation activities aimed at enhancing the grass quality at the enclosure. Livestock in Samburu County are normally grazed on communal rangelands, however, with well-regulated enclosures; we assume that the livestock walks less in search for pastures. Reduced movement results in more milk yield, the cost of production is lower because the animals are less prone to diseases, mortality is lower, calving rates and offtake rates are higher, and livestock fetches better prices in the market (de Ridder et al., 2015). Milk yields are adjusted from observed (0.5 litre per day) to 1 litre/day per cow per day. We assumed on average that a quarter of the herd is lactating year round and that in addition to grazing on pastures they are supplemented with grasses that are cut in the hilly areas or areas close to the forest. Each lactating cow receives a quarter 'backload' of grass per day using the prevailing cost of livestock feeds in the local market at KSh 50. The farmers bear the cost of supplementation. We did not take into account household off-farm income. We assume that drought occurs once every four years.

For each simulation, the model keeps track of farm income and FSR. We report the changes in the distribution of food security (i.e., FSR) and farmers' income (i.e., income capita^{-1} day^{-1}) over 25 years and the implication of improved farming, improved market prices, livestock intensification and climate change as outlined in scenarios 1 to 4.

5.3 Results

5.3.1 Food self-sufficiency, food security and food availability

Our empirical analyses show that households in Samburu County experience food shortages, especially at the drier sites. Households who experience food shortage for about four months increases from nil in cropping/moderate access (CM) to about 26% in livestock/very low market access (LVL) (Table 5.3). FSSR is higher in cropping/good market access (CG) than at other sites ($p<0.05$) (Fig. 5.2a), presumably because households have larger croplands at CG (Table 5.1). FSR is similar across all sites. FAR in LL is only higher ($p<0.05$) than at CM, which is related to the larger energy available from livestock products (sold and consumed) and larger herd size in livestock/low market access (LL) than in all other sites ($p<0.05$). Herd size is an important component of FAR in most sites. The capacity to save money among households is also related to a higher FAR in LL. Across all sites, there is an important and similar (30-40%) contribution of off-farm income to FAR (Fig. 5.2b). The contribution of crop products consumed and sold to FAR ranges between 35-45% in CG, CM and mixed farming/moderate access (MM) where cropping is practiced (Table 5.1). The importance of cropping to FAR declines substantially from CG to MM (Fig. 5.3a). In addition, the number of household with cropland decreases from 98, to 50 to 33% from CG to MM. The contribution of livestock (consumed and sold) increases (i.e., 31%, 53% and 67%) significantly ($p<0.05$) from CG to CM and MM. However, the contribution of livestock sold and consumed is similar for MM, LL, and LVL. All households in LL and LVL depend on livestock and off-farm income. The market prices for livestock are similar for MM, LL and LVL (Fig. A5.1).

Table 5.3: Percentage (%) of households that experienced food shortage in 2011

	Sites				
	CG	CM	MM	LL	LVL
Households (%) that experienced food shortage for 1 month	92	78	70	78	62
Households (%) that experienced food shortage for 2 months	4	13	2	2	9
Households (%) that experienced food shortage for 3 months	4	9	2	5	3
Households (%) that experienced food shortage for 4 months	0	0	15	26	26

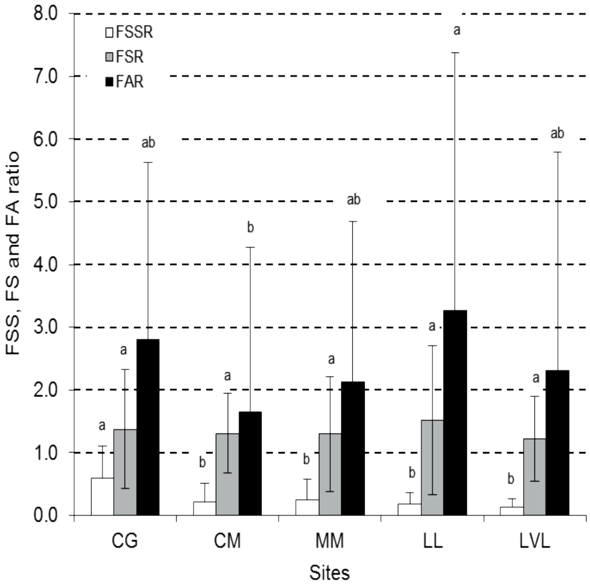

Fig. 5.2a The food self-sufficiency (FSSR), food security (FSR) and food availability ratio (FAR) for households across the five sites (i.e., CG, CM, MM, LL and LVL). CG, CM, MM, LL and LVL stands for cropping/good market access, cropping/moderate market access, mixed farming/ moderate market access, livestock / low market access and livestock / very low market access respectively. Means for FSSR, FSR and FAR with the same letter across the sites were not significantly different (at p< 0.05 level).

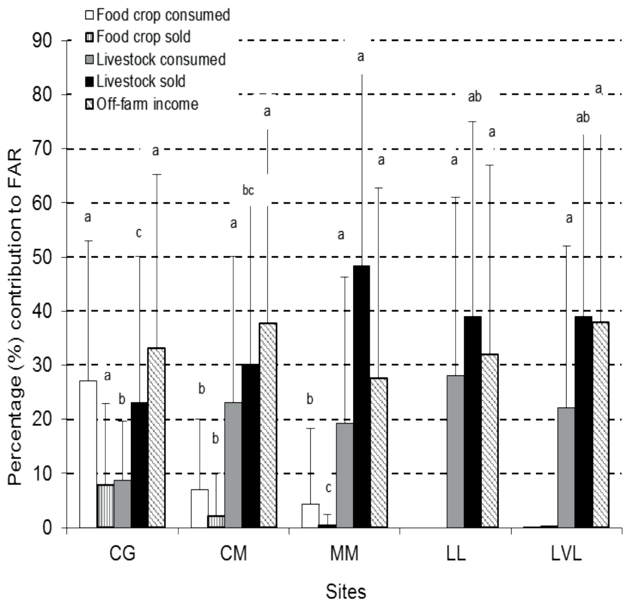

Fig. 5.2b The percentage contribution of food consumed, livestock consumed, livestock sold, crop sold and off-farm income to household food availability ratio across the five sites (i.e., CG, CM, MM, LL and LVL). CG, CM, MM, LL and LVL stands for cropping/good market access, cropping/moderate market access, mixed farming/ moderate market access, livestock / low market access and livestock / very low market access respectively. Means for the contribution of the different components to FAR sharing a letter across the sites are not significantly different at the 5% level.

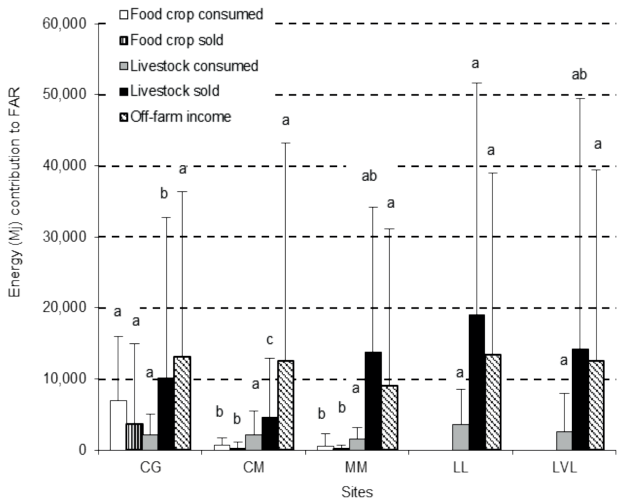

Fig. 5.3a The Energy contribution of food consumed, livestock consumed, livestock sold, crop sold and off-farm income to food availability ratio of households across the five sites. CG, CM, MM, LL and LVL stands for cropping/good market access, cropping/moderate market access, mixed farming/ moderate market access, livestock / low market access and livestock / very low market access respectively. Means for the energy contribution of the different components to FAR sharing a letter across the sites are not significantly different at the 5% level.

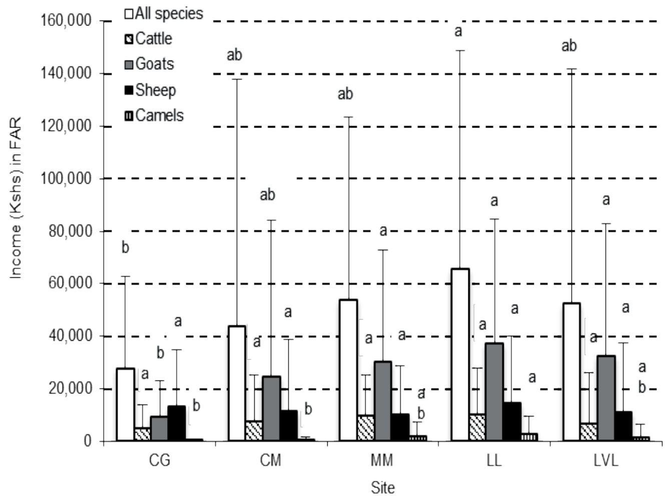

Fig. 5.3b Income contribution by all species of livestock, cattle, goats, sheep and camel to food availability ratio of households across the five sites. CG, CM, MM, LL and LVL stands for cropping/good market access, cropping/moderate market access, mixed farming/ moderate market access, livestock / low market access and livestock / very low market access respectively. Means for the percentage contribution of the different components to FAR sharing a letter across the sites are not significantly different at the 5% level.

Although CG has more agricultural potential, the contribution of crops and livestock (both sold and consumed) is similar to others sites. The share of crop consumed to FAR is greater than livestock consumed, and livestock sold is greater than crop sold in CG (Fig. 5.3a). The relative contribution of livestock sold to FAR for CG, CM, MM, LL and LVL is 23, 30, 48, 39 and 38%, respectively. Only MM and CG are significantly different ($p<0.05$) (Fig. 5.2b). The importance of livestock sold expressed as energy and in absolute terms is only higher in LL than in CM ($p<0.05$) (Fig. 5.3a). The income contribution from livestock to FAR is only higher ($p<0.05$) in LL than in CG (Fig. 5.3b). Income from cattle and sheep is similar across all sites. However, the contribution of goat income to FAR is higher ($p<0.05$) in MM, LL and LVL than CG. The importance of income from goats to FAR is higher in sites where the contribution of livestock (consumed and sold) in terms of energy is similar (Fig. 5.2a), livestock prices are similar (Fig. A5.1) and access to market is moderate or poor (Table 5.1). Camel income in FAR is higher ($p<0.05$) in LL than in CG and CM. The price of cattle is higher ($p<0.05$) in CG and CM compared to MM, LL and LVL (Fig. A5.1). However, the number of cattle owned per household is similar across sites ($p>0.05$). The price of small ruminants (sheep and goats) is similar ($p>0.05$) across sites. The number of sheep owned per household is higher ($p<0.05$) at CG ($x=44$ sheep) than CM, MM, LL and LVL (Table 5.1). The number of goats owned per household is higher ($p<0.05$) at LL ($x= 59$ goats). There are few camels across sites and their price per head ranges between KSh 18,000-28,000.

5.3.2 Model results

The simulations show that in CM for the baseline scenario '*current farming*', over a period of 25 years, about 74% of the distribution of FSR is below 1 (i.e., the WHO requirements of 2500 Kcal day^{-1} adult equivalent^{-1}). Compared to the '*baseline*' scenario, in the '*adapted farming*' scenario the distribution of FSR below 1 decreased from 74% to 29% (Fig. 5.4). This effect is due to higher crop and livestock yield as a resulting from the use of certified seeds, recommended plant spacing, early planting, soil conservation, and feeding of livestock on high quality pastures. High crop and livestock yield, in turn, increases the available food for consumption and for sale hence food security. Sensitivity analysis shows that compared to the '*baseline*' an increase in the price of crop and livestock products by 10% (i.e., '*adapted farming + 10% price increase*') reduce the distribution of FSR that is below 1 over the 25 years from 74% to 9% (Fig. 5.4). This effect is due to an increase in the price of crop and livestock products, which in turn increases households' income. Higher income increases households ability to purchase food and hence FSR. Compared to the '*baseline*', a further increase in the price of crop and livestock product by 20% (i.e., '*adapted farming + 20% price increase*') reduce the distribution of FSR that is below 1 over the 25 years from 74% to 7% (Fig. 5.4).

Compared to the '*baseline'*, if the probability of drought increases by about 10% (i.e., '*adapted farming + 10% drought increase*) the distribution of FSR that is below 1 over the 25 years decreases from 74 to about 38% (Fig. 5.4). This effect is due to the increase in crop and livestock yield as a result of using certified seeds, recommended spacing, early planting, and improved livestock feeding. The increase in the probability of droughts by 10%, however, reduces the crop and livestock yield, so that the decrease in the distribution of FSR that is below 1 is lower compared to the *adapted farming* scenario. A further increase in the probability of drought by about 20% (i.e., '*adapted farming + 20% drought increase'*) lead a decrease in the distribution of FSR that is below 1 over the 25 years from 74 to about 62% (Fig. 5.4).

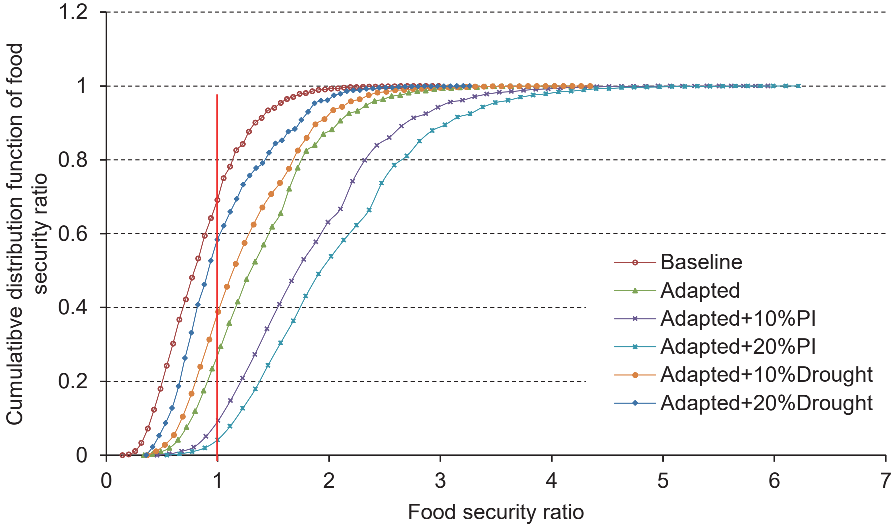

Figure 5.4: The distribution of food security outcome (potential food security ratio) in site CM for baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20%Drought scenarios. CM stands for cropping/moderate market access. Baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20%Drought stands for current farming, improved farm management, improved farm management plus 10% price increase, improved farm management plus 20% price increase, improved farm management plus 10% probability of drought and improved farm management plus 20% probability of drought respectively. The red line indicates a food security ratio of 1 and indicates where WHO energy requirement (of 2500kcal per adult equivalent^{-1} day^{-1}) has been met

Compared to the '*baseline*' scenario, the simulated results in the '*changed livestock and intensify*' scenario in site LVL shows that the distribution of FSR that is below 1 over the 25 years decreases from 73% to 45% (Fig. 5.5). This result suggests that there is potential for improving food security outcome among the livestock keeper by intensifying their livestock production. This finding suggests that strategies aimed at improving the quality of available pastures (e.g., through regulating the use of the pastures through enclosures), and encouraging feed conservation strategies (e.g., hay) when pasture is plenty could help go a long way in improving food security situation among households. This finding also underscores a need for strategic investment on mechanisms that can enlighten the farmers on how to improve animal production, for example by way of agricultural extension support. Reduction of herd sizes and intensifying can also prevent overgrazing which in turn ensure adequate pasture is available.

Sensitivity analysis shows that compared to the 'baseline' an increase in price of livestock and livestock product by 10% (i.e., 'changed livestock and intensify' + 10% price increase) caused a decrease in the distribution of FSR that is below 1 over the 25 years of about 36% (i.e., 73% to 37%) (Fig. 5.5). This effect is due to an increase in the price of livestock products, which in turn increases households' income. Higher income increases households ability to purchase food and hence FSR. A 20% increase in price, lead to a decrease the distribution of FSR that is below 1 of about 50% (i.e., 73% to 23%) (Fig. 5.5). This suggests that intensification of livestock production, when combined with mechanisms that improve the price of livestock and livestock products, hold a lot of potential for boosting food security outcomes in semi-arid areas.

Compared to the '*baseline*, an increase in the probability of drought by about 10% (i.e., '*changed livestock and intensify + 10% drought increase'*) causes the distribution of FSR that is below 1 over the 25 years to decrease from 73% to 67% (Fig. 5.5). But a further increase in the probability of drought by about 20% causes an increase in the distribution of FSR that is below 1 over the 25 years from 73% to 80 (Fig. 5.5). This result suggests that in sites where households keeps livestock only, an increase in the probability of drought could easily worsen their food security outcomes, but an intensification of livestock production, can help to reduce this negative impact.

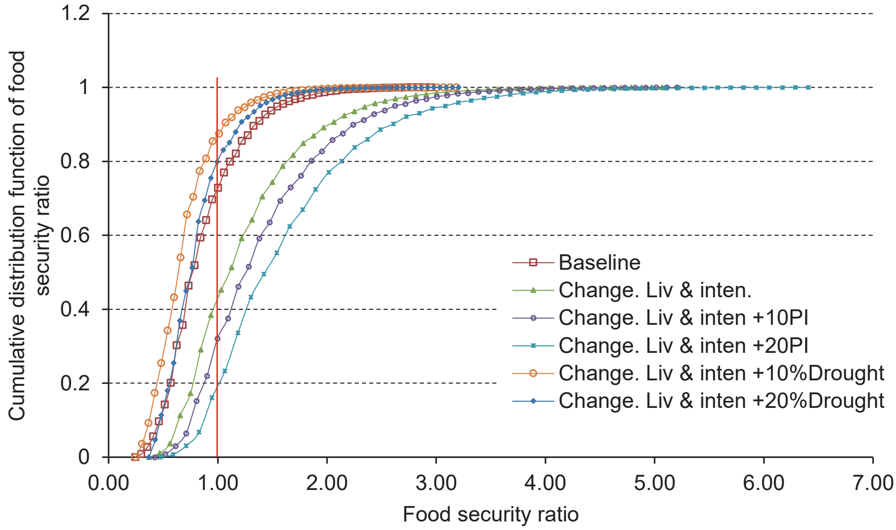

Figure 5.5: The distribution of food security outcome (potential food security ratio) in site LVL for baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20%Drought scenarios. LVL stands for livestock / very low market access. Baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20%Drought stands for current farming, improved farm management, improved farm management plus 10% price increase, improved farm management plus 20% price increase, improved farm management plus 10% probability of drought and improved farm management plus 20% probability of drought respectively. The red line indicates a food security ratio of 1 and indicates where WHO energy requirement (i.e., 2500kcal adult equivalent^{-1} day^{-1}) has been met

Compared to the *baseline* scenario, in the *'adapted farming'* scenario, the distribution of income capita^{-1} day^{-1} that is below KSh 75 (i.e., the national poverty[32] line in Kenya) over the 25 years decreases from 94% to 63% (Fig. 5.6). This finding shows that improved farming holds enormous potential for raising farmers' income. Considering that Samburu is one of the poorest counties in Kenya (with 77% of

[32] Poverty line is estimated at KSh 1,562 and KSh 2,319 per person per month for rural and urban household respectively (KNBS and SID, 2013). In this study we use an average of the two (i.e., 1,562+2,319)/2= KSh 4,475 per month (i.e., about KSh 75 capita^{-1} day^{-1}) (KNBS and SID, 2013).

households below the poverty line), this finding underscores the importance of investing in farming strategies that are yield enhancing (i.e., use of animal manure and fertilizer, and improved seeds). The potential of improved farming in improving income in among households, therefore, calls for a strategic investment by the Samburu County government on mechanisms that can help in enlightening the farmers on how to improve their farm management and also the use of appropriate technologies.

Sensitivity analysis shows that when the price of crop yields and livestock product is increased by 10% (*Adapted farming' +10% price*)', the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years decreases by about 58% (i.e., 94% to 36%) (Fig. 5.6). An increase in price by 20% (*intensify + 20% price scenario*)', causes the distribution of income capita^{-1} day^{-1} that is below KSh 75 to decreases by about 72% (i.e., 94% to 22%) (Fig. 5.6). This finding suggests that a combination of strategies (i.e., adapted farming and price increase) has the potential of increasing households' income.

Compared to the '*baseline'* scenario, an increase in the probability of drought increases by about 10% (*intensify + 10% drought increase*) causes the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years to decrease from 94% to about 68% (Fig. 5.6). A further increase in the probability of drought by about 20% (*intensify + 20% drought increase*) causes the distribution of income capita^{-1} day^{-1} that is below KSh 75 to decrease from 94% to about 82% (Fig. 5.6). This finding suggests that with improved farming, the impact of drought on farm income could be reduced.

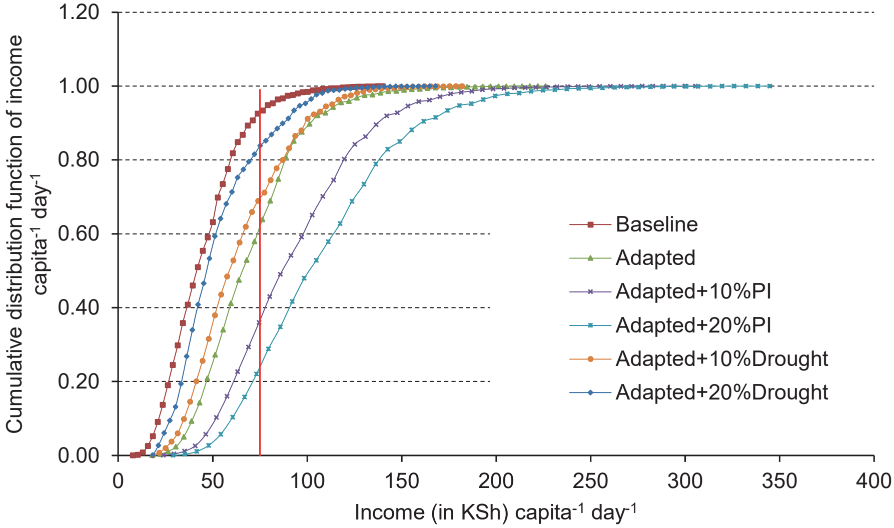

Figure 5.6: The distribution of income per capita per day in site CM for baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20 %Drought scenarios. CM stands for cropping/moderate market access. Baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20 %Drought stands for current farming, improved farm management, improved farm management plus 10% price increase, improved farm management plus 20% price increase, improved farm management plus 10% probability of drought and improved farm management plus 20% probability of drought respectively. The red line indicates the national poverty line in Kenya (i.e., KSh 75 capita $^{-1}$day^{-1}) has been met.

Compared to the 'baseline' scenario, in the *'changed livestock and intensify'* scenario in LVL site, the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years decreases by about 20% (i.e., from 92 to 72%) (Fig. 5.7). Sensitivity analysis shows that when the price of livestock products is increased by 10% (*changed livestock and intensify +10% price*)', the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years decreases by about 32% (i.e., from 92 to 60%) (Fig. 5.7), when compared to the *'baseline'*. A further increase in the price of livestock products *('changed livestock and intensify + 20% price')* scenario causes the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years to decrease by about 40% (i.e., from 92 to 52%) (Fig. 5.7). This indicates that improvement in the price of livestock products is important for improving income outcomes among livestock keepers.

If the probability of drought increases by about 10% (*changed livestock and intensify + 10% drought increase*), the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years decreases by only 4% (i.e., from 92 to 88%) (Fig. 5.7). A further increase in the probability of drought by about 20% (*changed livestock and intensify + 20% drought increase*) causes the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years to be higher than that of baseline by 2% (i.e., from 92 to 94%) (Fig. 5.7). This finding suggests that if the probability drought increases, the potential for improving income outcome among households dwindles, and that livestock production intensification helps to reduce this negative impact. This finding suggests that, in Samburu County and other semi-arid areas that experience crop failure and livestock losses due to frequent droughts, policies aimed at supporting adoption of livestock yield enhancing technologies, such as livestock intensification are key in enhancing food security and income among households. The early warning system could also help the households to put in place measures that can help them to reduce the impact of droughts on their food security and income over time.

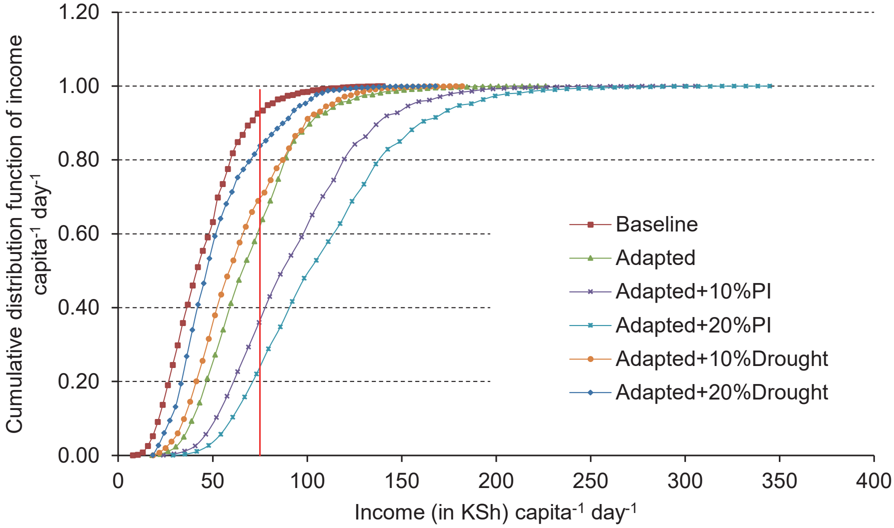

Figure 5.7: The distribution of income per capita per day in site LVL for baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20%Drought scenarios. LVL stands for livestock / very low market access. Baseline, adapted, adapted+10%PI, adapted+20%PI, adapted+10%Drought, and adapted+20%Drought stands for current farming, improved farm management, improved farm management plus 10% price increase, improved farm management+20% price increase, improved farm management+10% probability of drought and improved farm management plus 20% probability of drought respectively. The red line indicates the national poverty line in Kenya (i.e., KSh 75 capita -1day-1) has been met.

A comparison of non-incremental scenarios shows that shifting to *'adapted farming*' and *'changed livestock and intensify'* are key to reducing the distribution of FSR that is below 1 and income capita^{-1} day^{-1} that are below KSh 75 over the 25 years (Figures not shown). It also shows that an increase in price increases reducing the distribution of income capita^{-1} day^{-1} that is below KSh 75 over the 25 years and therefore food security outcomes. However, an increase in the probability of drought increases the distribution of FSR that is below 1 and income capita^{-1} day^{-1} that are below KSh 75 over the 25 years.

5.4 Discussion

We assessed food self-sufficiency (FSSR), food security (FSR) and food availability ratio (FAR) using data from agro-pastoral households across five sites in Samburu County. While in general terms the findings of our study confirm the importance of relative factors (land and livestock) in FSSR, FSR and FAR, we also found that as we move from wetter to drier areas the contribution of crop and livestock to FSSR and FAR varies. The present work also assesses the potential consequences of climate shocks which cause crop failure and livestock mortality. We find that improved farming, livestock intensification and an increase in price (modelled through different scenarios) are key to improving food security and income for the pastoral and agro-pastoral households. These findings are clearly important for other semi-arid areas in East Africa where agro-ecological and socio-economic conditions are similar to those of Samburu County.

5.4.1 Food self-sufficiency, food security and food availability across sites

Households in Samburu County experience food shortages. These food shortages are mainly caused by environmental or socio-economic shocks (Greiner, 2013; Ongoro and Ogara, 2012). FSSR was higher in the site where households had large croplands. As we move from wetter areas to the drier areas (i.e., CG, CM, and MM) the number of households with cropland decreases and the importance of crop consumed to FAR also declines. Households in semi-arid areas are motivated to participate in crop farming along livestock keeping as a means of alleviating negative effects such as those associated with drought (Solomon et al., 2007). Cropping and livestock keeping tend to ensure that households are food secure (Bati, 2013). High FSSR in CG where cropland is large agrees with the literature which shows that the arable land is positively associated with improved food security (Ibid). Our finding also shows that the contribution of food crop consumed and sold is high in CG, where crop farming is practiced, but decreases as we move to CM and MM, as the environment gets drier.

In three of the five study sites (i.e., CG, MM, and LVL) the FAR were similar (i.e., not statistically different at 5%). LL had a significantly higher FAR than CM (Fig. 5.2a). In light of findings of the large range in food availability index found in Lushoto (Tanzania), Wote (Kenya), Lawra (Ghana) or Borana (Ethiopia) (Ritzema et al., 2017), the FAR in Samburu seems low. This finding, however, highlights the large diversity in livelihood strategies across households in Samburu County. This variation could be partly due to the uncertainties in households data – for instance on agricultural productivity – provided during the survey (e.g., Carletto et al., 2015; Birthe et al., 2017). It could also be related to sensitive information that households are not willing to provide (e.g., off-farm income) during a one-off cross-sectional survey (Ritzema et al., 2017; Ng'ang'a et al., 2016). The productive assets such as arable land and livestock may also determine the resources that the households can access and hence their FAR (Table 5.1). Our results on the distribution of FAR ratio is akin to those found in Rwanda (Birthe et al., 2017), in East, and West Africa (Ritzema et al., 2017), because in our study FAR was not correlated to the size of arable land and to the agro-ecological potential across the five sites

The finding that the contribution of livestock (consumed and sold) to FAR increases from 31%, 53% and 67% in CG, CM, and MM, suggest that as the environmental constraints increase the contribution of livestock to households food security increases. But the similarity of livestock contribution to households FAR in MM, LL, and LVL could be due to environmental constraints in areas with lower agricultural potential leading to lower quality of pasture in LL and LVL, which limit production of livestock that households own. The low contribution of livestock to households FAR in CG compared to CM and MM could be because agro-pastoralists have less livestock grazing areas compared to the pastoralists.

FAR was higher in LL, the only site with large energy (consumed and sold) from livestock, large herd size, and off-farm income (Fig. 5.2b). This finding shows that accumulating livestock wealth, and engaging in off-farm income generating activities contribute positively to households' food security. Evidence from the published literature shows that an increase in livestock holdings, in the semi-arid environment, improves households' food security through livestock offtake which provides income and hence improved access to food (Bati, 2013). This is not a claim that overall production and hence food security would only be increased through large herds, but it does indicate one reason why households may consider it worthwhile to increase their stock. Households who have more stock initially tend to have a good basis for rebuilding their herd once the crisis is over (Carter et al., 2007; Lybbert et al., 2004). Off-farm income is an important contributor to households income, especially as the per capita livestock holding continue to decrease due to the frequent droughts and conflicts over natural resources (Majekodunmi et al., 2014).

The income from camels in FAR is higher in LL when compared CM and CG. In the semi-arid areas, milk production is becoming a rationale for camel ownership contrary to assumptions that regarded the function of camels as pack animals (Cousin and Upton, 1987; Coppock, 1994). Camel feed on higher strata of plants which reduce their competition with other livestock species for feed (Doti, 2010). Information from focus group discussions shows that camel milk fetches a higher price compared to that of cattle and goat. The relative contribution of livestock sold to FAR across the five sites ranged from 23% to 48%. Sale of livestock is important in compensating for food expenditure through contributing to the highly variable income among households in the semi-arid environment (Hänke and Barkmann, 2017). This is particularly so during the dry period when the largest proportion of revenue from livestock sale is spent on purchasing grain (Berhanu and Fayissa, 2010). Our results show the importance of income from goats to FAR is higher on sites that fall in low agricultural potential areas (i.e., MM, LL and LVL). This could be due to the vital roles that goats play as a major source of meat and milk for consumption and income. This suggests that multiple species improve food availability and offer choices for offtake (Regassa and Stoecker, 2012).

5.4.2 Understanding outputs from the assumptions made in modelling

We assess the consequences climate shocks on food security outcomes and farm income over a period of 25 years. Specifically, we estimate a dynamic model that takes into account crop failure and herd losses arising from the occurrence of frequent droughts. We assumed that the farmers are risk neutral and only care about expected income. Evidence from the literature shows that the farmers who are risk averse will produce less of a marketable crop or livestock if the production of the crop or livestock is characterized by high risks (Theuvsen, 2013). In such cases, therefore, how much the households choose to produce reflect their risk attitudes. In the semi-arid environment pastoralists are not only driven by risk aversion but also seek to attain reliable income by using the available technologies (i.e., accumulation and mobility) to manage risks better (Roe et al., 1998). Therefore, by assuming households are risk neutral we are thinking of pastoralist as seeking for a production plan that will probably deliver the highest expected income every year. This is in line with evidence which shows that households in the semi-arid environment are continually in search for improvement by seeking essential information and being on alert for resources to exploit (La Porte, 1996; Agrawal, 1992). For example, Reckers (1994) shows that in order to achieve better animal performance the herd owner decides on a daily basis where to go and graze their livestock.

In this study, we use FSR as food security indicator by assuming that households prioritize meeting food requirement above all the other expenses (Coates, 2013). Cash is assumed to be used in purchasing the staple food in quantities required by the households to increase their food security. Together, these assumptions arguably make our FSR an optimistic indicator of food security. Other studies in East and West Africa shows that food security indicator provides a reasonable insight into overall food security status across households (Frelat et al., 2016; Hammond et al., 2017; Paul et al., 2016; Ritzema et al., 2017). The Food Availability indicator has been found useful for assessing food security situation in systems where agricultural productivity is a constraining factor (e.g., Frelat et al., 2016; Ritzema et al., 2017).

5.4.3 Understanding how adaptation practices can support food security

The finding that improved farming (in site where crop farming and livestock farming is practiced) and livestock intensification (in site where households keep livestock only) reduces the distribution of FSR that is below 1 by 45% and 31% respectively (Fig.5.4 and Fig. 5.5), implies these strategies are a key to improving the food security situation among households in the semi-arid areas. Low level of input adoption by farmers is a major impediment to improving food security and incomes in sub-Saharan Africa (Koussoubé and Nauges, 2017). The high cost of inputs (i.e., fertilisers and improved seeds), weak institutional support, weak fertiliser markets, weak agricultural extension services, lack of innovation that addresses challenges faced by farmers and lack of access to credit are some of the reasons why adoption of improved farming is low (Chianu et al., 2012; Fujisaka, 1994; Langyintuo and Mungoma, 2008). Evidence from the literature has shown that frequent climate change-related shocks, such as droughts farmers experience ultimately influence their farming strategy (Bunting et al., 2013). These shocks may prompt households to put in place adaptation strategies such as changing production plans (Quinn et al., 2003) and improved livestock feeding (Shikuku et al., 2017). Investing in interventions that can enhance the adoption and implementation of improved farming and livestock intensification, therefore, could enhance adaptation through increasing crop and livestock yield (Campbell et al., 2014; Lipper et al., 2014). Evidence from the literature shows that results from regional and aggregated modelling studies may not be able to inform what may happen to specific types of farming systems (Herrero et al., 2014). Exploration studies evaluating adaptation strategies to climate change for households based on survey data are more appropriate (Claessens et al., 2012). Our study provides important insights of what may happen to food security and income for households and can, therefore, inform policies aimed at improving food security and income in semi-arid environments. These insights align well with the plans that both the Samburu County and national government of Kenya has for enhancing food security and income among households (Republic of Kenya, 2011; Samburu County, 2013b).

Our finding shows that improved farming and livestock intensification, when combined with an increase in the price of crop and livestock products, improves food security and expected farm income. The positive impact on food security and farm income is in line with earlier evidence that an increase in farm gate prices for agricultural products improves households welfare and food security (Karfakis et al., 2008). The simulation results have shown that in face of stochastic shocks, a combination of improving farm management and better market prices, can largely improve food outcomes and farm income over time. This implies that there is a need for supporting households in the semi-arid areas providing them with improved farm management and technologies that are well adapted. In addition, there is need to support the flow of market information by investment on infrastructures (i.e., markets, roads, and telecommunication) and supporting farmers with agricultural extension services. Good infrastructures can improve the spread of yield-enhancing technologies (Bashir and Schilizzi, 2013; Kiprono and Matsumoto, 2014), improve households trading options such as the supply of higher-value livestock products (Rueff, 2016), prompt households to organize in groups to achieve economies of scale along the value chain (Tatwangire, 2013; ILRI, 2016) and enhance flows information and price signals (Ellis and Hine, 1998).

Based on these findings we can speculate that policies to improve on information flow on production technologies that suit farmers in the different areas of Samburu are needed. For farmers it would be good to have trained agricultural and livestock production officers (Porter, 2014). These trained officers also need to be facilitated. But since a shift in farming strategy requires resources which majority of the households may not afford for purchasing feeds and for building a small structure for conserving feeds for example. One precondition for the implementation of '*adapted farming'* or '*change livestock and intensify'* strategies would for farmers to have access to sufficient resources to cover the cost of these changes, especially at the start. This resources could be provided as a credit to the farmers.

We also speculate that policy aimed at improving the flow of information particularly on prices may be very helpful. Information flow improves agricultural market performance (Nakasone et al., 2014). Provision of prices through mobile phones reduces search and communication costs and improves households' potential to get better prices for their farm produce (Aker and Fafchamps, 2010). Other measures that would help households would be to: i) improve the roads by making them all-weather roads, and ii) improve financial capital provision. Evidence from the literature suggests that interventions aimed at improving access to improved technologies and productive assets are central to stimulating escape from semi-subsistence poverty traps (Barrett, 2008).

5.5 Conclusions

We studied how adoption of adaptation practices can support food security in diverse agro-pastoralist households in the semi-arid environment using a plausible set of scenarios informed by the potential for crop and livestock production that exists in different sites for the households. This exploration enhanced our understanding of how households' food security and income would be improved if implemented, and the fact that it uses household level data provides legitimacy to this type of analysis and increases the likelihood that it will be taken up by the farmers (Chaudhury et al., 2012). Improved farming (in a site where crop farming and livestock farming is practiced) and livestock intensification (in a site where households keeps livestock only) improves food security farm income outcomes. So while an increase in the probability of drought can increase the food insecurity situation in the semi-arid environment, a combination of improving farm management, livestock intensification, and better market price, can reduce by a large margin the distribution of food outcomes and farm income over time. We conclude that putting in place an adaptation strategy such as improved farm management (i.e., use of improved seeds, the use fertilisers, soil conservation and adhering to the recommended crop spacing and timing of planting) and changing livestock and intensifying (by supplementing the lactating cows for example) is an undertaking that has potential of reducing the probability of farmers from falling into situation of food insecurity and low expected farm income over time. Thus policies aimed at supporting improved farm management, livestock intensification and improving market prices for crop and livestock products can foster food security and farm income outcomes for households in an adverse environment.

Appendix: Chapter 5

Appendix 5.1. Calibration of the model

When running the model for the average households in the two sites (i.e., cropping/moderate access (CM) and livestock/very low market access (LVL)) with the observed data, calibration of the model for was needed. Although the model has quite an elaborate set of constraints, they are still somewhat generic and cannot reflect farmer behaviour exactly; and they may also not reflect the specific local conditions such as the limited amounts of inputs being available due to local market constraints such as the limited market access. Therefore, a process of calibration of some model constraints was carried out. This involved modifying the market prices of crops (maize and beans) and livestock commodities (i.e., milk and whole animals) to reflect the internal transactions costs incurred by the households. This was followed by calibration of the model by adjusting the total factor productivity of crop and livestock until the FSR output results from the model (i.e., the optimal baseline model) for the two site were similar to the observed results for the average farm as explained in section 3.1. The optimal baseline model constituted the starting point for subsequent runs.

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Chapter 6

General Discussion

6.1 Introduction

In arid and semi-arid lands (ASALs) in East Africa, the majority of the households are pastoralists and agro-pastoralists. In these areas, the effects of climate change (such as floods and frequent droughts) on the livelihood of households may be particularly severe. This is because the households depend directly on agriculture for their livelihoods and they have limited access to alternative sources of income (Osman Elasha et al., 2006). To make matters worse, according to the current climate projections for East Africa, the region will experience an extreme level of climate change. Droughts and floods are expected to become more frequent (Christensen et al., 2007). The annual temperatures in East Africa are projected to increase by between 1.4 and 5.5^{0} C, and the median precipitation by between -2% and +20%, by the end of 21^{st} century (Adhikari et al., 2015). The impact of these changes will be felt more acutely in the ASALs (Thornton 2010; Thornton et al., 2007). Given these trends, there is little doubt that climate change will dramatically affect pastoralists and agro-pastoralists, and that they will need to adapt to new climate conditions (Adger et al., 2007) in order to reduce the severity of their effects. Scientific research conducted with the aim of modifying or improving the existing coping and adaptation strategies, can help to point out the most viable ways to adapt to climate change. It can provide a basis for proposing appropriate policies, targeted investment strategies, and effective interventions.

This study provides a detailed analysis of how households in the semi-arid areas in East Africa cope with and adapt to weather shocks, by addressing four specific albeit interrelated research objectives (see section 1.2) that were discussed in each of the preceding chapters.

1. To explore whether households accumulate livestock wealth and social capital as insurance against risks and shocks associated with climate change in dry areas;
2. To analyse whether the migration of household members facilitates the adoption of agricultural innovations that provide protection against weather shocks in semi-arid areas;

3. To ascertain whether the quality of local institutions determines adaptation at the household level;
4. To further the understanding of how the adoption of adaptation practices is related to food security and farm income in different types of agro-pastoral households.

This study focused on Samburu County in Kenya and Borena region in Ethiopia, small parts of the ASALs in East Africa, in order to gain a deeper understanding at the household and regional level.

I summarize the evidence that has been gathered for providing answers to the research questions in Section 6.2. In Section 6.3, I discuss the scientific relevance of these findings. I then indicate the policy implications of the findings in Section 6.4. Finally, I outline some major limitations of this study, and suggest avenues for future research in Section 6.5.

6.2. Findings

In **Chapter 2** the way households respond to climate shocks by investing in natural capital (i.e. livestock wealth) and social capital (i.e. cognitive social capital or trust and structural social capital) is analysed by using a model that captures the heterogeneity in the responses by clustering households into three groups: the wealthy (HG1), the poor (HG2), and the financially-integrated (HG3). These groups of households exhibit some differences, which can be expressed in terms of the five forms of capital (human, natural, financial, physical and social) (see Table 2.2, in Chapter 2). A regression model, that takes into account the household groups' access to infrastructure (such as roads and markets) and their positioning with regard to the ecological gradient (i.e. relatively wet to relatively dry), was then used.

The findings in Chapter 2 show that as we move from wetter to the drier environment, households tend to accumulate more livestock wealth (although the evidence was not very robust). This points to the fact that in the semi-arid areas accumulation of livestock is an important strategy that households utilize to address risks associated with unpredictable weather conditions. The drier areas are subject to frequent weather shocks (such as droughts), which may lead to vegetation scarcity and thereby decrease livestock holdings. Households in these areas, therefore, try to manage the risk of livestock loss through herd accumulation. However, this does not rule out the possibility that households invest in livestock for other reasons, like those concerned with social status.

The findings in Chapter 2 did not provide evidence for a link between investment in social capital and rainfall. However, the findings indicate that in the drier environment, financially-integrated households place more value on trust. For the wealthy households, the environment does not matter for trust, as they can use other strategies (such as harvesting natural resources and crop products, and accumulating livestock) for self-protection. These findings suggest that resource endowment plays an important role in determining the choice among self-protection measures. The high trust in the drier areas among the financially-integrated households could be explained by the fact that they need to develop strong relations, to ensure that peers will act as guarantors in case credit is needed. Land is generally not scarce; that is why those depending on the produce of their own lands cannot use their productive assets as collateral to access credit. The livestock also does not have collateral value (Binswanger and Rosenzweig, 1986). They have to look for alternative options, like those provided by guarantors – who function as social collateral. Despite the fact that our findings in Chapter 2 showed little variation in structural social capital, we did establish that across social groups the participation in group meetings is higher in the drier environment (see Table 2.5 in Chapter 2). We take this as a weak support for the hypothesis that households accumulate social capital under dry conditions.

The findings in Chapter 2 also indicate that livestock wealth increases with the distance to local markets and motorable roads. This indicates that in situations where market-mediated risk-reduction strategies are lacking, households opt for the accumulation of livestock as a risk-reduction strategy. Our finding that in the drier environment poor households have lower livestock wealth compared to the financially-integrated and the wealthy households, suggests that the poor derive little insurance from livestock wealth. This could explain why some households seek other mechanisms for self-protection, such as engaging in petty trade (see Table 2.3 in Chapter 2).

In **Chapter 3**, we went into the question whether the migration of household members in the Kenyan study area should be considered to be a complement or an alternative to the adoption of local adaptation practices. Because migration status is an endogenous variable in the adoption model, and certain omitted variables, such as curiosity, may drive adoption and migration, we had to identify exogenous variation in our migration variable in order to establish causality. Consequently, we introduced two previously excluded instruments: the number of family members in a household working outside Samburu County for a period of more than 10 years in formal employment, and the number of kin group members in a village (see Table 3.1 in Chapter 3). We then used a two-stage least squares (2SLS) model that explains both determinants of migration and the causal impact of migration on the adoption of adaptive measures, by distinguishing between financially costly and not-so-costly adaptive practices. The analysis revealed that migration, via remittances, facilitates the adoption of costly adaptation practices, but not of the not-so-costly adaptation practices (see Table 3.5 in Chapter 3). This finding suggests that migration plays an important role in relaxing financial constraints. The results also show that, all else being equal, migrant households consume more calories than non-migrant households. Migration affects consumption for households with costly and not-so-costly adaptation practices alike; that the results for consumption are different from those concerning investments. Our analysis also revealed that migration affects consumption both directly and indirectly, by fostering the adoption of new technologies that involve a change in activities or an investment that is costly. Thus we concluded that for households in the semi-arid areas of Northern Kenya, migration, and the adoption of adaptive agricultural practices are complementary mechanisms for self-protection.

In **Chapter 4**, our attention was directed towards understanding the link between the adoption of agricultural adaptation practices and the determinant of adaptive capacity (AC). We focused on autonomous adaptation and analysed the relationship between the adoption of agricultural options that can reduce the vulnerability to climate change and the adaptive capacity among pastoralists, using a sample of 400 households from the Borena region in Ethiopia. We examined the correlation among household socio-economic variables and isolated variables that had a high correlation coefficient. We then computed the AC by aggregating household information. The correlation between AC on the one hand, and the number of adopted agricultural adaptation practices, and three dimensions of local institutions (i.e. tenure security, rule of law, governance and accountability) on the other, were tested. Our results revealed that AC was positively and significantly correlated with the number of adopted practices, and also to the three dimension of local institutions combined. This finding suggests that the three dimensions of local institutions are complementary. The explanatory power of the model using individual household information was stronger for the relation of AC to the total number of adopted agricultural adaptation practices and for the adoption of each of the adaptation practices. This suggests that aggregating households leads to a loss of information. Our results also showed that better local institutions were correlated with household level characteristics such as membership of community groups, access to credit, financial savings and income, which positively affect the adoption of agricultural adaptation practices. It does seem, therefore, that improving the quality of local institutions may make it easier for households to adapt, and may enhance their AC by stimulating changes in the households characteristics.

In **Chapter 5** we sought to understand how the adoption of selected adaptation practices can increase food security for different types of agro-pastoralist households. A dynamic-modelling approach was used to allocate farming activities to maximize expected farm income, subject to a set of constraints relating to labour, arable land, crop harvest, livestock harvest, and livestock herd size. We used data from two representative households, one from a site where both cultivation and livestock keeping are practiced, and one from a site where only livestock keeping is practiced. We found that the adoption of improved farming methods – which involve the application of fertilizer, certified seeds, early planting and the recommended plant spacing – at the site where both cultivation and livestock keeping are practiced, increased food security and farm income by 45% and 31% respectively, compared to the baseline scenario. At the site where only livestock keeping is practiced, we found that the adoption of livestock intensification – which involves changing the livestock type and improving the management and feeding of the livestock – increased food security and farm income by 28% and 20% respectively. At a site where both cultivation and livestock keeping are practiced, a combination of improved farming methods and an increase in the price of crop and livestock products by 10% led to an increase in food security and farm income of 65% and 58% respectively. At a site where only livestock keeping is practiced, a combination of livestock intensification and an increase in the price of livestock and livestock product by 10% led to an improvement in food security and farm income of about 36% and 32% respectively. More frequent climate shocks – explored by increasing the probability of drought by 10% – led to a decline in food security and farm income at all sites. However, even in this case the implementation of improved farming methods and livestock intensification showed a lot of potential for minimizing the probability of households falling into food insecurity and suffering income loss.

6.3 Scientific relevance

6.3.1 Heterogeneity in coping and adaptation strategies

The research findings described in this thesis are relevant for theoretical debates on coping with and adaptation to climate change in the semi-arid environment. The findings concerning the importance of livestock wealth as a coping strategy for pastoralists and agro-pastoralists are in line with the existing literature (e.g. Binswanger and McIntire 1987; Little et al., 2008). We have added to the stock of knowledge by differentiating between the adaptation strategies of three groups of households: the poor, the wealthy and the financially-integrated (see Table 2.3 in Chapter 2). The latter two groups have more resources (income and access to credit) they can use to invest in herd building. The observed differences in the use of livestock wealth as a coping strategy among households as we move from wetter to drier environments, can be accounted for indirectly by the differences in resource endowment among households. The households most constrained in terms of their ability to adapt to climate change in Samburu County are the poor (most of which are women-headed households).

Using the agroecology and market access gradients, Dorward et al. (2009) differentiate between three types of livelihood strategies among households in the rural areas: the 'hanging-in' households situated in places with low agroecological potential and poor market access; the 'stepping-up' households situated in areas with high agroecological potential where current production is boosted by the accumulation of assets; and the 'stepping-out' households who accumulate assets to facilitate shifting to non-farm-related activities, such as migration into urban areas or trade. Apart from agroecology and market access factors, differences in household livelihood strategies may also be accounted for to some extent by the differences in resource endowment defined in terms of the five capitals – human, financial, physical, natural and social (Scoones, 1998). In line with the insights from Dorward (2009), we can argue that the wealthy households are better placed to 'step up' and adapt on their own (i.e. their adaptive capacity is higher). However, support and interventions aimed at improving their asset base (e.g. by providing drought-tolerant animals) remain necessary (see also Chantarat et al., 2013). The rearing of livestock provides households with an opportunity to 'step up', if they can sell their livestock; through re-investment for example (see e.g. Dorward et al., 2009), and this could improve their ability to adapt in the future. Our results showed that in drier environment, financially integrated households are associated with more trust, which facilitates economic exchange and responsibility (i.e., social collateral in case credit is needed) among peers. These households thus have access to credit, and they are able to save some money (see Table 2.2 in Chapter 2). They are likely to have resources to invest in particular adaptation practices, and therefore have some potential to 'step up' on their own. But, as has been argued by scholars (Binswanger and McIntire, 1987), most households in ASALs face constraints for accessing credit. Therefore, interventions aimed at improving the households' ability to access credit can improve their ability to adapt.

Our results in Chapter 2 showed that the majority of the poor households strongly depend on safety nets, such as borrowing food and paying in kind, selling labour, and petty trade. According to the literature, the reliance on such strategies by the poor households is common (Woittiez et al., 2013). In order to help poor households to adapt to future climate change, and not just to cope to ensure their survival (i.e. 'hang in'), well-tailored strategies and interventions are needed, so that they can 'step up'.

The grouping of households into wealthy, financially integrated, and poor (see Fig. 2.3 in Chapter 2) helped us to understand the different strategies they use to adapt, and provided insights that could be used as entry points for interventions aimed at improving their ability to adapt. However, although such grouping is important for an in-depth understanding of the self-protection measures taken against risks, most of the studied households are considered to be below the national poverty line (Kenya National Bureau of Statistics 2013). Therefore, also the wealthy and financially-integrated households in the study area are relatively poor compared to wealthier households elsewhere in Kenya.

Our findings showed that where market-mediated risk-reduction strategies cannot be applied, households consider investing in livestock wealth as a risk-reduction strategy. Poor access to markets is an important constraint that households face in semi-arid environments. Households situated far from main urban markets are generally poorer (Collier 2007). Therefore, some studies use market access as a proxy for poverty (Okwi et al., 2006). Our findings show that poor market access is related to high livestock wealth, and therefore is not automatically an indication of poverty. Our results indicate that there is a trade-off between the advantages of being close to the market, and the availability of sufficient pastures for livestock grazing (households closer to markets tend to be concentrated in a small area). In areas far from the market, the population density is low, and pasture is readily available (Little 2003). This does not mean that households with poor market access are better off; it is harder for them to generate cash income through the sale of livestock. The distance to the market also affects the costs associated with accessing market information and crop and livestock inputs.

6.3.2 Social capital as insurance against climate risks

Evidence from the published literature shows that social capital may help reduce the negative effects of climate change, by enabling collective action in solving problems (Adger 2003; Adger 2010; Bowles and Gintis 2002), including disaster management (Adger 2010; Allen 2006). Our results showed that even though the overall social capital does not increase as we move from wetter to drier environments, some of its constituents, specifically participation in group meetings, do increase across all groups (see Table 2.5 in Chapter 2). Participation in groups meetings is an important first step toward achieving the consensus necessary for collective action in communities. Findings from focus group discussions revealed that the actions that households seek consensus on include the conservation of grazing areas, the maintenance of water pans, and the tackling of livestock-related diseases. Group meetings, therefore, provide an important avenue through which households can be mobilized to take collective action in the face of risks and shocks associated with climate change.

Our results showed that wealthy households are less dependent on trust (cognitive social capital) compared to the financially-integrated and the poor households (see Table 2.5 in Chapter 2). As we move from wet to dry areas, trust increases only among the financially-integrated households. The wealthy households have alternative strategies for dealing with risks (see Table 2.5 in Chapter 2); for example, they can turn to the harvesting of natural resources or crop production for food and income. But for the financially-integrated households, trust is important for accessing external resources such as credit (because of the need of guarantors).

6.3.3 Migration and adaptation to climate change

Rural-urban migration has been singled out by policy maker as a key pathway for the improvement of farm household livelihoods in Africa (Beauchemin 2011; Francis 2002). The decision to migrate is usually taken jointly by the members of extended families (Stark and Lucas 1988). The flow of remittances and goods sent by migrant members of households reduces income fluctuations (Barrett et al., 2001; Stark, 1991; Taylor, 1999), and facilitates additional consumption (De Brauw and Rozelle, 2008). However, the existing literature has little to say about the opportunities migration offers for a better management of agriculture by households in the areas of origin (Mendola, 2012).

Some studies report that the adoption of new agricultural practices helps to improve the livelihoods of households (Bryan et al., 2013; Rufino et al., 2013). Others show that investment in education has a positive impact on livelihoods, by enabling access to salaried income, which can facilitate migration to urban areas (Coppock 1994; Fratkin and Smith 1995). Migration can help to furnish the initial investments necessary for embarking on these courses of action. Our findings are in line with the theory that migration is one of the main strategies used by households to diversify, secure, and improve their sources of income, and is often combined with agricultural intensification (McDowell and De Haan, 1997). We found that in the semi-arid areas migration is positively related to the adoption of adaptation strategies that are considered costly, such as changing the livestock type, introducing feed conservation (for pastoral households) or hybrid and fast-maturing seed varieties (for non-pastoral households). In addition, we discovered that migration is associated with an increase in calories consumed by households with and without access to credit (see Chapter 3), that migration relaxes liquidity constraints, and that it reduces income fluctuations occasioned by climate shocks. Clearly, migration enhances the ability of households to adapt, and improves food security.

6.3.4 Credit and adaptation

We found that migration facilitates the adoption of adaptation strategies, especially for households without access to credit (see Chapter 3). Obviously, a lack of credit may constrain the ability of households to invest in appropriate adaptation strategies. The supporting and strengthening of credit-providing institutions is therefore necessary (see Ajayi et al., 2007; Ebi et al., 2011). However, even with such institutions in place and functioning, households in the semi-arid areas may still be credit-constrained for two reasons: i) in many land-abundant semi-arid areas, such as Samburu County, land cannot serve as collateral, because of its low sale value, and ii) livestock are a poor source of collateral (Binswanger and McIntire 1987). Financing institutions are often reluctant to give credit to households without any form of collateral; that is one of the reasons why the financially-integrated households depend on guarantors (i.e. social collateral) (see Chapter 3). But social collateral depends on trust which takes some time to develop. Therefore, alternative ways are needed through which households can get credit even without social collateral. Perhaps one way through which this could be achieved, is by the government supporting, and providing incentives, for the establishment of informal credit markets (composed of credit societies, traders, and rotating savings and credit associations, or ROSCAs). Compared to formal credit markets, the informal credit markets are easy to access, charge low administrative and procedural costs, require little or no collateral; therefore, they are well-suited to cater to the needs of low-income households. This does not mean that the informal credit markets are a panacea for all challenges associated with liquidity constraints, but they could certainly help to enhance the ability of households to deal with risks and shocks.

6.3.5 The role of local institutions in facilitating adaptation

Evidence from the literature points to two broad and overlapping categories of adaptation practices (Vermeulen et al., 2012): i) practices that households develop over time, with the resources at their disposal, on the basis of their long-term experience with shocks, and ii) adaptation practices that are planned, in view of predicted developments. A poor understanding on the part of policy makers and their scientific advisors of what shapes the households' adaptive capacity may lead to inept strategies that constrain the ability of households to adopt appropriate adaptation practices (of both categories) in the face of climate change-related risks (Adger et al., 2003; Shiferaw et al., 2009).

In chapter 4, we focused on the way local institutions and socio-economic characteristics shape the ability of households to adapt to climate change. The available options for adaptation depend on the way institutions regulate and structure the interactions between households and other actors within and outside communities (Agrawal, 2008). Our findings showed that the three dimensions of local institutions (i.e. tenure security, rule of law and accountability) were positively related to the number of adopted practices. This corroborates the evidence presented in the literature (e.g. Adger, 1999; Berkes and Jolly, 2001; Ivey et al., 2004; Eakin 2005) which shows that local institutions modify the effects of climate change on household livelihoods in several ways: i) by acting as a medium through which external interventions can reinforce existing adaptation practices, ii) by creating an incentive framework for individual and collection action, and iii) by structuring environmental risks and thereby reducing the vulnerability to climate impacts. For example, the effects of shocks, such as droughts, to households can be minimized in a situation where local institutions increase access to livelihood resources such as land, water, and grazing areas in an equitable way. This requires transparency, good governance and accountability on the part of these institutions.

Following a suggestion that adaptive capacity can be used to compare the households' potential to adapt to climate change across systems (Dulal et al., 2010;

Eakin and Bojorqueztapia 2008), we developed an adaptive capacity indicator. We analysed household behaviours toward the adoption of adaptation practices at a specific site, taking into consideration both internal and external factors. Our findings showed that adaptive capacity was high when the quality of local institutions was good. This suggests that development interventions aiming to improve the welfare of households should also aim at improving local institutions. In fact, in order to increase the potential of households to adapt and to lessen the negative effects of climate change, it may be necessary to strengthen institutions at all levels (Ostrom, 2009). Evidence from the published literature shows that when the state and local institutions deal in a collaborative and cooperative manner with challenges such as those associated with land and water use, the chances of mitigating the effects of climate-related shocks are higher (Crane, 2013). The finding that tenure security, rule of law and accountability have a positive and complementary effect on adaptive capacity, contribute to the debate on how to ensure a greater capacity to adapt locally (see Agrawal, 2008; Crane, 2013), and on how local efforts at improvement can benefit from those attempted at other levels (ibid.). This study contributes to this debate by focusing on tenure security, rule of law and governance and accountability provided by local institutions, and by showing that the capacity of households to adapt depends to a high degree on them. The quality of local institutions determines the way households in a community accumulate their resources, which in turn, determines their welfare level (Little et al., 2001), and hence their adaptive capacity.

This does not mean that improving the quality of local institutions would suffice to prepare households for the risks that climate change entails. Chances are that in the longer term climate change may pose challenges that local institutions cannot deal with alone. Our argument is that local institutions can play an important role in regulating access to resources that are needed to realise a viable adaptation strategy at the household level.

6.3.6 The role of household characteristics and the spatial variable

The results in Chapter 4 showed that the characteristics of households determine to a large extent the willingness to invest in specific adaptation strategies, like improving soil fertility, intensifying crop production, income diversification, or migration. The findings also showed that, apart from household characteristics and the quality of local institutions, spatial variables affect the adoption of adaptation strategies. For example, while in Samburu County we find that distance to the local market is positively related to livestock wealth across all households (see Chapter 2), in Borena region we find that the distance to the tarmac road is positively and negatively associated with crop and livestock intensification respectively (see Chapter 4). This suggests that differences in the main sources of livelihood among households partly determine how the spatial variable affects the adoption of adaptation strategies. In Borena region we find that households with poor access to the road, and hence to the market, diversify and intensify their agricultural activities in order to obtain sufficient yields to satisfy their needs, with the distance to the market serving as a disincentive to the intensification of the rearing of livestock, used for cash generation. In contrast, in Samburu County we find that poor access to the market is correlated with high livestock wealth. These findings underscore the important role that the spatial variable plays on the household welfare level. This means that that policy prescriptions and interventions aimed at furthering the adoption of adaptation strategies among households in the semi-arid environment need to take into account the specific context, the differences in the characteristics (including resource endowment) of households, and spatial variables. Clearly, there is no 'one size fits all' solution.

Our findings showed that the variables of natural, physical, social, financial and natural capital had less explanatory power than the household characteristics. This suggests that even though the adaptive capacity index and the five capitals provide a way of representing the potential of households to adapt (e.g. Adger and Vincent 2005; Dulal et al., 2010; Eakin and Bojorquez-Tapia 2008; Tompkins and Adger 2004) in a way that allows a comparison across systems, they might not be suitable if we want to analyse the behaviour of households at a specific site. If we want to do this, we do best to use household level information directly.

6.3.7. The potential effects of adaptation on food security and farm income

Food security is said to exist 'when all people at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life' (FAO, 1996). This definition points to four main aspects of food security: the physical availability of food, the economic and physical access to it, its utilization, and the stability of these three dimensions over time. In Chapter 5, the focus was on the physical access of households to energy provided by their own of crops and livestock, and the food they purchase. Our findings showed that most of the households in the study area experience food shortages (see Table 5.3 in Chapter 5). These food shortages can be attributed to both environmental and socio-economic shocks – such as conflict over resources such as water and pastures – that households have to deal with (Ongoro and Ogara, 2012). Our findings showed that the contribution of crops to food self-sufficiency decreased as we move from wetter to drier areas, and correlates with the amount of arable land owned. The crop yields are lower in drier areas, which impacts food security negatively (Maxwel and Fitzpatrick 2012). Our findings also showed that as we move from wetter to drier sites, livestock makes a more important contribution to the food availability ratio. In the drier areas we find fewer households with arable land and more specializing in livestock keeping. The household food availability ratio varied across sites, and was not related to the average annual rainfall. This could be explained by the highly diverse livelihood strategies and farm characteristics of households in the study site. Evidence from the published literature suggests that food security at a given site is linked to productive resources possessed by individual households (Ritzema et al., 2017). We found however, that across all the sites studied off-farm income was a key contributor to the food availability ratio. This points to the importance of other sources of income in supporting food availability, particularly in areas where there is limited potential for crop and livestock production (Douxchamps et al., 2016). It seems, therefore, that interventions aimed at transforming livelihood systems in semi-arid areas can help to improve the food availability potential, especially among households that have few assets – such as land and livestock – to build on (as is also argued by Jayne et al., 2014; Kristjanson et al., 2010; and Otsuka and Yamano et al., 2006).

Studies aiming to achieve an ex-ante understanding of how different technologies and interventions affect resource-use efficiencies, crop and livestock productivity, the availability of and access to food, often use modelling approaches whereby scenarios – harnessing relevant stakeholders perspectives – are analysed (Claessens et al., 2012; Herrero et al., 2014; Kanellopoulos et al., 2014). The scenarios are viewed as a tool which enables the researcher to capture experiences and narratives in a way that can be integrated into quantitative formulations through modelling, so as to gain insight into what may happen in the future (Volkery et al., 2008). Scenario analysis thus enables the researcher to gain an in-depth understanding of how a system may perform if different interventions are implemented (Kok et al., 2011). In this study, dynamic modelling was used to explore how the adoption of adaptation strategies can support household food security and farm income under conditions of climate change. Some household expenses, such as school fees, clothing, and medicine were not taken into account, due to lack of reliable data. Therefore, the food security and income outcomes in Chapter 4 represent 'potential outcomes', rather than full outcomes. Other authors have concluded that the use of potential outcomes is useful in quantifying the performance of farming systems where agricultural productivity is a major challenge (Frelat et al., 2016; Ritzema et al., 2017). We compared the results from the different scenarios with the results of the baseline scenario. Our findings showed that, if improved farming and livestock intensification are implemented, food insecurity would be reduced and farm income for households would increase – even if droughts occur more frequently. We also found that an increase in the prices of crops and livestock products would improve food security and farm income substantially. This points to the importance of investments in infrastructure (such as roads) and value chain development, as these will enable households to get higher prices for their crop and livestock products. Our claim that intensification combined with the adoption of a more market-oriented is the best strategy to prevent food the insecurity that households in Northern Kenya frequently experience, concurs with the conclusions of past research (e.g. Ritzema et al., 2017).

It is clear the occurrence of extreme climatic events such as droughts may have a substantial negative impact on crop and livestock production (Collier et al., 2008; Toulmin, 2009). Our exploration results showed that even if climate change will progress as projected, improved farming and livestock intensification have the potential to limit the impact of droughts on food security and improve the economic performance of households in the semi-arid areas.

6.4 Policy Implications

This thesis explored strategies that pastoral and agro-pastoral households use to cope with and adapt to climate change in arid and semi-arid areas in East Africa. The findings have a number of policy implications. The finding in Chapter 2 that as we move from wetter to drier environments, the accumulation of livestock wealth and social capital varies across groups (although the evidence for this effect is not robust), suggests that multifaceted interventions, rather than a singular approach, are called for in order to help households in the semi-arid areas to improve their adaptation. For households that tend to accumulate livestock as a response to the environment becoming drier, programmes aiming to enhance the livelihoods of pastoral and agro-pastoral households, such as Index-Based Livestock Insurance (IBLI) in Northern Kenya and Southern Ethiopia, run by International Livestock Research Institute (e.g. Chantarat et al., 2013), could be important. However, for some households, provision of such support by IBLI may take away the incentive to invest in social relationships. The findings in Chapter 2 also suggest that there is a need for programs that can improve the selection and breeding of drought-tolerant animals.

The finding in Chapter 2 that most of the poor households depend on other insurance strategies, which do not generate substantial income streams, such as borrowing food and paying in kind, petty trade, and selling their own labour, suggests that policies aimed at helping pastoral and agro-pastoral households to cope and adapt need to be complemented with policies that increase the opportunities for these households. The finding that trust levels vary with environmental conditions for financially-integrated households only, and not for the wealthy households, suggests that the adaptation strategies that households use are as the resultant of many factors. Therefore, there is a need for well-designed policies that promote developments in several dimensions (assets, social relations, the household economy, relevant institutions, e.g. those providing credit), while simultaneously protecting the environment.

Our finding in Chapter 3 that remittances are the channel through which migration facilitates the adoption of costly adaptation strategies, and that migration increases consumption both directly and indirectly, suggests that policies aimed at improving the food-security situation should support both on-farm and off-farm strategies. By strengthening credit-providing institutions they may facilitate the implementation of promising adaptation strategies.

Our finding in Chapter 4 that adaptive capacity is tied to the quality of local institutions, implies that there is need for policy measures that can help strengthen and improve the quality of these institutions, and that also take advantage of the already existing institutions that regulate how households access resources in a community.

Our findings in Chapter 5 showed that the adoption of new technologies and methods, such as the use of fertilizer and certified seeds, timely planting, adequate spacing, and improved livestock feeding, is necessary for improving household food security and farm income. This implies that policy measures should encourage the adoption of improved farming and livestock intensification. An increase in prices of farm products was also found to have a positive impact on food security and farm income, suggesting that policies aimed at supporting the improvement of infrastructure and communication are important for enhancing the ability of households to adapt.

6.5 Limitations and future research agenda

At the conception of this study, I intended to use data from two contrasting sites in Kenya: Pokot County and Samburu County. I believed that this approach would help me to gain insight into key issues that may affect coping and adaptation strategies among households in the semi-arid areas. However, this plan was frustrated by an eruption of conflict between the Pokot and Turkana communities, causing a serious insecurity situation that made it very difficult for me to conduct interviews among households in Pokot County. Faced with this constraint, I decided to focus only on Samburu County, which was relatively calm.

It was also my intention to explore the historical perspective and other issues, such as the spending on guns in Samburu, during my second year of study. However, just about the time when I concluded the household survey during my first year, a serious insecurity situation occurred in Samburu County. About forty policemen were killed. Thus, it became impossible to have a chapter on the historical perspective and on the spending on guns. In the future, it would be interesting to conduct a study that looks into these issues, and the way they impact the choice of coping and adaptation strategies.

As climate change is in nature temporal, it is difficult to study household responses in real time, and in a dynamic setting. In chapter 2, we proposed a ‘shortcut approach’ for studying the relation between climate shocks and responses to them. In order to gain more insight into how different households respond to shocks, and in order to design effective policies, further research is needed in other semi-arid areas in East Africa. This will allow more justice to be done to the variation of spatial and climate patterns. In addition, it would be worthwhile to do more research, in other geographical areas, to test the hypotheses that households accumulate livestock wealth in response to living in the drier environment, and that households invest in either structural or cognitive social capital as an insurance against climate risks. In this study we found only a very weak confirmation, and none at all, respectively, of these hypotheses.

In our probing of the mechanisms linking migration to adaptation in Chapter 3, we performed robustness analysis by replacing a binary migration variable with a continuous remittances variable defined as *ln*(remittances +1). The reason we use 'remittances +1' is that many migrant households were unwilling, or unable, to provide an estimate of the remittances; therefore, these were entered as missing observations. We did not probe into the reasons for the unwillingness to share this information. However, it would be good to know what the robust result would have looked like say, i.e. if all the household had provided the full details of remittances received. Further research, based on an understanding of the underlying reasons that could be preventing households from providing such information, would help to bring into view the effect of migration on the welfare of households and on the adoption of adaptation practices.

In Chapter 4, we assumed that the five capitals (physical, financial, social, human and natural) are of equal importance. We computed an indicator for the variable of household adaptive capacity on the basis of this assumption. Adaptive capacity is a complex multidimensional phenomenon, as it is composed of several sub-components of the five types of capital (Below et al., 2012). For instance, if we assume that the financial well-being of a household is a sub-component of adaptive capacity, income and expenditure can be considered as indicator variables. The composite structure of these indices requires us to make clear how the different variables and components should be weighed. When dealing with index aggregates, the collapsing of observable indicator variables into one variable, such as adaptive capacity, is not uncommon (see e.g. Hinkel, 2011). The literature on index studies carried out to date has not yet identified an objective method for selecting indicator variables and for weighing them (ibid.). Therefore, the aggregation of the five capitals on the assumption of equal importance is a flawed procedure. Aware of this shortcoming, some scientists interpret empirical data on the basis of experts' knowledge (Hahn et al., 2009), while others try to determine the weight of the index components through a principal component analysis (e.g. Gbetibouo et al., 2010). In this study we did not use any of the two methods, because they also have some major shortcomings. A major weakness of interpreting data on the basis of experts' knowledge, for example, is that the weights developed depend on the availability of this type of knowledge, and are very relative (ibid.). Principal component analysis may also result in paradoxical weights, if not properly executed (Kolenikov and Angeles, 2009). The published literature indicates that for one to be able to generate reliable weights using principal component analysis, a first principal component must be identified that reflects the concept of adaptive capacity (Keil et al., 2008). However, it is difficult to identify the first component in an unequivocal way in the case of households' adaptation processes that usually serve multiple purposes (Bryceson, 2002). This problem underscores the need for future research that can help to identify a suitable method for aggregating the adaptive capacity indicator in a more objective way at different scales (national, regional, and local).

In our analysis in Chapter 4, we were not able to establish whether the quality of local institutions is more important than the characteristics of households. This can partly be explained by the analytical approach we used. To be able to establish which of the two is more important, perhaps a method that takes into account their relative weight is required; this is an area that needs further probing in the future.

The analysis of the effects of interventions aiming to improve farm management and boost food prices on food security and farm incomes, by means of modelling long-term developments, as performed in Chapter 5, can mask significant factors that may affect the outcomes for pastoral and agro-pastoral households in the intermediate term. More could be learned by applying a more dynamic modelling based on the trajectories of pastoral and agro-pastoral households as reported by the households themselves. It would also be interesting to quantify the magnitude of crop and livestock losses when a shock such as a drought occurs. Our findings indicating that improved farming and livestock intensification can help to improve food security and farm incomes, point to a need for further research that examines how improved agricultural technologies can best be implemented (and what could hinder their implementation) in the semi-arid areas.

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Summary

In this thesis I set out to investigate how households cope and adapt to climate change in the context of arid and semi-arid areas of East Africa. This research fits well in the wider literature on the relationship between climate change and variability and household responses in term of coping and adaptation. Yet, there is still much to be learned about coping and adaptation strategies in light of climate change in the arid and semi-arid areas. I present evidence from the semi-arid areas of Kenya and Ethiopia based on household level data using a range of analytical methods.

In Chapter 1, I present an overview of the importance of arid and semi-arid areas to the livelihoods of pastoralist and agro-pastoralist, and the risks and uncertainties that these households face. I also highlight climate-related risk and the expected exacerbation of these risks due to future climate change. This discussion leads towards highlighting the importance of the impacts and risks associated with current climate variability to understand how households adapt now and how they could adapt to future, greater risks.

In Chapter 2, I analyse how natural environment and market accessibility affect coping and adaptation strategies of pastoralist, using a set of detailed data collected from a sample of 500 households in Samburu County in Kenya. Specifically, the research question that I seek to answer is whether households accumulate livestock wealth and invest in structural and cognitive social capital to protect themselves against climate risks. I find evidence, albeit weak, that households accumulate livestock wealth in response to living in an environment that is drier. I find no evidence that the households invest in either structural or cognitive social capital as insurance against climate risks. However, my results show that the coping strategies used by households varied across social groups in that, while rainfall does not robustly affect cognitive social capital among the wealthy households, there is a greater mutual trust among the ‘poor’ and ‘financially integrated’ households. These findings suggest that policies aiming to support strategies for improving household adaptive capacity in the semi-arid areas

should incorporate information on the socio-economic condition, differential access to infrastructure, and dynamic and differentiated responses that households use.

In Chapter 3, I explore whether migration of household members enhances adoption of agricultural innovations that aim to provide protection against weather shocks. Specifically, I seek to find out whether migration and adaptation are complementary mechanisms that households or substitutes. I find evidence, which suggests that remittance from migrant households that can help to relax capital constraints. I also find that remittances are important mechanisms linking migration to adoption, by enabling households to adopt new technologies, particularly, those that involve high costs such as purchasing of drought tolerant livestock. These results indicate that households with at least one member who has migrated are able to overcome barriers of adopting costly adaptation practices by using remittances received. In this way, households enhance their self-protection against climate-related shocks.

In Chapter 4, using data from a sample of 400 households from Borena in Oromia region of Ethiopia, I investigate what drives adoption of adaptation agricultural practices that can decrease the vulnerability of agro-pastoralists to climate change. I find that households with strong adaptive capacity adopt a larger number of practices. I also find that households' adaptive capacity is strong when the quality of local institutions is high. However, the explanatory power of adaptive capacity in explaining the adoption of adaptation practices is lower than household socio-economic characteristics. This finding suggests that aggregating information into one indicator of adaptive capacity for site-specific studies might not be able to explain adoption behaviour of households. The study also shows that strong local institutions lead to changes in key household characteristics, which positively affect adoption of both crops and livestock related adaptation practices. This analysis suggests that policies aiming to improve household adaptive capacity in the semi-arid areas should focus on strengthening local institutions.

In Chapter 5, I use a dynamic modelling approach to enhance my understanding of how the adoption of selected adaptation practices affect the food security and income for diverse agro-pastoralist households. I also explored the impact of climate change through increased probability of the drought on food security and farm income. I find that in sites where both cropping and livestock keeping is practiced, improved farm management (i.e., the use of fertiliser, certified seeds, preparing land early, and planting using the recommended rate) has the potential of preventing households from falling into food insecurity situation. In sites where only livestock keeping is practiced, I find that livestock intensification (i.e., changing livestock type and improving livestock management and livestock feeding) is key in preventing households from falling into food insecurity situation. I also find that improvement of market prices for farm products in all sites improves household food security and income. I also find that implementing improved farming and livestock intensification has the potential for minimizing the negative impact of drought – even when the probability of drought increases – on households' food security and income. This exploration suggests that to improve food security and farm income in the semi-arid areas, policies should aim to support the use of fertiliser, certified seeds, provision of appropriate advice to households through agricultural extension officers and investment on infrastructures such as road and communication.

Chapter 6 provides a synthesis and discusses the broader implication from the research finding from this thesis. Adoption of innovative self-protection coping and adaptation strategies – which sometimes varies spatially among social groups – and local institutions play a key role as vehicles of change for improved households adaptation in the arid and semi-arid areas. Yet, these vehicles of change may also act as an obstacle to adaptation if they are not properly understood, because in such cases it may be difficult to modify, improve or support them. Therefore, an in-depth understanding of the role of self-protective coping and adaptation strategies and local institutions among households is of utmost importance

Curriculum vitae

Stanley Karanja Ng'ang'a was born on the 15th August 1977 in Nakuru County – Kenya. In 1996, he completed high school in Nakuru and in 2004 he completed his Bachelor of Science degree from the Faculty of Agriculture at Egerton University – Kenya. After graduation he worked as a trader in Nakuru, but later joined International Livestock Research Institute (ILRI) as full time research assistant. In 2008, he commenced part time MSc study at College of Agriculture and Veterinary Sciences at the University of Nairobi -Kenya, in collaboration with University of Pretoria – South Africa. In 2010, he completed his MSc in Agricultural and Applied economics researching the role of non-marketed benefits of livestock in the arid and semi-arid areas of Mozambique. During his MSc study he continued to work as a research associate at ILRI where he was supporting various projects looking at increasing the adaptive capacity of agro-pastoralists to climate change in selected countries in East, West and Southern Africa. In 2011, after obtaining a PhD scholarship from Sustainable Livestock Futures program at ILRI, he started his PhD research at Wageningen University in the Plant Production Systems and Development Economics groups. In 2012, he was offered the opportunity to attend a training on exploring trade-offs around livelihood in farming systems at Swedish University of Agricultural Sciences, and that ignited his interests in the of use of mathematical models in agricultural science. During his PhD research, he studied how households cope and adapt to climate change and variability in arid and semi-arid areas of East Africa. He is currently working as agricultural development economist at the International Center of Tropical Agriculture, where he conducts analysis on costs, benefit and trade-offs of potential climate smart agricultural practices. He can be contacted at stanley.karanja@gmail.com.

PE&RC and WASS PhD education statement form

Stanley Karanja Ng'ang'a
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/ Institute	Year	ECTS*
A) Project related competences			
Review of the literature	WUR	2011	6
Writing of the project proposal	WUR	2011	4.5
Central themes in development economics (DEC 30306)	WUR	2011	1.5
Quantitative analysis of cropping and grassland (PPS 30806)	WUR	2011	1.5
Exploring trade analysis through modelling	SLU – Sweden	2012	3.0
B) General research related competences			
PE & RC Introduction weekend	WUR	2011	0.9
Generalized linear models	PE&RC	2011	0.6
Working with Endnote 4	WUR library	2011	0.6
Reviewing in scientific papers: Journal of Arid Environment and International Journal of Disaster and Risk management (Elsevier)	ILRI	2013, 2014	2
'Exploring use of livestock wealth and social capital by pastoral and agro-households in ASALs as insurance against climate change and variability risks: A case of Samburu District in Kenya'	4th International conference African Association of Agricultural Economists, Tunisia	2013	1
C) Career related competences/personal development			
Participating in monthly meetings for sustainable livestock Future (Now PLE), weekly seminars	ILRI	2011-2014	3.0
Attendance and participation in weekly seminars at university of Nairobi (CaVS) Agricultural economics and LARMAT, ICRAF, ICIPE, ICRISAT (7 Meetings)	University of Nairobi, ICRAF, ICIPE, ICRISAT	2011-2014	4.5
Attendance and ILRI livestock talk seminars (once a month)	ILRI	2012-2015	1.5
Total			**30.6**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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