Institute of Animal Production in the Tropics and Subtropics

Climate change, cattle herd vulnerability and food insecurity: Adaptation through livestock diversification in the Borana pastoral system of Ethiopia

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DECLARATION

I hereby declare that this doctoral thesis is a result of my personal work and that no other than the indicated aids have been used for its completion. All quotations and statements that have been inferred literally or in a general manner from published or unpublished sources are marked as such. Furthermore, I assure that the work has not been used, neither completely nor in part, for achieving any other academic degree.

Bekele Megersa Bati,

Stuttgart-Hohenheim, 02 July 2013

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LIST OF ACRONYMS AND ABBREVIATIONS

°C:	Degree Celsius
C_3 and C_4.plants:	are metabolic pathways for carbon fixation in plant photosynthesis, in which organic molecules containing 3-carbon and 4-carbon atoms are produced
CO_2:	Carbon dioxide
CV:	Coefficient of Variation
DDS:	Dietary Diversity Score
FAO:	Food and Agriculture Organization of the United Nations
GAM:	Generalized Additive Model
HFIAS:	Household Food Insecurity Access Scale
IPCC:	Intergovernmental Panel on Climate Change
ML:	Milliliter
MM:	Millimeter
N:	Number of observation
NA:	Not Applicable
PA:	Pastoral Associations
SAS:	Statistical Analysis System
SD:	Standard Deviation
TLU:	Tropical Livestock Unit
WISP:	World Initiative for Sustainable Pastoralism

1 General introduction

1.1 Background and research objectives

Anthropogenic global warming, caused by increasing atmospheric concentrations of greenhouse gasses since the mid-20th century, has brought about observable changes on our planet. Changing patterns in precipitation, a rise in global mean temperature, and increasing frequencies of extreme events such as flooding, drought and heat waves are, among others, so far evidenced (IPCC 2007). The magnitude of such changes and adverse effects are not uniform across the globe with much more negative effects in lower latitudes. On the other hand, increasing temperature and CO_2 sequestration may temporarily be advantageous for crop and pasture productivity in higher latitudes (IPCC 2007). The impacts of rising average temperature, rainfall variability and increase in the frequency and intensity of droughts are undeniably more severe in the tropics than temperate regions. Different studies (Funk and Verdin 2010; Williams and Funk 2011; Williams et al. 2012) have shown that the eastern Africa is getting drier, as climate change increases the sea surface temperature of the Indian Ocean. The same authors ascribed increased drought recurrences to the anthropogenic climate change. Several other studies (Cheung et al. 2008; Rao et al. 2011; Omondi et al. 2012; Kassie et al. 2013) have also shown a long-term reduction in mean precipitation, particularly in the major rainy seasons, which is suggestive of climatic change impacts in the region.

Long-term changes in temperature and precipitation patterns are two of the commonly used proxy indicators for regional climate change. A large body of available literature emphasizes the greater influence of precipitation changes in East Africa (Funk and Verdin 2010; Williams and Funk 2011; Omondi et al. 2012; Viste et al. 2013; Williams et al. 2012) compared to similar trends in temperature (Collins 2011). A potential reason for this can be seen in the higher volatility in interannual precipitation that decisively affects a vast majority of the population, who rely upon rain-fed agriculture for their livelihoods (Kotir 2011; Kassie et al. 2013). The high susceptibility of agriculture to climate change scenarios emanates from its inherent link to climatic factors and natural resources, which are extremely sensitive to changes in climate variables (Howden et al.

2007; Anwar et al. 2013). Hence, climate change is posing unprecedented challenges to crop cultivation and livestock production in East Africa (Kassie et al. 2013). The prevailing smallholder livestock production in the region, such as pastoralism, is highly vulnerable to changing climatic factors given the high dependency of the sector on scarce natural resources and a low adaptive capacity of the developing countries' economies.

Increases in temperature directly pose thermal stresses on animals, impair feed intake, metabolic activities and defense mechanisms, thereby hindering their production and reproductive performances (Nardone et al. 2010). Rises in temperature also adversely affect pastoral livestock production through indirect impacts on pasture growth, water availability and disease distributions (Thornton et al. 2009). Changes in climate and CO_2 concentrations affect the function and distribution of plants and thus, alter the rangeland vegetation composition. An increase in atmospheric CO_2 concentration could favor the dominance of C_3 woody plants over C_4 grasses due to higher rates of net photosynthesis in C_3 plants (Ward 2010). Drought episodes and stress conditions may also have a disproportionate effect on plant communities, with a profound negative outcome on the herbaceous biomass, while favoring the recruitment of vigorous woody plants (Hiernaux et al. 2009). A decline in herbaceous biomass production would subsequently reduce the carrying capacity of rangelands (Morton 2007; Thornton et al. 2007). Rising temperatures, coupled with declined precipitation reduce the crude protein and digestible organic matter contents of the plants, thereby posing nutritional stresses to grazing animals (Craine et al. 2010). The lower the water and feed availability, and the nutritional quality of pastures, the higher the negative impacts on the productivity and health status of livestock (Thornton et al. 2009; Nardone et al. 2010). As animals suffer from nutritional stresses and energy deficits, they subsequently succumb to extreme weather conditions.

Notably, recurrent droughts are evidenced to be the most destructive to the asset basis of pastoral people like the Borana of East Africa. Droughts can lead to herd depletion through increased mortalities, forced off-takes, and emergency slaughter (Cossins and Upton 1988). Desta and Coppock (2002) have anticipated that drought occurrences cause massive cattle losses every 5 to 6 years on the Borana Plateau. Such quasi-periodic shocks have been evidenced to cause substantial declines in cattle herds, such as by 43% in 1983/1984 (Cossins and Upton 1988), 42% in 1991/1992, 25% in 1996 (Tache 2008) and 53% in 1999/2000 (Angassa and Oba 2007). As a result, a total of 45 million dollars asset losses have been estimated for a target population of 7000 households between 1980 and 1997 (Desta and Coppock 2002). Although drought is one of the common risks that pastoralists were able to cope with in the past, climate change likely alters its frequency and severity, and undermines the traditional coping strategies. Risk management operations that served herders in the past are no longer as effective as they were and are eventually constrained by internal and external pressures (Desta and Coppock 2004; Homann et al. 2008). In particular, population pressure, climate change, rangeland resource degradation and fragmentation of the dry period grazing areas have emerged as critical factors limiting the coping options of pastoralists with climate risks. Apart from reports on drought related impacts on livestock mortalities, there is no empirical evidence that disentangles the adversities of contemporary climate change on the livelihood base of the Borana people. This implies the necessity of an in-depth study on the effects of climate change and its variability on traditional cattle pastoralism and household food security.

Food security exists "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). Food availability, access to available food and its biological utilization form the three interrelated pillars of food security (Barrett 2010). According to Pinstrup-Andersen (2009), availability does not necessarily assure access to food given the challenges in its distribution, and access alone also may not ensure utilization. Access to available food has also gender and cultural dimensions that account for differentials in intra-house allocation, often disfavoring women and children (Negin et al. 2009). Food utilization is the biological use of food which in turn depends on non-food factors such as health conditions of individuals, sufficient sanitation facilities, access to potable water and individual's knowledge on the basic principles of nutrition (Negin et al. 2009; Barrett 2010). By necessity, addressing food security issues thus requires bearing its dynamic nature in mind.

Interactions among the agro-ecological, socio-economic and biological factors unanimously affect the stability of the pillars of food security in a given region (Gregory et al. 2005; Barrett 2010). In Ethiopia, seasonal food insecurities that have roots in low-input farming, poor markets and rural infrastructure, and low economic status of smallholders (Ferro-Luzzi et al. 2001; Regassa and Stoecker 2012), are triggered by climate shocks and further exacerbated by market failures (Desta and Coppock 2004; Devereux 2009). While food insecurity is a major concern in developing nations, accentuated by climate variability and change, pastoralists' unpredictable exposure to climate risks could make them the worst affected. In pastoral regions of Ethiopia, food deficits often occur in dry spells and drought periods as a downward cyclical pattern of availability and access to food. Thus, food shortage coincides with diminishing purchasing power of the households due to unfavorable terms of trade between livestock and staple cereals or "the exchange failure" (Devereux 2009). Although the impacts of climate change on household food security have been highlighted in the literature (Gregory et al. 2005), understanding the depth of its severity and the existing coping strategies of the local people is of paramount importance in combating food insecurity.

Measurements of food security combine different proxy indicators due to a conventionally lack of a precise tool that accurately estimates food security status of a region, a household or an individual. Among the proxy measures, the household food insecurity access scale (HFIAS) and the dietary diversity score (DDS) have been widely applied to assess food security on household (Becquey et al. 2010; Regassa and Stoecker 2012) and individual levels (Oldewage-Theron and Kruger 2011). These measures were reported to perform well in approximating diet adequacy and assessing household food security (Becquey et al. 2010). The association between dietary diversity and the nutrient adequacy ratio designates the dietary diversity score as a simple, but good indicator of food security (Oldewage-Theron and Kruger 2011). Such a simple and adequate tool is of importance in measuring food security under pastoral conditions, where mobility, gender dimension and seasonality affect dietary intake (Villa et al. 2011).

The risk of severe cattle losses during recurrent droughts and the associated food insecurity might have forced the Borana herders to diversify into livestock species such as camels, goats and sheep. Recent studies have shown that cattle are generally the most sensitive livestock species to the adverse effects of climate change scenarios (Seo et al., 2010; Lesnoff et al. 2012). Lunde and Lindtjørn (2013) have demonstrated the highest vulnerability to climate variability to be in arid environments. In line with this, different studies have documented herders' responses to such environmental challenges (Seo et al. 2009, 2010; Silvestri et al. 2012). Livestock keepers seem to increasingly shift from vulnerable to more adapted species, e.g. from cattle to goats in Africa (Seo et al. 2009), from cattle to sheep in the Andean region (Seo et al. 2010), or from cattle to camels in Africa (Faye et al. 2012). Similarly, reporting on diversification of herd composition among the Borana herders is on the rise (Homann et al. 2008; Zander 2011). Differences among livestock species in their tolerance to drought, heat stress, or water and feed shortages, offer livestock keepers the possibility of choosing species that are better adapted to changing environmental conditions (Seo et al. 2009; Doti 2010; Speranza 2010). Species diversification also endows herders with different complementing utilities and rangeland resource uses in addition to buffering ability against risks (Seo et al. 2009; Doti, 2010). While livestock diversification is increasingly highlighted in the literature as an adaptation strategy to climatic changes (Seo et al. 2009; Doti, 2010; 2010; Speranza 2010), there is little empirical evidence regarding its role in improving livelihoods and resilience to climate change in a pastoral context, which gave impetus to this study.

Therefore, the present study was aimed at investigating the impacts of climate change driven factors on traditional cattle pastoralism and household food security, as well as the role of livestock species diversification as a local adaptation strategy in the Borana pastoral production system of southern Ethiopia. The overall objective of this study was addressed through achieving the following specific objectives in the subsequent chapters (papers) of the thesis:

1) Documenting the perception of the Borana livestock keepers toward climate change and its impacts on their traditional cattle-based livelihoods,

2) Exploring the relationship between trends in long-term climate data and cattle herd sizes to portray climate change and its variability as a major driver of cattle population dynamics,
3) Examining the role of livestock diversification in combating household food insecurity under changing climatic conditions,
4) Analyzing household level livestock diversification, its drivers and restraining factors, and functions of different species,
5) Assessing the vulnerability and adaptability of different livestock species to climate change scenarios.

1.2 Overview of the study

The study was carried out in the Borana zone of Oromia Regional State, southern Ethiopia (Figure 1.1). Two districts, Dire and Yabelo, were purposively selected to represent the Borana area. The districts are similar in terms of ethnicity, production system and agro-ecology. They are predominantly inhabited by the Borana Oromo, and are characterized by a (agro) pastoral production system and a semi-arid environment. Minor differences between the two districts refer to the permanent water sources, where in Dire a *Tula*-well water system is utilized while Yabelo is a non-*Tula* ecosystem (use of surface water harvesting ponds). *Tula*-wells are clusters of nine deep well complexes, which serve as a permanent source of water supply and focal points for social organizations (Coppock 1994). Accordingly, the districts were considered as explanatory factors in different data analysis approaches. Following district selection, three pastoral associations (PA), the lowest administrative unit, were sampled from each district, and were fitted as random effects in some analyses. The estimated total sample size of 242 households was distributed equally between the two districts and six PAs. It was estimated from the districts data that 200 to 400 households are living in a PA. Subsequently, households were selected using a systematic random sampling by selecting every fourth household (every fourth house) from a village settlement by walking with an informant through a village.

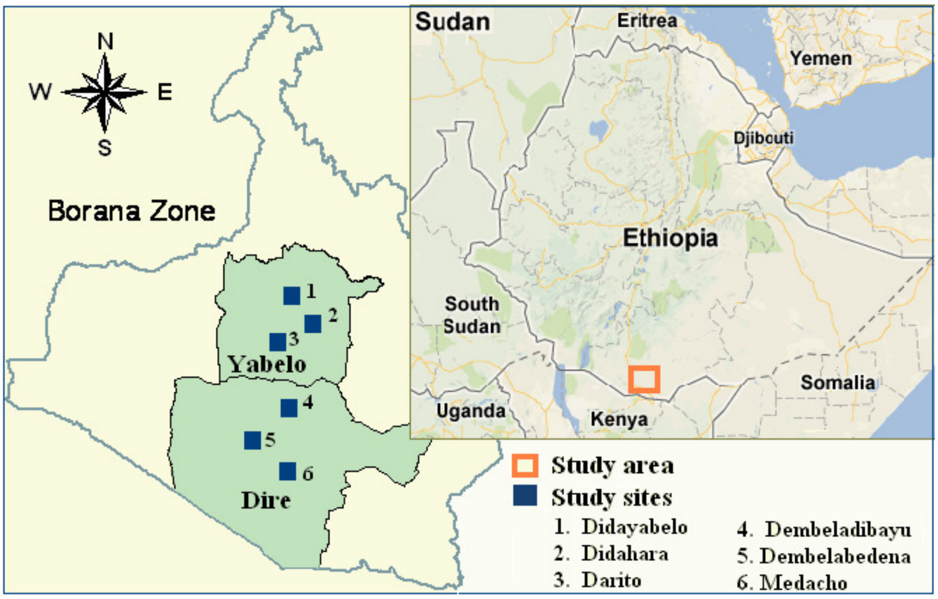

Figure 1.1 Map of study area and study sites (source: maps.google.de with modifications)

Data collection encompassed different methods such as (1) a household surveys, (2) participatory discussions, (3) a dietary diversity survey and (4) the acquisition of long-term meteorological data of the study area. Brief descriptions of each of these components are given in the following paragraphs. Questionnaire surveys were administered to 242 households between August and December 2011. The well known "*gada"* timeline in the study area (Legesse 1973) was used to capture perceived changing trends in climate, livestock production and household food security as well as to reconstruct cattle herd history. The herd history recall method has been used in similar studies and was shown to be an effective approach under pastoral conditions where written documents do not exist (Desta and Coppock 2002; Angassa and Oba 2007; Tache and Oba 2010). The questionnaire also contained household's socio-economic variables, e.g. type and number of livestock holdings, farmland size, off-farm income sources and other household characteristics. Household level livestock mortalities, particularly cattle death losses due to the drought of 2010-2011, were also recorded.

In addition to the administered questionnaires, six participatory group discussions with eight to twelve key informants in each group per PA were carried out to get a broader picture of the herders' perceptions on changing trends in climate, rangeland ecosystem, livestock production and household food security. The discussions served to trace back past events such as drought occurrences, flooding, livestock disease epidemics and others by using the *"gada"* timeline. The information was captured by scoring, ranking and semi-structured discussions.

The next methodological approach of the study accommodated a longitudinal dietary diversity survey conducted at the beginning (September 2011) and at the end (December 2011) of the short rainy season. One or more individuals of a household such as the household's head, his wife and their children above 15 years of age, were interviewed twice to assess the seasonal patterns of dietary diversity. Accordingly, dietary data were collected from 339 individuals using the 24-hour recall method based on a 14-food group model for measuring individual dietary diversity (FAO 2007). The quantity of each ingredient in the meal was then estimated using households' measurement utensils in order to regard the meal as single or multiple food groups. Foods consumed on feasts and other special occasions were intentionally excluded, while paying particular attention to those foods that may easily be missed during the recall, such as animal fats, butter, oil, spices, and small amounts of meat and vegetables.

Monthly rainfall and temperature data covering the years 1970 to 2009 were obtained from the Ethiopian National Meteorological Agency (ENMA) for Yabelo (Yabelo station) and Dire (Mega station) districts. Additionally, climate records of the Southern Rangelands Development Unit and the Yabelo Research Center from 2010 to 2011 were used to fill missing values in the ENMA data.

1.3 Outline of the thesis

Chapter 2 of the thesis addressing "Impacts of climate change and its variability on cattle production in southern Ethiopia" was submitted to Agricultural Systems. The chapter analyses perceptions of herders and long-term cattle herd and climatic data to provide insights into how climate change and variability adversely affected pastoral cattle production in the Borana region of southern Ethiopia. It portrays the relationship between trends in cattle herd changes and climate variability using a generalized additive model (GAM). The chapter further deals with patterns in interannual precipitation and temperature and looks for evidence of a quasi-periodicity in the annual rainfall. This chapter also relates patterns of seasonal precipitations and drought occurrences with cattle herd anomalies to describe climate variability as a major driver of cattle population dynamics.

Chapter 3 focuses on "The role of livestock diversification in ensuring household food security under a changing climate in Borana", submitted to Food Security. It explores the changing trends in livestock production (from the traditional cattle-based livelihood to multispecies herding) and food security. By using herders' perceptions, a household food insecurity access scale and dietary diversity scores, the chapter examines the role of livestock diversification in alleviating household food insecurity under a changing climate, taking the case of the 2010/2011 drought as an example. Additionally, other socio-economic variables affecting household food security, such as per capita livestock holdings, family size, off-farm income and farmland size were analyzed using a generalized linear model (GLM). An ordered logit model was applied to analyze terciles of dietary diversity for household and individual level predictors.

Chapter 4 corresponds to "Livestock diversification as an adaptation strategy to climate and rangeland ecosystem changes in southern Ethiopia" and was submitted to Livestock Science. The adaptation and vulnerability of livestock species to climate change and the overall role of species diversity as adaptation strategy were assessed. Drivers and restraining factors of livestock diversification and the utilities of different species were highlighted. Much emphasis was given to the four major livestock species, i.e. cattle, camels, sheep and goats. The chapter compares the adaptation of livestock species to environmental changes using a set of nine adaptive traits. The comparative vulnerability of the livestock species to climate variability was further evaluated based on livestock mortality records from the drought of 2010/2011.

Chapter 5 consolidates the findings of the preceding three chapters, and discusses the relationship between climate change, household food security and herders adaptation strategy referring to the relevant research literature. The strengths and limitations of the methodologies applied in this study are addressed and conclusive remarks are provided. Finally, Chapter 6 and Chapter 7 contain an extensive summary of the thesis in English and German, respectively.

1.4 References

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2 Impacts of climate change and variability on cattle production in southern Ethiopia: Perceptions and empirical evidences

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Chapter 2 Impacts of climate change and its variability on cattle production in southern Ethiopia: Perceptions and empirical evidences

Abstract

Climate change and variability can severely constrain the productivity of pastoral herds by reducing water availability, forage production and quality, and hence the carrying capacity of rangelands. In particular, the risk of heavy livestock losses suffered during recurrent severe droughts associated with climate change and variability presents one of the most serious threats to pastoral livestock keepers. To generate insights into how climate change and variability adversely affect cattle production in the Borana of southern Ethiopia, we analyzed perceptions of herders and long-term changes in cattle numbers and climate data. A total of 242 households were surveyed to generate data on perceived trends in climate, rangeland condition and livestock production. Socio-demographic characteristics of households and cattle mortality due to the 2010/2011 drought were also recorded. Using a local time calendar, cattle herd history was reconstructed for periods spanning five major droughts to portray the linkage between changes in cattle number and changes in rainfall and temperature. Most of the herders perceived that rainfall has become more unpredictable, less in amount and shorter in duration, while drought recurrence and temperature have increased. Similarly, the majority perceived a decreasing trend in cattle herd sizes and their production performances. The 2010/2011 drought was associated with a substantial decline in cattle herd sizes due to heightened mortality (26%) and forced off-take (19%). Death occurrences and mortality rates varied significantly by district, herd size and feed supplementation. Spectral density analysis revealed a quasi-periodic pattern in the annual rainfall with an approximate cycle period of 8.4 years; suggesting that droughts recur approximately in every half cycle of 4.2 dry years. A downward trend in cattle population mirrored a similar underlying trend in interannual rainfall variation. Accordingly, changes in cattle number were significantly linked with changes in rainfall. In conclusion, perceptions corroborated by empirical evidences showed that climate change and variability were associated with declining cattle number, portending a precarious future to the sustainability of cattle pastoralism in southern Ethiopia and other pastoral systems.

Chapter 2 Impacts of climate change and its variability on cattle production in southern Ethiopia: Perceptions and empirical evidences

***Keywords*:** Climate Change; Drought; Rainfall Variability; Cattle Vulnerability; Pastoral System; Borana

2.1 Introduction

Traditional pastoral cattle production is the major livelihood strategy for the Borana community of East Africa (Cossins and Upton 1987; Coppock 1994). The possession of cattle, therefore, constitutes an integral part of the social, economic and ritual life for the people. An individual without cattle may not qualify to fulfill the requirements of certain social standards or to execute certain social obligations (Tache and Sjaastad 2010). In comparison to other pastoral livestock, the Borana cattle herd productivity was found to be higher due to their remarkable production and reproductive performances, low mortality rates, and suitability for arid environments (Cossins and Upton 1988b). At present, however, the Borana production system is coming under increasing pressure from various stressors, including human population growth, degrading and shrinking rangelands, insecure communal land rights, market failures, and recurrent climatic shocks (Desta and Coppock 2004; Angassa and Oba 2007; Homann et al. 2008; Tache and Sjaastad 2010). Climate change, especially increasing frequency and intensity of droughts, accentuates the impacts of these stressors, undermining the traditional coping strategies and deepening the vulnerability of the Borana pastoralists. Cattle are the livestock species most susceptible to water and feed shortages engendered by climate change (Seo et al. 2010). As a result, the Borana herders who have historically been cattle pastoralists are reportedly responding to environmental changes by adjusting their herd composition, i.e., keeping more tolerant species such as camels and goats (Zander 2011).

A long-term change in regional or global climate, in particular increasing temperatures, declining trend and increasing variability in precipitation, is typically used to assess climate change and its associated impacts (IPCC 2007). For Africa, however, the available evidence emphasizes a greater importance of the trend and variability in precipitation (Funk and Verdin 2009; Williams and Funk 2010; Williams and Funk 2011; Omondi et al. 2012; Viste et al. 2013; Williams et al. 2012) over similar changes in temperature (Collins 2011). This stems from the immediate detrimental effects of droughts on livelihoods that are dependent on rain-fed cultivation or pastoralism. Accordingly, climate change has already brought about observable changes in East Africa, such as declines in rainfall, changing rainfall seasonality, and increasing frequency of droughts (Funk and Verdin 2009; Williams and Funk 2010; Williams and Funk 2011). Evidence for declining rainfall has also been documented for Ethiopia (Cheung et al. 2008; Viste et al. 2013) with a significant decrease in the long rains (March–May) in the southern part of the country (Viste et al. 2013). East African rainfall is characteristically bimodal, and is largely influenced by atmospheric and oceanic forces through rising sea surface temperatures and the El Niño-Southern Oscillation (Omondi et al. 2012). Williams and Funk (2011) suggested a strong link between recurrent droughts in East Africa and rising Indian Ocean temperatures caused by anthropogenic warming. Consequently, the downward trend evident in the long rains (March-June) over much of the past 30 years in Ethiopia and Kenya has been attributed to climate change (Funk and Verdin, 2009 Williams and Funk 2010).

Droughts have been anticipated to occur every five to six years in the Borana rangeland (Desta and Coppock 2002), but both their frequency and severity may be rising. Droughts deplete cattle population through heightening mortality and forced off-take. A warming and drying trend in climate negatively affects the rangeland productivity by lowering the quantity and nutritional quality of forages besides causing water scarcity (Thornton et al. 2009; Nardone et al. 2010). Rising temperatures aggravate the influence of moisture stress on plant growth and thermal stress on animals. Increasing drought frequencies may unevenly affect plant communities, lowering the herbaceous biomass while potentially facilitating the invasion of vigorous woody plants (Hiernaux et al. 2009). Decreasing precipitation reduces the primary production and forage quality. It lowers soil moisture, which in turn affects nitrogen (N) cycle and reduces the amount of nitrogen available for plant uptake (Beier et al. 2008). Moreover, soil N content is already deficient in moisture stressed arid environments (Delgado-Baquerizo et al. 2013). Projected drier and warmer conditions as a consequence of climate change therefore likely worsen N deficiency and adversely affect the growth and nutritional quality of plants. Likewise, Craine et al. (2010) have demonstrated that declining precipitation and rising temperatures decrease the crude protein and digestible organic matter contents of plants. Consequently, low levels of N together with reduced levels of fermentable energy contents of forages can be expected to adversely affect rumen microflora and impair microbial protein synthesis (Calsamiglia et al. 2010). These conditions hamper the production and reproduction performances of cattle, and hence their population growth.

Previous studies have either focused mainly on assessing effects of droughts on cattle mortality (Cossins and Upton 1988a) or on relating long-term rainfall variability and grazing pressure with cattle mortalities (Desta and Coppock 2002; Angassa and Oba 2007). These studies have documented a strong influence of rainfall variability on changes in cattle numbers, but have produced mixed results regarding the effect of grazing pressure on variation in cattle numbers. However, the relationship between trends in precipitation and temperature, and contemporaneous trends in cattle numbers has attracted relatively little attention thus far. Hence, understanding the relationship between changing trends in climate and cattle numbers would advance our knowledge of the impacts of local changes in climate on the diversity of animal breeds (species) and pastoral livelihoods (Thornton et al. 2009). Documenting herders' perceptions of the changes in climate, rangeland and livestock productivity over time could reinforce the available empirical evidences. This study therefore aimed at investigating the linkages between temporal changes in precipitation and temperature and concurrent changes in cattle numbers in southern Ethiopia.

2.2 Methods

2.2.1 Study area

The study was conducted in Dire and Yabelo districts in the Borana zone of Oromia Regional State, southern Ethiopia (Figure 2.1). The Borana zone, predominantly inhabited by the Borana Oromo, extends south to the Kenyan border. It borders the Somali Region to the south east, the Southern Region to the west and north, and the Guji zone to the north east. The climate is generally semi-arid with an average annual rainfall ranging from 300 mm to 600 mm and average daily temperature from 19°C to 26°C (Coppock 1994). The area has a bimodal rainfall distribution, with the long rains "*Ganna*" extending from March to May and the short rains "*Hagaya*" from September to November. A cool dry period *"Adoolessa"* (June to August) bridges the two rainy seasons, while a warm dry season (major dry season) *"Bona Hagaya"* runs from December to February (Coppock 1994; Angassa and Oba 2007).

Droughts have frequently hit the Borana area, causing heavy livestock mortalities, particularly of cattle (Desta and Coppock 2002; Angassa and Oba 2007). Drought is an extreme weather event, which results when rainfall is far below average (failure of rainfall). In Borana area, droughts occur either due to failure of the long rains or below-average of both the short and the long rains. But, failure of the short rains alone may not result in drought if the long rains resume timely and traditional coping strategies are properly implemented. A range of strategies have been developed by Borana herders to cope with feed and water shortages, and to reduce risks related to droughts. These include moving herds between seasonal grazing areas, splitting herds into mobile and homestead milk herds, and reserving grazing areas for calves and weak animals. Veterinary treatments (e.g., ecto-parasite treatment and deworming) are also increasing during the dry periods because animals lose body condition and become more susceptible to diseases due to heightened water and food shortages. Diversification of herd species compositions, keeping other species such as camels, sheep and goats along with cattle, is also increasingly being practiced in response to changing environmental conditions (Homann et al. 2008; Zander 2011). The traditional social security system "*Busa gonofa*", which obliges the clan members to redistribute animals to those clan mates who lose livestock, is also a notable local ex-post risk management strategy (Tache and Sjaastad 2010).

The Borana production system relies on the three key rangeland resources i.e. natural pastures, water and mineral licks, besides animal health care as a vital external input (Homann et al. 2008; Tache and Sjaastad 2010). The Borana rangeland is characterized by mixed savannah vegetation dominated by woody species and perennial grasses with a continuous expansion of bush encroachment (Dalle et al. 2006), thus a reduction in grass cover and species diversity of palatable herbaceous plant species (Tefera et al. 2007). Clusters of nine deep well complexes known as

"Tula" wells serve as permanent sources of water (Coppock 1994). Constructions of surface water harvesting ponds have been undertaken since the 1970s to counteract the seasonal shortages in water supply. But the ponds have been faulted as being a major cause of rangeland degradation and weakening of social organizations (Helland 2000).

The Borana Oromos practice the "*gada"* system that governs their socio-economic and political interests. The "*gada"* system divides the society into age sets, and five generation classes "*luba",* who take turns to come to a position of authority for an eight-year cycle (Legesse 1973). In the Borana community, traditions and historical events are taught through oral narratives passed on from generation to generation, each referring to the "*gada"* period. Within a "*gada"* period, the three major reference points helpful for recalling information are (*i*) the event of taking over power (*ballii fudhan*) from the predecessor "*abba gada"*(president) which occurs at the end of a preceding "*gada"* regime, (*ii*) the general assembly (*gumi gayo*) which takes place at the fourth year (middle) of a regime, and (*iii*) handing over of power (*balli kennan*) to the next successor, which occurs at the end of eight years (Legesse 1973). In addition to the three time markers within a "*gada"* period, specific years with key political, social, cultural and natural events are also useful in assisting the recall and reconstruction of the timeline events.

2.2.2 Sampling and household survey

The two districts, Yabelo and Dire, were purposively selected to represent different sources of water, with Dire representing a *Tula*-well and Yabelo a non-*Tula* ecosystem. Three pastoral associations (PA), the lowest administrative unit, were sampled from each district. From the districts' profile data, it was estimated that 200 to 400 households may dwell in a PA. We estimated the required sample size based a presumed proportion (80%) of households practicing livestock species diversification and other adaptation strategies to counteract the impact of climate change and variability, a 95% confidence interval and a 5% margin of error. The calculated sample size of 242 households was then distributed equally between two districts and six PAs. Households were selected from villages using systematic random sampling at every fourth household based on the sampling frame identified during site selection and the pre-test phase in August 2011. If eligible members, e.g. head of a selected household, were absent during the scheduled data collection time or if a household had no livestock, then it was replaced by the next one. Households without cattle (livestock) are expected to be between 5% and 10% in the sampled villages (Tache and Sjaastad 2010). In the course of systematic selections, a household without livestock was encountered and replaced by the next one. No selected household deliberately refused to participate in the survey.

2.2.3 Data collection

Questionnaire surveys were administered to 242 households between August and December 2011. The four "*gada*" periods, Jilo Aga (1976-1984), Boru Guyo (1984-1992), Boru Madha (1992-2000), Liben Jeldesa (2000-2008) and three years (2009, 2010 and 2011) from the "*gada*" of Guyo Goba (2008-2016), were used to generate timeline data. Respondents were asked to answer questions regarding trends in rainfall, temperature, drought frequency, pasture availability, rangeland cover, water availability and livestock production by choosing one of the following options: (1) increasing, (2) decreasing, or (3) no change for each specific perception question. Perceived changes regarding milk off-take per cow, number of calves per cow, age at first calving, calving intervals and cattle frame size were also recorded. It was assumed that herders have experience with changes in climate and rangeland conditions, so that the majority would be able to perceive such environmental changes and their associated impacts. Their perceptions were expected to be consistent with published information as well as empirical records.

Similarly, members of each household were requested to provide census data on cattle and camels (if this present) starting from the most recent to the most distant past, in a stepwise manner following the "*gada*" periods. For an effective use of the recalling system and a systematic capturing of data, circumstances that potentially affect cattle herd dynamics such as droughts, epidemics, and major household ceremonial events were used as a check list and attached to the respective year in which they occurred. Such an approach has been used in similar studies and was shown to be effective for pastoral contexts where written documents do not exist (Desta and Coppock 2002; Angassa and Oba 2007; Tache and Oba 2010; McCabe et al. 2010). Although the approach raises concerns about the general burden of a recall exercise, the overall data accuracy and the time to be devoted, special values attached to livestock, particularly cattle, and the well-developed tradition of the people to track animal inventories using the "*gada*" calendar are among the vital inputs that make such a survey feasible. Finally, it is worth noting that cattle or camel numbers collected from different households at a particular point in time may not necessarily demonstrate high accuracy, but provide sufficient information to show patterns and trends associated with temporal climate variability.

The study also included collection of data on socio-demographic characteristics of the households, including livestock numbers and species composition, constraints to livestock production, crop cultivation, and other non-pastoral income sources. The year when crop cultivation first started and estimated farmland size in hectares were also recorded, and used to estimate the annual cropland cover of the survey households. Information on herd mobility and intervention measures taken to reduce the risk of the 2010-2011 drought, and the associated livestock mortalities were recorded. Additionally, six participatory group discussions with eight to twelve key informants in each group per PA were conducted. The discussions were used to trace back such past events as drought occurrences, flooding, livestock disease epidemics and other events, using the *"gada"* timeline. Score values were given to precipitation, temperature, drought frequency, pasture and water availability by distributing 20 small stones over five *"gada"* periods separately for each variable. The rural human population sizes of the two districts were estimated per annum using the population census results for 1994 (77,936 for Dire, and 46,556 for Yabelo) and for 2007 (113,926 for Dire, and 84,668 for Yabelo) after calculating the average annual growth rate between the two census periods.

Monthly rainfall and temperature data (covering 1970 to 2009) were obtained from the Ethiopian National Meteorological Agency (ENMA) for Yabelo (Yabelo station) and Dire (Mega station) districts. The remaining data were obtained from the Yabelo Research Center (2010 to 2011) for

Yabelo (Yabelo station) and Dire (Dembelwachu and Ilamu stations). Climate data of the former Southern Rangelands Development Unit (SORDU) for Yabelo and Dire (Dembelwachu and Web stations) were used to fill in missing values in the ENMA data set. Monthly rainfall data for eight years in Yabelo and four years in Dire had no values for one to three months per year. These included months in both the dry and rainy seasons. Months without values were then filled by the corresponding monthly records from SORDU. Where the alternative source had no records, missing values for a particular month was filled with the mean for the same month computed over the preceding five years.

2.2.4 Statistical analyses

Descriptive summaries of perception data were expressed in percentages and frequency distributions. Time series of rainfall, temperature, cattle and camel numbers were summarized as decadal averages for comparisons. For the rainfall data, we calculated monthly and annual averages, intra- and interannual variability, and the coefficient of variation. The standardized deviates (SDt) of interannual variability in rainfall and temperature were calculated as $SDt = \left(X - \overline{X}\right)/s$, where *X* is the annual average, while $\overline{X}$ and s are the long-term (1970 to 2011) mean and standard deviation, respectively. Standard deviates of seasonal rainfall and cattle number, and drought occurrences were plotted against time period spanning 1976 to 2011. Annual rainfall variability was also assessed by the coefficient of variation (CV) as $CV = 100\left(s/\overline{X}\right)$

The spectral analysis of the annual rainfall data were analyzed using spectra procedure in SAS (SAS Institute 2012). Spectral density of annual precipitations was then estimated using the Fast Fourier transformation (a mathematical function of time) which transforms the rainfall data series y_t into a sum of sine and cosine waves of different amplitudes and wavelengths: $f(y_t) = \frac{\mu}{2} + \sum_{k=1}^{m}\left[\alpha_k \cos(\omega_k t) + \beta_k \sin(\omega_k t)\right]$ where t is the time subscript, $t = 1,\ 2,\ 3 \ldots n$, n is total number of observations in the time series (n=42), m is the number of frequencies in the Fourier transformation: $m = \frac{n}{2}$ if n is even (m=21); $m = \frac{n-1}{2}$ if n is odd, μ is the mean term (mean rainfall), k is the frequency subscription $k = 1, 2, 3,..., m$, α_k and β_k are the cosine and the sine coefficients, ω_k are the Fourier frequencies: $\omega_k = \frac{2\pi k}{n}$.

A five-year moving average of annual precipitation was also computed to empirically check for evidence of quasi-periodic rainfall variation formulated as: $\tilde{y}_t = \frac{1}{5}\sum_{i=t-4}^{t} y_i$ where y_t is the rainfall at time t (t=1970, 1971,…2011). Cyclical pattern in the same rainfall data series was also assessed using the structural time series model as $y_t = \mu_t + \psi_t + \varepsilon_t,\ t = 1, 2,...n$, where y_t is the observed rainfall at time t, μ_t is the stochastic trend ($\mu_t = \alpha + \beta_t$), $\psi_t = \alpha \cos \lambda_c t + \beta \sin \lambda_c t$ is the stochastic cyclical pattern with frequency λ_c (measured in radians), so that the period of the cycle is $2\pi / \lambda_c$), and ε_t is the irregular (error) components.

We used a logit model to identify factors influencing death occurrence (dummy variable for cattle herds with death and those without) in cattle herds during the 2010-2011 drought as: $\log[p_{ij} / (1 - p_{ij})] = \beta_0 + \beta_1 x_{1j} + \beta_2 x_{2j} + \beta_3 x_{3ij} + \beta_4 x_{4ij} + \beta_5 x_{5i}$

where p_{ij} is the probability of death of cattle in a herd belonging to the j^{th} household (p_{ij} =1 for death observation and 0 otherwise), β_0 is the intercept, β_1 to β_5 are regression coefficients, x_{1j} is the pre-drought cattle herd size, x_{2j} is the family size, x_{3ij} is feed supplementation (x_{3ij} =1 for supplemented herds and 0 otherwise), x_{4ij} is feed purchase (x_{4ij} =1 for purchased feed and 0 otherwise) and x_{5i} is the district (x_{5i} =1 for Yabelo and 0 for Dire). For herds that experienced mortalities, we calculated mortality rate as the proportion of the number of animals that died to the pre-drought herd size. Mortality rates were further analyzed to identify factors influencing variation in mortality rate using a general linear model (GLM). The mean mortality rates are expected to decrease with intervention measures (e.g. feed supplementation) and demographic variables (e.g. herd and family sizes) with residuals having acceptable normal distribution on normality tests.

A vector autoregressive model was fitted to assess the relationship among multivariate time series variables using the first order process (i.e. current value is based on an immediate preceding value) as $Y_t = \alpha + \sum_{i=1}^{6} \phi_i Y_{t-i} + \varepsilon_t$ where Y_t is the vector of response time series variables at time t, containing six elements $(y_{1t}, y_{2t}, y_{3t}, y_{4t}, y_{5t}, y_{6t})$ namely cattle number, long rains in current year (t^{th} year), long rains in preceding year (t-1^{th} year), temperature, cropland area and rural population, α is a 6×1 vector of intercept, ϕ_i $(i = 1,...,6)$ are 6×6 coefficient matrices for each i, Y_{t-i} are the immediately preceding values of Y_t, ε_t is a 6×1 vector of error terms assumed to be uncorrelated (white noise). Since it was not possible to include the seasonal rainfall components in the same model, the short rains and long rains were analyzed separately. Prior to analysis, all the covariates were standardized to zero mean and unit variance to minimize the influence of measurement scale on the modeled relationships.

A generalized additive model (GAM) was used to further analyze the relationship between annual changes in cattle herd size and seasonal and annual rainfall in the preceding and current year as well as the average annual temperature as follows:

$$\eta(E[y_i]) = \beta_0 + f_1(x_{1i}) + f_2(x_{2i}) + f_3(x_{3i}) + f_4(x_{4i}) + f_5(x_{5i})$$

where η is a monotonic link function, $E[y_i]$ is the expected value of y_i, the average change in cattle numbers, β_0 is the intercept term, f_1 to f_5 are smooth functions of each covariate, x_{1i} and x_{2i} are the long and short rains in the i^{th} year, x_{3i} and x_{4i} are the long and short rains in the i-1^{th} year, respectively. Whereas x_{5i} is the average annual temperature for the i^{th} year. We used GAMs to uncover possible non-linear relationships between changes in cattle numbers and each of the covariate using flexible non-parameteric smoothing functions (Cai 2008).

2.3 Results

2.3.1 Herders' perceptions on changes in climate and cattle production

Nearly half of the respondents (45%) had already received information regarding climate change from different sources, including government experts (50.5%), radio (27.5), community discussions (21.1%) and students (0.9%). They mainly associated the causes with deforestation, desertification and degradation of the rangeland. The majority perceived that rain has become more unpredictable, less in amount and shorter in duration, but divergent views were expressed regarding flooding (Table 2.1). By contrast, most of the respondents perceived an increase in temperature, dry spells and drought frequencies.

Regarding the temporal trends in cattle production performances, most respondents mentioned declines in milk off-take, number of calves born per cow and calf growth performance. They also noted that age at first calving and calving interval had both increased over time. Drought related cattle mortalities were much more of a concern to the herders than mortalities due to diseases. The herders indicated that the number of cattle per household was declining, and animals were often in poor body condition and becoming smaller in size. Accordingly, the small-framed cattle "*Ayuna*" dominated the cattle herds with the proportion of large-frame Borana cattle *"Qorti"* declining in herds due to their higher vulnerability to droughts. A considerable proportion of households (39.3%) were keeping the highland zebu cattle. The majority also reported an increase in the diversity of livestock species kept by the household. On average, 94%, 85%, and 40% of the households kept goats, sheep and camels, respectively. Rearing backyard chickens was also reported by 50% of the households.

Table 2.1 Herders' perception on changing trends in climate and cattle production variables over five "gada" periods (1976-2011)

Variables	Decrease (%)	No change (%)	Increase (%)
Climate			
Precipitation	92.1	6.2	1.7
Length of rainy season	94.2	5.8	0.0
Timely onset	91.3	8.7	0.0
Heavy rain/flood	46.7	8.7	44.6
Temperature	2.1	17.4	80.6
Long dry spells	1.2	7.4	91.3
Drought recurrence	1.2	9.5	89.3
Livestock			
Milk off-take per cow	93.0	7.0	0.0
Number of calves per cow	89.7	7.9	2.5
Calving interval	2.9	7.4	89.7
Age at first calving	5.0	7.4	87.6
Calf growth performance	86.0	7.0	7.0
Mortality to disease	76.0	11.2	12.8
Mortality to drought	12.0	15.7	72.3
Cattle body conditions	88.4	9.5	2.1
Adult cattle frame size [a]	87.6	9.9	2.5
Household cattle herd size	61.2	9.9	28.9
Household species diversity [b]	7.9	11.2	81.0
Rangeland			
Grassland cover	91.7	5.8	2.5
Grass species diversity	88.4	10.3	1.2
Bushland cover	1.7	2.9	95.5

Sample size (n=242 households), [a] frame size is qualitative judgments of change to height and body length of mature cattle over time, [b] species diversity indicates number of four major livestock species (cattle, camels, sheep, goats) at household level

Similarly, herders perceived that grass cover (92%) and grass species diversity (88%) had declined while bush cover (95%) had increased over the course of five *"gada"* periods (Table 1). They also indicated that some of the desired grass species such as *Panicum* species, *Cinchrus ciliaris*, *Chrysopogon aucheri*, *Pennisetum* species *and Eleusine jaegeri* were declining in abundance.

2.3.2 Climate of the study area

Long-term climate data for the study area showed that the mean daily temperatures were 19.8±1.1°C for Yabelo and 19.3±1.3°C for Dire. The overall mean daily temperature was 19.6±1.2°C while the maximum and minimum were 25.2±2.3°C and 14.0±1.3°C, respectively. The mean monthly minimum temperature showed alternating phases of sustained rise and fall but no consistent long-term trend during 1970-2011 (Figure 2.1a). In contrast, the maximum temperature first fluctuated about the 1970-2011 mean from 1970 to 1999 and then steadily increased from 2003 to 2011, exceeding the long-term mean from 2004 onwards (Figure 2.1b).

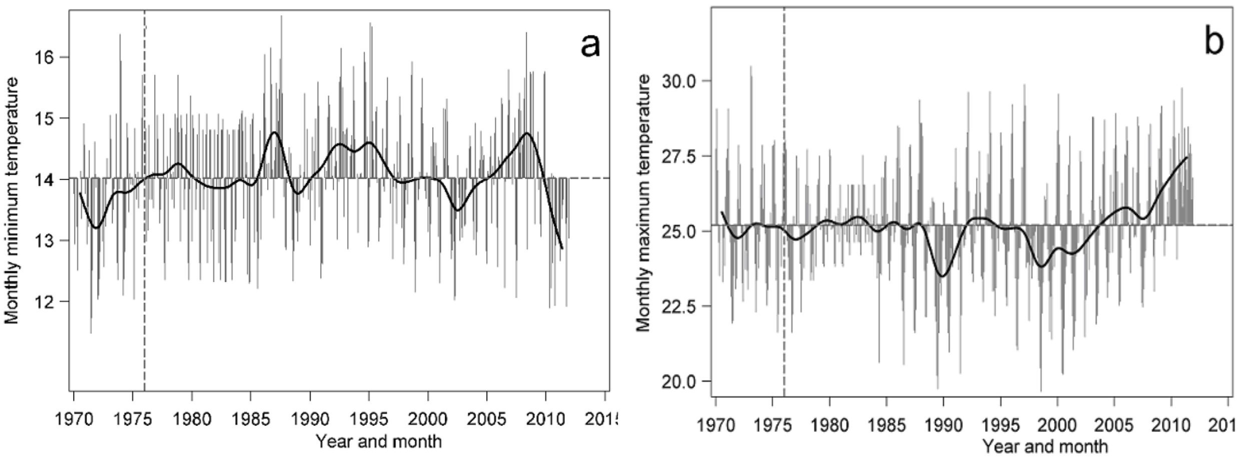

Figure 2.1 (a) Minimum (mean=14.0 °C, SD=1.3 °C) and (b) maximum (mean=25.2 °C, SD=2.3 °C) temperature by month and year time scales and fitted long-term mean and 5-month moving average using January 1976 as starting year (1970 to 2011).

The study area has a mean annual rainfall of 598.2±188.4 mm and a percent coefficient of variation (CV) of 31.5%. Rainfall was somewhat higher and more erratic in Dire with an annual mean of 613.3±315.9 mm (CV=51.5%) compared to Yabelo with an annual mean of 579.0±172.6 mm (CV=29.8%). Rainfall is characteristically bimodal (Figure 2.2); with 49.1% of the annual total falling during the long rains and 29.7% during the short rains. Of the remaining 21.3%, occasional rains in the cool dry and the hot dry seasons contribute 9.7% and 11.6%, respectively. The onset and duration of both the long (CV=41.3%) and short (CV=61.3%) rains are irregular, more so for the short rains.

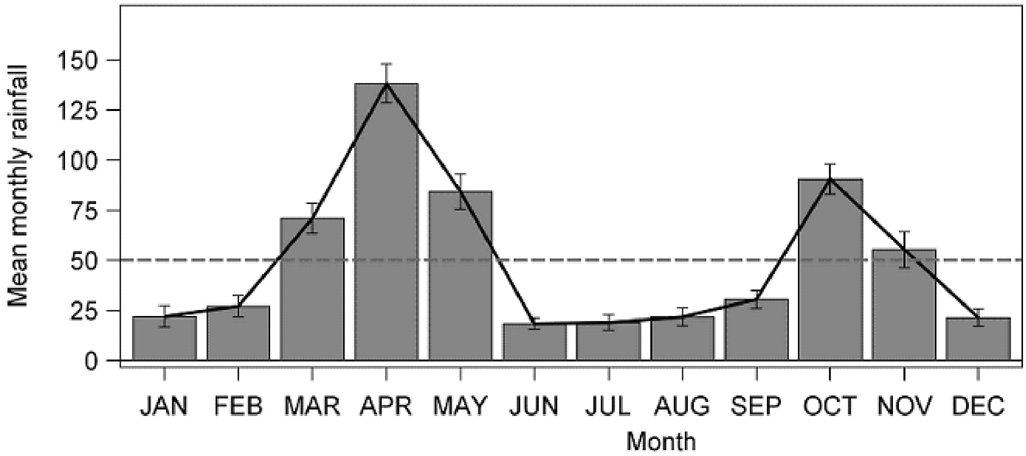

Figure 2.2 Mean monthly rainfall of Yabelo and Dire showing bimodal patterns (mean=50.0 mm, SD=55.6 mm, for periods from 1970 to 2011)

2.3.3 Effects of climate variability on cattle mortality: The case of 2010/2011 drought

The drought of 2010/2011 gave insights into how short-term climate variability can affect cattle populations and how such effects might be mitigated. Records of cattle mortality for 193 out of 242 surveyed households showed that 1938 (26%) animals died due to the drought of 2010-11. The drought had dwindled cattle numbers by causing heavy mortalities (26%) and escalating early sales (18.9%). Adult females (46.1%) were the most affected demographic segment followed by young animals (23.4%) and calves (21.7%). The percentages of death losses by animal type showed that relatively high proportions of calves (35.4%) and juveniles (34.2%) were lost to the drought.

Different coping strategies that have been applied to reduce losses included herd mobility (88%), supplementing animals with feed stuffs collected from the fields including grasses, tree foliage and crop residues (20%), feed purchase (76%), sale of cattle (86%), and treatment of sick animals and those in poor body conditions (99%). Table 2.2 presents factors affecting death occurrence and mortality rates among cattle herds exposed to the drought, of which 193 herds (80%) experienced mortality losses during the drought. For each unit increase in the number of cattle per household and family size, the likelihood of a death occurrence in a cattle herd increased by a factor of 1.2 and 1.6, respectively. But, mortality rates significantly decreased with increasing family size and number of cattle per household. In other words deaths were more likely to be prevented from occurring in smaller herds compared to large herd sizes, but the proportion of death losses decreases with increasing herd sizes. In Yabelo district, both death occurrences and mortality rates were significantly lower than in Dire. Cattle herds supplemented with collected feed stuffs had 0.2 times lower odds of death occurrences compared to those receiving no feed supplementation.

Table 2.2 Factors affecting death occurrence and magnitude of mortality rate in cattle herds during 2010 /2011 drought

Predictor variables		Mean[a]	Death occurrence (N=242)[b]		Mortality rate (N=193)[c]	
			Odds Ratios	P-value	Coefficient	P-value
Family size		9.9	1.2	0.008	-0.007	0.007
Pre drought cattle per capita		3.2	1.6	0.001	-0.014	0.001
District[d]	Yabelo	0.5	0.4	0.021	-0.075	0.000
Feed supplement[d]	Yes	0.2	0.2	0.001	-0.037	0.248
Feed purchase[d]	Yes	0.8	0.5	0.112	0.002	0.922

[a] mean for quantitative variable and proportion for dummy variables, [b] presence or absence of death was analyzed by logistic regression, [c] proportion of number of deaths at household level to pre-drought herd size was analyzed by general linear model (note that herds without death were excluded from mortality rate analysis) [d] dummy variables

We also examined whether the purchase of feeds (such as hay, straw and concentrate) during the drought had any impact on cattle mortalities. But this intervention had no significant effect. Feeds were purchased by most of the households and selectively fed to weak animals, cows and calves. It was difficult to quantify the amounts of the different feed types purchased or their sufficiency for the targeted animals until the rain resumed. It was, however, clear that this intervention was started after the drought effects were already well advanced. It was not possible to test for the effects on mortality of treatment and herd mobility because most of the sampled households had implemented them. Still, moving herds to less affected areas, a traditional strategy for ameliorating climate risks, did not prevent deaths from occurring in Dire as the movements of the herds out of the district started well after the impact of the drought had already advanced. It is probable, however, that these movements reduced the extent of the mortality losses because they occurred after the herders had determined that there was insufficient natural forage left to sustain the herds in the district.

2.3.4 Relationship between changes in cattle herd size and climate

Seasonal patterns in the standardized deviates of rainfall revealed that the droughts were mainly manifested by sequential failures in the short and the long rains (Figure 2.3). Droughts were found to approximately occur every four to six years since the worst drought of 1983/1984. The annual rainfall was well above average from the mid 1970s to the early 1980s, but fell and remained below average thereafter (Figures 2.4).

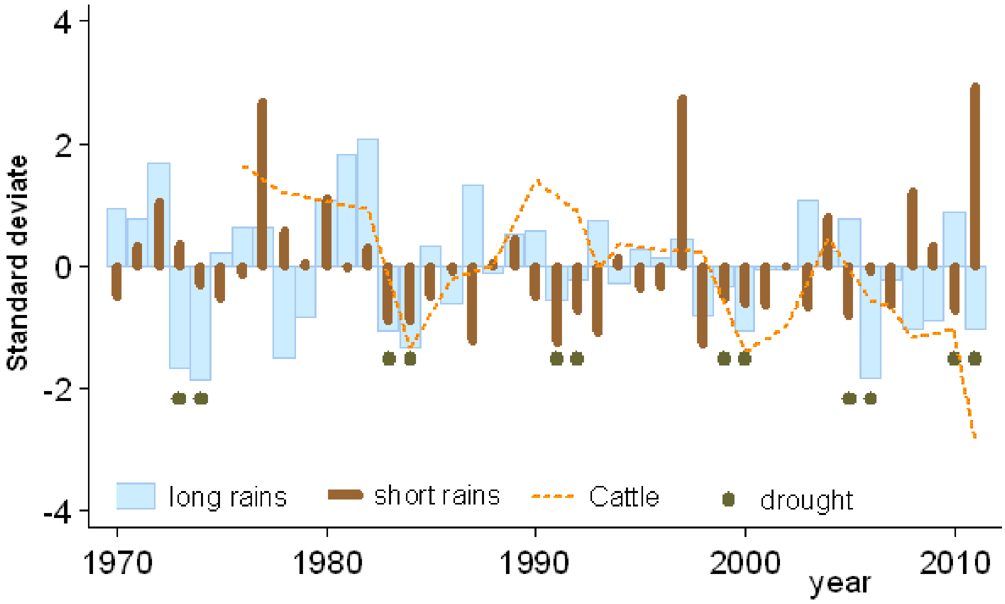

Figure 2.3 Patterns of seasonal rainfall and cattle herd anomalies, and their relationship with droughts; note that sequential declines of short and long rains features most of the drought years

Both the 5-year moving average of the annual rainfall (Figure 2.4) and cyclical components did not show a clear cyclical pattern of precipitation (Figure 2.5). However, spectral analysis of the annual rainfall revealed a quasi-cyclical pattern with an approximate cycle period of 8.4 years (Figure 2.6), suggesting that drought is expected to occur at least once in a half cycle of 4.2 dry years, while remaining half cycle can be regarded as wet years. Correspondingly, the standardized deviates of cattle number appeared to mirror the interannual rainfall variability in rainfall.

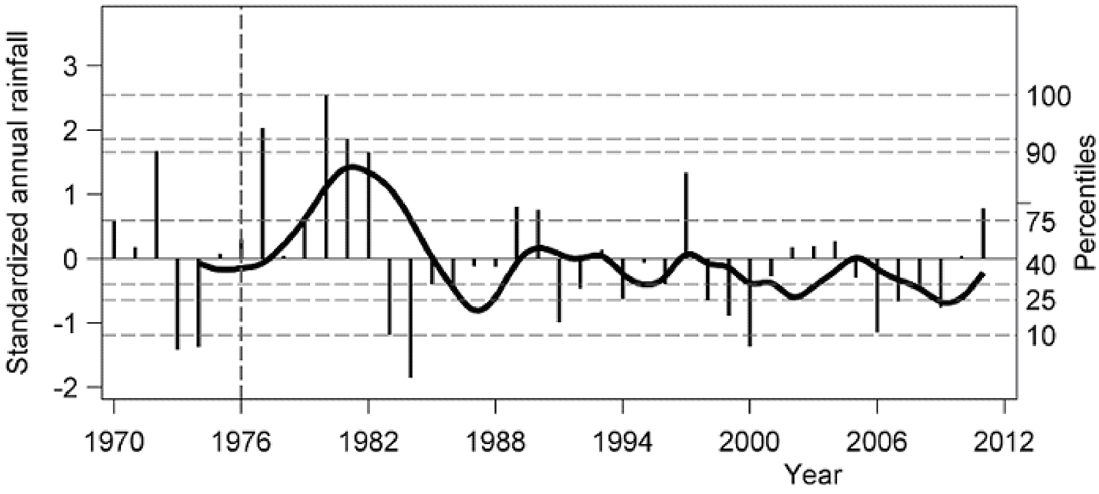

Figure 2.4 Standardized annual rainfall fitted 5-year moving average for evidence of quasi-periodic drought occurrences and trends in precipitation (mean=598.2, SD=188.4), Rainfall anomalies and percentiles were plotted on first and second y-axis, respectively, Note that precipitation below 30 to 20th percentile may indicate mild drought (dry year), 20 to 10th percentile: moderate drought and less than 10th percentile severe drought.

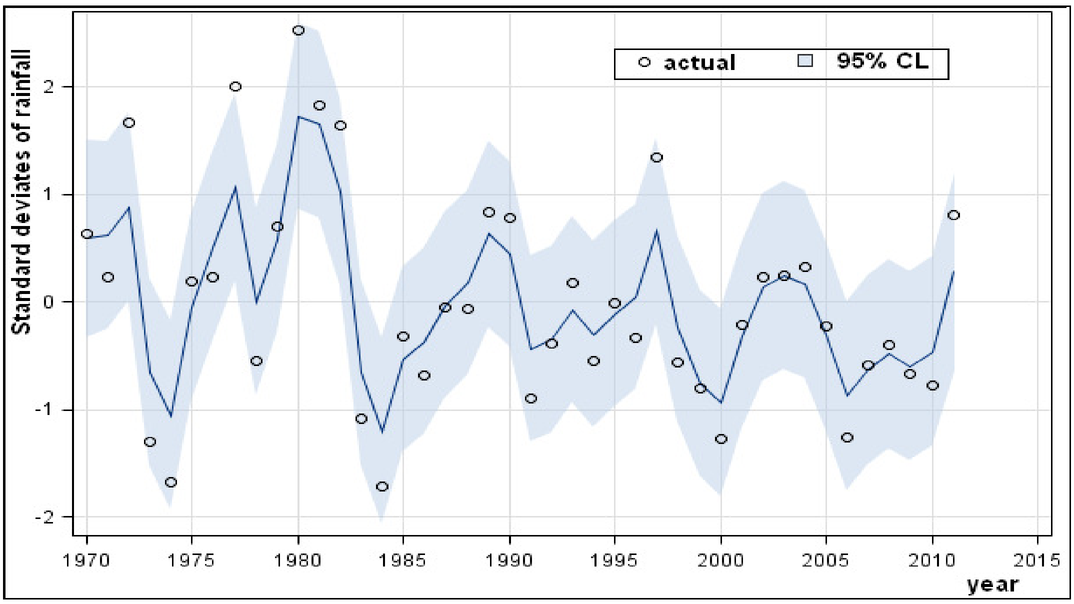

Figure 2.5. Trends and cycles of annual precipitations the vertical axis is the standardized deviates of precipitation, the solid line is the cyclical patterns in annual rainfall with the 95% CL, dots are actual observations.

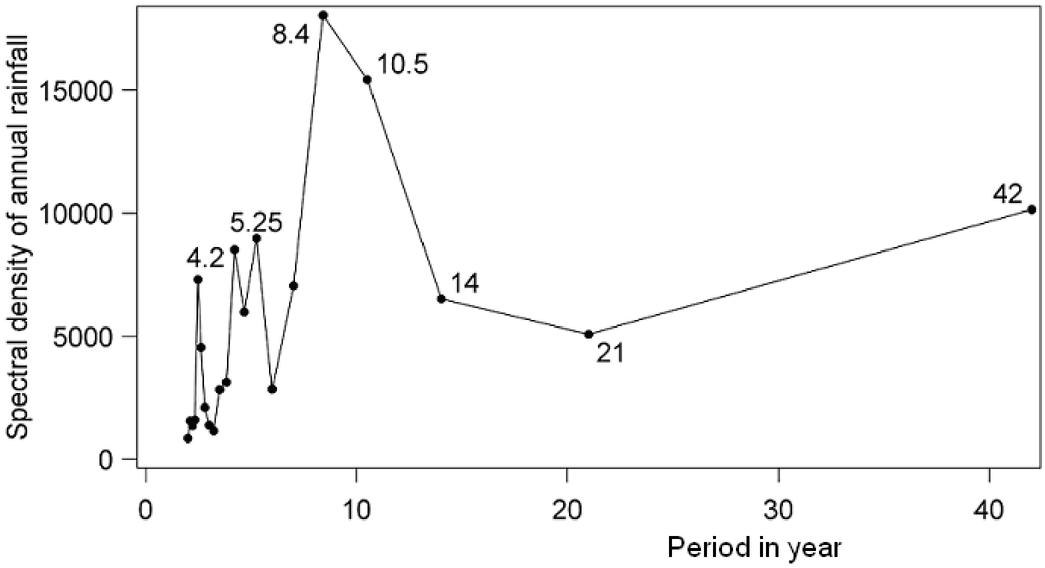

Figure 2.6 Spectral analysis of annual rainfall showing quasi-cyclic oscillation of approximately every 8.4 years, horizontal axis is period in years while vertical axis represents the contribution of each period in frequency.

The long rains in both the preceding and the current year were significantly and positively correlated with the annual changes in cattle numbers at lag 0 (Table 2.3a). The annual mean temperature had a negative but insignificant correlation with cattle numbers. Cropland cover and human population size were also negatively correlated with cattle numbers at lag 0. There was also a significant positive correlation between cropland area and the rural population in the district as both increased over time. Similarly, cattle numbers had a significant negative correlation with the short rains in the preceding year at lag 0, whereas a positive correlation was observed with the current short rains at lag 1, the value of which footnoted under Table 2.3b.

Table 2.3a. Time series multivariate cross-correlation matrix of residuals (long rains)

Lag§	Variable	Cattle	Longrain	Prlongrain	Temp	Cropland	Population
0	Cattle	1.000	0.344*	0.735*	-0.141	-0.337*	-0.735*
	Longrain	0.344*	1.000	0.062	-0.003	0.052	-0.062
	Prlongrain	0.735*	0.062	1.000	-0.111	-0.437*	-1.000*
	Temp [a]	-0.141	-0.003	-0.111	1.000	0.021	0.111
	Cropland [b]	-0.337*	0.052	-0.437*	0.021	1.000	0.436*
	Population [c]	-0.735*	-0.062	-1.000*	0.111	0.436*	1.000

Prlongrain: long rains in the preceding year (t-1th), long rains in current year(tth), [a] temperature, [b] total cropland area cultivated by the survey households, [c] estimated rural population of the districts, * correlation is significant at P<0.05. § No variables had significant relationship at lag1 and thus results were not shown.

Table 2.3b. Time series multivariate cross-correlation matrix of residuals (short rains)

Lag§	Variable	Cattle	Shortrain	Prshortrain	Temp	Cropland	Population
0	Cattle	1.000	-0.044	-0.710*	-0.101	-0.315*	-0.710*
	Shortrain	-0.044	1.000	-0.033	0.044	-0.112	-0.034
	Prshortrain	-0.710*	-0.033	1.000	0.116	0.413*	1.000*
	Temp [a]	-0.101	0.044	0.116	1.000	0.000	0.116
	Cropland [b]	-0.315*	-0.112	0.413*	0.000	1.000	0.413*
	Population [c]	-0.710*	-0.034	1.000*	0.116	0.413*	1.000

Prshortrain: Short rains in the preceding year (1975-2010), short rains (1976-2011), [a] temperature, [b] total cropland area cultivated by the survey households, [c] estimated rural population of the districts, * correlation is significant at P<0.05. § Short rains had significant relation with cattle number (0.382) and rural population (-0.468) at lag1, the results of which were not shown as other coefficients did not differ from zero.

Table 2.5 displays changes in decadal averages of livestock holdings, rainfall and temperature. Timeline data on cattle and camel herd sizes showed inverse trends. When the average herd size for 1976-1985 was compared with those for 2006-2011, cattle decreased by 29.2%, while camels increased by 557.2% (inflated by a relatively small initial herd size). By 1976 only a few households (7 out of 242) kept camels, which had increased to 40% (97 of 242 households) by 2011.

Table 2.4 Decadal average rainfall, temperature and livestock holdings

Variables	1976-1985	1986-1995	1996-2005	2006-2011	% change[a]
Cattle herd size	40.9	38.5	34.0	29.0	-29.2
Camel herd size[b]	0.3	0.9	1.8	2.1	+557.2
Annual rain fall (mm)	688.2	575.8	562.0	525.4	-23.7
Long rains (mm)	314.9	312.6	296.8	215.7	-31.5
Short rains (mm)	399.1	262.4	326.5	454.3	+13.8
Cold dry period rains (mm)	109.1	34.9	29.0	37.7	-65.5
Hot dry period rains (mm)	64.6	97.0	73.0	46.0	-28.8
Temperature (°C)	19.6	19.6	19.3	20.3	+3.4

[a] Percent change is the difference between 1976-1985 and 2006-2011 averages, [b] camel size was calculated by dividing average number of camels in a decade by all respondents regardless of their possession for comparison purpose (n=242 households).

The downward trend in cattle herd size as function of changing climate variables, based on a GAM analysis, is presented in Figure 2.7. There is a significant dependence of changes in cattle holdings on the preceding long and short rains. However, herds did not show a significant dependence on precipitation and temperature in the current year.

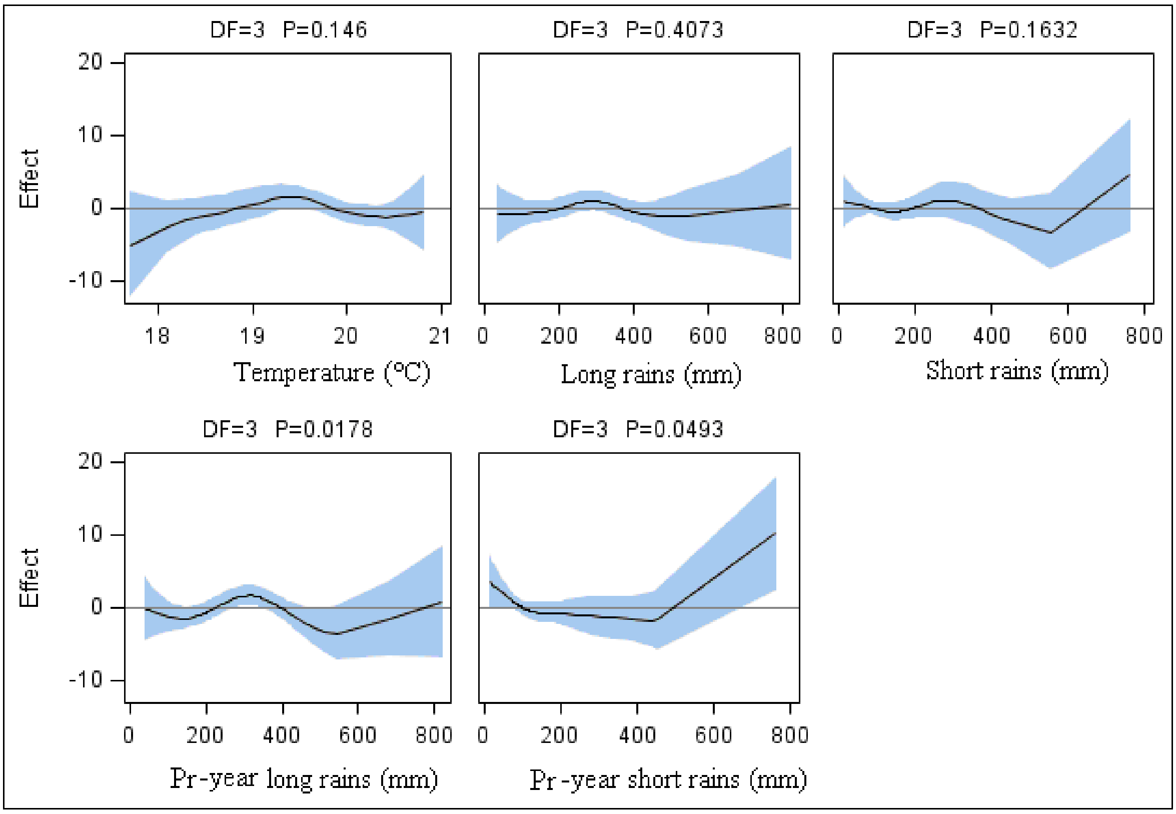

Figure 2.7 Dependence of cattle herd changes on seasonal precipitations, Pr-year represents previous or preceding year rainfall (1975–2010) while others are same year records with herds (1976–2011). Smoothing components with 95% CL heading above zero show positive relationship between herds and climate, and vice-versa.

2.4 Discussion

The perceptions of local people are increasingly being used to assess and anticipate the adverse effects of climate change in agricultural research. A trend of declining amount and variability of rainfall as well as rising temperature reported by the herders of Southern Ethiopia reinforce similar perceptions of local people documented elsewhere in Ethiopia (Kassahun et al. 2008), Ghana (Fosu-Mensah et al. 2012), Kenya (Rao et al. 2011) and Senegal (Mertz et al. 2009). Various studies have demonstrated a good match between perceptions of the local people and empirical trends in long-term climate data (Mertz et al. 2009; Rao et al. 2011; Fosu-Mensah et al. 2012). Our climate data also support the views expressed by herders, specifically the declining trend and high interannual variability of rainfall and recurrent droughts. Temperature data, especially the steady increase in the maximum component since 2004, also reinforced the perceived rise in temperature. Perceptions of flooding were dominated by two divergent view points. Half of the respondents (46.7%) felt that the frequency of flooding had decreased due to a general decline in precipitation, whereas the other half (44.6%) claimed that flooding had actually become more frequent, as rainfall became more erratic and intense with short-lasting storms. It is thus important to examine trends in climatic data carefully to validate such apparently contradictory but equally valid local perceptions, or to establish if local people are indeed perceiving climatic risks to be more excessive than warranted by the actual trends in climatic data (Rao et al. 2011).

While manifold factors interact to magnify the detrimental effects of climate change, cattle pastoralism mainly suffers from exposure to unpredictable droughts and the associated substantial asset losses (Desta and Coppock 2002; Angassa and Oba 2007). An earlier study had anticipated drought and cattle mortalities to occur once every five to six years in the Borana area (Desta and Coppock 2002). So far, four major droughts have occurred at intervals of 6, 6, 4 and 4 years since the severe drought of 1983-1984. The spectral analysis of the annual rainfall series also suggested an alternating half cycle of wet and dry years in which drought is likely to recur at least once in every 4.2 dry years. Consequently, such recurrent droughts may lead to a continual decline in cattle numbers. For instance, a substantial decrease of herd size by at least 45% (26% due to mortalities and 19% forced off-take) was recorded during the 2010/2011 drought, similar to reports in earlier droughts that estimated cattle to decrease by 43% in 1983-1984 (Cossin and Upton 1988a), 42% in 1991-1992 (Desta and Coppock 2002) and 53% in 1999-2000 (Angassa and Oba 2007).

The mortality patterns we documented for cows, calves and young cattle are in accordance with patterns reported for the previous droughts (Cossin and Upton 1988a; Angassa and Oba 2007). The higher proportion of deaths in cows we observed could be due to the fact that breeding females suffer most from energy deficits, coupled with production stresses and elevated nutritional requirements during lactation and late pregnancy. The high mortalities in breeding females and young animals along with a decline in calving rates can severely hinder cattle herd recovery, which usually requires at least seven normal years (Cossin and Upton 1988a). Recovery can be prolonged by interruptions due to subsequent shocks, which are more likely to occur under scenarios of increased drought frequency (Lesnoff et al. 2012). Hence, given the shortening period between successive droughts, with approximate interval of four to six years, it is highly unlikely that most cattle herds would have sufficient time to increase to their pre-drought numbers.

As a coping strategy to drought, some households have selectively supplemented weak animals with crop residues, grasses and tree foliages, which significantly reduced death occurrences. This may further motivate herders to practice animal feed preservation and supplementation during the periods of feed shortages. The effects of the purchased feeds on cattle mortalities was not significant perhaps due to insufficient amounts of feed purchased or late timing of the purchases. Although large families benefit from the excess labor that might play a role in reducing climate risks through herd mobility, herd splitting and provision of weak animals with water and feed supplements, our findings contradict the notion that large families should suffer fewer cattle losses than small families. But it supports the view that large families should suffer proportionally less mortality losses in their herds. According to Naess (2013) the availability of labor influences decisions on herd mobility, a key drought retreatment strategy and an efficient way of ephemeral vegetation use, thus is expected to have an inverse relationship with mortality. Conversely, Scoones (1992) found no significant difference between labor availability and livestock mortality during a drought period in southern Zimbabwe, suggesting that a larger labor pool may not perform better than smaller pool. In the present study, large families correspond to larger herds in which numerically higher deaths could be tolerated, since mortality rate decreased with increasing herd size. This shows that large herd sizes cushion households against climatic shocks and justifies the tendency by pastoralists to maximize herd sizes as a risk aversion strategy (Doti 2010). The likelihood of death occurrences and mortality rates were higher in Dire than in Yabelo, as the latter received lower long and short rains in 2010 than the former.

The seasonal patterns of precipitation revealed that droughts were triggered by the failure of short rains and worsened if the long rains also failed. In most cases, it was the sequential rain failures of the short and long rains that resulted in droughts. Between the two rainy seasons, short and long rains, lies a seasonal bridge of a hot dry period spanning December to mid-March. It is therefore less likely that such consecutive seasonal rain failures can be captured by using the total annual rainfall because successive failures of short and long rains may occur in two different years. Seasonal analysis thus offers more insight into patterns of rainfall deficits and their effects on livestock production. A discursive analysis by Ellis and Galvin (1994) showed why the bimodal and unimodal rainfall patterns dictate that the land use system to be predominantly pastoral in the East and crop farming in the West African dry lands, respectively. Correspondingly, in areas with bimodal rainfall patterns, the seasonal amount and distribution of precipitation is more important than the annual amount in determining primary production that governs livestock population abundance.

The annual rainfall was predominantly below average from the early 1980s to 2011, with a downward trend evident in the long rains similar to reports elsewhere in the Horn of Africa (Cheung et al. 2008; Mertz et al. 2009; Rao et al. 2011; Omondi et al. 2012; Viste et al. 2013). The long rains are more essential for forage production, crop cultivation and replenishment of water resources, and hence the declining trend is detrimental to pastoral livestock production.

The Inter-Tropical Convergence Zone that drives the bimodal rainfall pattern in East Africa during its seasonal north-south migrations (Ellis and Galvin 1994) is to a large extent influenced by atmospheric and oceanic factors (Omondi et al. 2012), thus affecting the onset and duration of rainfall. More importantly, climate change is perturbing the oceanic forcing through progressive warming of the ocean surface temperatures (IPCC 2007), thereby altering regional and global atmospheric circulations. Not surprisingly, Williams and Funk (2011) have shown that warming of the Indian Ocean temperatures is causing a westward extension of the Walker circulation. The associated alteration of the atmospheric circulation is linked to an increased export of dry air towards East Africa and reduced regional precipitation (Williams and Funk 2011; William et al. 2012). In particular, a marked decline in the long rains (March to May) over the past 30 years in Ethiopia and Kenya has been ascribed to increasing sea surface temperatures in the Indian Ocean

(Funk and Verdin 2009; Williams and Funk 2010). Correspondingly, recurrent droughts that frequently hit the East African region have been linked to the anthropogenic climate change (Funk and Verdin 2009; Williams and Funk 2011; William et al. 2012). A continued warming of the sea surface temperatures over the Indian Ocean is projected to lead to a drier climate over large parts of East Africa (Williams and Funk 2011).

The declining trend in cattle number per household in the present study and its significant correlation with variation in the long and short rains in the preceding year, suggest that reduction in the rainfall amount and widening rainfall variation drive the downward trend in cattle number in southern Ethiopia. Other authors (Cossins and Upton, 1988a Ellis and Swift 1988; Angassa and Oba 2007) have also pointed out that rainfall amount and distribution determine forage production, and hence livestock populations. In arid and semi-arid ecosystems such as the Borana region, precipitation is highly erratic, and thereby largely accounts for the spatio-temporal heterogeneity in the key resources (pasture and water) that determine livestock population abundance (Ellis and Swift 1988). Change in cattle number was also a negatively correlated with rural population and farmland areas as the latter two variables were increasing overtime. The minimum temperature showed striking temporal variability whereas the steady increase in the maximum temperature from 2004 to 2011 showed evidence of warming and hence progressive habitat desiccation. The weak negative correlation between cattle numbers and rising temperatures could also indicate the effects of reduced water availability due to increased evaporative water loss and reduced forage availability and quality due to a reduced retention of green leaves by plants in the dry season. Hence, the elevated temperatures during droughts are likely to exacerbate the decline in cattle numbers by accentuating water and forage shortages as well as thermal stresses.

Climate change therefore likely affects the productive and reproductive performances of cattle, and consequently their population growth through its indirect effects on the quantity and quality of pastures and water availability in addition to increasing thermal stresses on animals (Thornton et al. 2009; Nardone et al. 2010). Increasing drought frequency can alter plant communities, often by disfavoring herbaceous pasture production while promoting the recruitment of invasive woody plants (Hiernaux et al. 2009). In the Borana rangeland in particular, bush encroachment is expanding (Dalle et al. 2006) while grass cover and palatable herbaceous plant species' diversity is declining (Tefera et al. 2007). Increasing human population and crop cultivation contribute to fragmentation of the grazing area (Desta and Coppock 2004) and thus lowering the productivity and carrying capacity of rangeland.

Decreased precipitation reduces the primary production and the nutritional quality of plants through its effects on soil moisture and nitrogen (N) cycles (N fixation, ammonification, nitrification and denitrification). Soil moisture content affects the microbial activities and limits the biological use of N by plants, regardless of its high abundance in the atmosphere (Beier et al. 2008). Soil N content decreases with aridity and is further lowered by moisture deficits caused by recurrent droughts (Delgado-Baquerizo et al. 2013). Decreasing precipitation therefore heightens soil N deficiency and adversely affects the growth and nutritional quality of plants. Accordingly, a study by Craine et al. (2010) showed that drying and warming conditions decrease the crude protein content and digestibility of plants. Being a vital component in all amino acids, proteins, enzymes and nucleic acids N is crucial for all organisms. As a result, low levels of plant N content together with reduced fermentable energy of pastures reduce the rumen microbial populations and impair their protein synthesis (Calsamiglia et al. 2010), thereby affecting the productive and reproductive performances of ruminants. This could also be responsible for the perceived increase in the age at first calving and calving intervals, and decrease in the number of calves per cow. Such changes probably contributed to the dwindling cattle number over time, possibly triggering other livelihood strategies.

Herders' observations of a decline in the number of the large-framed Borana cattle *"Qorti"* in most herds is consistent with other reports (Homann et al. 2008; Zander 2011) and may portend the loss of a more productive, but less well adapted cattle breed under conditions of a changing future climate. Craine et al. (2010) pointed out the increasing likelihood of adopting breeds with smaller body size and lower maintenance requirements as feeds become increasingly scarce under a changed climate. From the available evidence, it is not possible to definitely establish whether feed shortages actually caused the increased stocking of the small highland zebu cattle in our study area (Homann et al. 2008). The possibility that recurrent droughts cause substantial declines in the Borana cattle population and trigger the restocking of depleted herds with this breed, which is readily available in the local market at relatively low prices, would seem more plausible (Zander 2011).

Shifting from cattle pastoralism to multispecies herding, particularly the adoption of camel husbandry, has increased overtime in response to climate change and variability. Sheep and goats represented 14% of the total livestock biomass, and thus appeared to have increased over time relative to an earlier report of 7.4% of the total livestock biomass (Cossins and Upton 1987). Climate variables were found to be the major determinant for the choice of the primary livestock species among farmers in Andean regions (Seo et al. 2010). Hence, changes in climate likely drive selection of animal species that are best able to cope under the changed conditions and thus alter livestock species composition at the household level. Cattle are apparently the most vulnerable livestock species to the adverse effects of climate change scenarios (Seo et al. 2010), and decrease in abundance along a drier and warmer climate gradients (Zhang et al. 2013). As a result, shifting from cattle to goats in Africa (Seo et al. 2009), from beef cattle to sheep in the Andean regions (Seo et al. 2010) and from cattle to camels elsewhere in Africa (Faye et al. 2012) has been linked to adaptation of livestock production to changing environmental conditions. Diversifying into livestock species that are browsers and are more drought-tolerant seems to be a primary adaptation strategy to changing climate and rangeland conditions in Southern Ethiopia. Differences among the livestock species in terms of their feeding behaviors and tolerance to water and feed shortages enable herders to utilize more diverse ecological niches and serve as a buffer against climate related risks in addition to economic benefits (Morton 2007; Doti 2010).

2.5 Conclusions

The study findings showed a declining trend and a high interannual variability in precipitation with drought occurring approximately recurring every four to six years. The interannual variation in seasonal rainfall was a better indicator of drought occurrences than variation in the total annual rainfall, as droughts often resulting from sequential deficits in the short and the long rains. The study further showed that declines in cattle numbers were associated with a similar underlying trend in precipitation and widening of its variability. As climate change advances, the downward trend in cattle numbers is expected to persist, implying that the centuries-old cattle pastoralism is likely to become a precarious livelihood option. As a result, herders are responding to the changing environmental conditions by adjusting their herd composition towards more diverse livestock species. This trend underlines the need to enhance the adaptive capacity of the Borana and other pastoralists through interventions that proactively reduce vulnerability while strengthening their ex-post risk management strategies. The adoption of early warning systems could be used to promote early livestock off-take and timely feed purchases to minimize livestock losses during droughts. The degree to which pastoralists manage droughts by selling livestock is a subject of current debate and merits further research (Morton 2007). Feed storage and preserving grass banks for the use in dry periods, herd mobility, livestock species diversification and improving animal health care are among mitigation strategies useful to reduce vulnerability to climate risks, and thus should be strengthened. Given the contribution of Borana cattle to the national export earnings and their socio-economic roles in the Borana community, future research should address how to sustain the profitability of pastoral cattle production under the changing environmental conditions.

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3 The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia

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Abstract

While food insecurity is a growing concern across the developing nations, accentuated by climate variability and change, it could be even worse for pastoralists given their unpredictable exposure to climate risks. The Borana herders experience food insecurity as a result of recurring droughts causing huge losses of cattle, and are thus increasingly shifting from cattle pastoralism to multi-species herding. The present study examines the role of livestock diversification in combating household food insecurity using herders' perceptions, a modified household food insecurity access scale (mHFIAS) and dietary diversity score. Herders perceived child growth, adult height and body condition to be decreasing as a result of declining milk production and changing dietary trends. Results also revealed a high level of seasonal food insecurity and low dietary diversity with the majority (81%) consuming one to three food groups. Livestock diversification was a major factor affecting household food security. Households practising diversification had significantly fewer months of food deficit (2.3 vs. 3.8), lower mHFIAS (5.5 vs. 8.7) and a higher average off-take in the form of livestock sales (7.4 vs. 4.0) than non-diversified ones. Diversification improved dietary intake of specific food groups and the average number of meals consumed per day. While fruits, eggs and fish are not part of the Borana diet, a large number of respondents consumed no vegetables (93%) or meat (96%), potentiating the risk of micronutrient deficiencies. This study highlights the particular significance of livestock diversification, among other socio-demographic factors, in attaining food security under a changing climate in the study area.

Keywords: climate variability; dietary diversity; food insecurity; livestock diversification; Borana

3.1 Introduction

Livestock production is the foundation of livelihood in Borana with cattle being the most valued animal species. The Borana have historically been cattle herders for whom cows' milk is the main staple and favorite food item (Cossins and Upton 1987). Owing to their remarkable reproductive performance, milk production potential and low mortality rate, Borana cattle were economically superior to other livestock species (Cossins and Upton 1987). Cattle have important socio-cultural roles and are regarded as part of pastoral identity (Berhanu et al. 2007; Tache and Sjaastad 2010). An individual without cattle has no braided tuft "*gutuu*" and does not fulfill the social standards of the society (Tache and Sjaastad 2010). Furthermore, the Borana have strong customary laws and social organizations that account for their effective management of livestock and rangeland resources. As a result, they were once regarded as managing one of the most viable and productive pastoral systems in east Africa (Cossins and Upton 1987). Presently, however, their production system appears to be confronted by the irregular rhythms of changing seasonality, climate variability and spatiotemporal heterogeneity of forage production (Desta and Coppock 2004; Angassa and Oba 2007; Tache and Sjaastad 2010). The Borana are gradually shifting from surplus towards subsistence production (Berhanu et al. 2007; Tache and Oba 2010). Convergence of environmental factors and external drivers such as inappropriate development interventions and population pressure have eroded their per capita cattle holdings (Desta and Coppock 2004; Tache and Oba 2010). Consequently, households are increasingly vulnerable to climatic shocks with a larger proportion (77%) reportedly becoming food insecure for more than 5 months per year (Desta et al. 2011).

Drought cycles regularly affect the Borana rangeland, causing huge losses of cattle. Previously, Desta and Coppock (2002) have anticipated a phenomenon of "boom and bust" in which they suggested high stocking rates along with failure of rainfall cause cattle mortality every 5 to 6 years. Such vicious cycles of drought and massive deaths occurred in 1973/74, 1983/84, 1991/92, 1999/00 and 2005/06 (Desta and Coppock 2002; Angassa and Oba 2007; Berhanu and Fayissa 2010). These might have compelled the Borana herders to pursue alternative livelihood strategies such as livestock diversification, crop cultivation and non-pastoral activities. Consequently, there is a progressive shift from centuries old socio-cultural cattle pastoralism to multi-species herding with an increasing tendency to keep more drought tolerant animal species. Indeed, camel production is gaining momentum on account of climate and rangeland ecosystem changes in Borana (Megersa et al. 2008) similar to the trends observed in other African countries (Faye et al. 2012). Due to differences in their tolerance to water and feed shortage, and resistance to drought among species, multi-species herding is of vital importance in minimizing climate related risks (Doti 2010). While livestock diversification is one of the adaptation strategies highlighted in the literature (Morton and Barton, 2002; Galvin et al. 2004; Speranza 2010), there is little empirical evidence as to what extent it makes a difference in adaptation to climate variability and combating household food insecurity in a pastoral context. This is the knowledge gap that has given the impetus to embark on this study.

Food security is a growing concern worldwide, particularly under imminent climate change and variability. It is generally considered to be built on three interrelated pillars: availability, access, and utilization (Barrett 2010). Stability of the pillars, which is affected by dynamic interactions of agro-ecology, socio-economy and biological factors, determines food security of a given area. In particular, climate variability and change adversely affect the pillars at different levels and disrupt the link between them, weakening their ability to deliver food security (Gregory et al. 2005). In Ethiopia, seasonal food insecurity is linked to low-input farming, poor market access, underdeveloped rural infrastructure and climatic variability (Ferro-Luzzi et al. 2001; Regassa and Stoecker 2012). Furthermore, increased climate variability and drought recurrences have disproportionate impacts on household food security in the Borana pastoral system (Desta and Coppock 2004; Doti 2010) and other pastoral areas of East Africa (Galvin et al. 2004; Speranza 2010).

As there is no conventionally exact measure of food security, different alternative measures are used to assess food consumption as indicators of actual caloric intake and diet quality. Among the proxy measures, dietary diversity score (DDS) and the household food insecurity access scale (HFIAS) have been widely applied to measure different aspects of food security (Becquey et al. 2010; Thorne-Lyman et al. 2010; Regassa and Stoecker 2012). These measures were reported to perform well in approximating diet adequacy and assessing household food security (Arimond and Ruel 2004; Becquey et al. 2010). The association between dietary diversity and the nutrient adequacy ratio suggests dietary diversity score to be a simple, but good indicator of food security (Oldewage-Theron and Kruger 2011; Headey and Ecker 2013). Accordingly, the present study in the Borana area was designed with the following objectives: (1) to investigate the changing trends and present status of food security, and (2) to understanding the role of livestock species diversification in household food security.

3.2 Methods

3.2.1 Study area

The study was conducted in the Borana rangeland in southern Ethiopia, which is mainly inhabited by the Borana Oromo, and has an elevation range of between 1,000 and 1,500 m above sea level (Figure 1). The climate is semi-arid with an annual average rainfall ranging from 300 mm to 600 mm (Coppock, 1994). Rainfall distribution is bimodal, the long rains ("*Ganna")* extending from March to May and the short rains ("*Hagaya")* from September to November. A cool dry period (*"Adoolessa"*) occurs from June to August, while a warm dry season (*"Bona Hagaya"*) runs from December to February (Coppock 1994; Angassa and Oba 2007). A particular feature of the plateau is the permanent supply of water by a cluster of nine deep wells, locally called "*Tulas",* which are the most fundamental resource that drives the pastoral production system (Cossins and Upton 1987; Coppock 1994). The "*Tula"* wells play a vital role in Borana society, not only providing a permanent source of water, but also cultural identity, and a focal point for social organization and ritual practice (Tiki et al. 2011).

The Borana production system is a pastoral/agro-pastoral system (detailed descriptions can be found in Cossins and Upton 1987; Coppock 1994; Desta and Coppock 2002; Angassa and Oba 2007), which has adapted to the variation of the changing seasons, climate variability and spatiotemporal heterogeneity of forage production (Desta and Coppock 2004; Angassa and Oba 2007). Livestock production is the main livelihood of the people, with increasing engagement in crop production and other livelihood strategies. Although seasonal herd mobility is practised, but on a considerably reduced scale, households have increasingly settled in villages (Desta and Coppock 2002)

The Borana Oromo practise the "*Gada"* system, a complex traditional democratic system of self-rule that governs the social, economic, political and spiritual life of the society (Coppock 1994; Tiki et al. 2011). A "*Gada"* period with the duration of eight years is known by a name of the presiding person *known as Abba Gada* (father of *Gada*) and a new *Abba Gada* is elected every eight years by a general assembly ("*Gumi Gayo"*). In the Borana community, traditions and historical events are taught through oral history and thus passed from generation to generation by referring to *"Gada"* periods. In this study, climate and household food insecurity data were acquired for five *"Gada"* periods: *"Jilo Aga"* (1976-1984), *"Boru Guyo"* (1984-1992), *"Boru Madha"* (1992-2000), *"Liben Jeldesa"* (2000-2008) and *"Guyo Goba"* (2008-2016).

3.2.2 Household survey sampling

Two districts, Yabelo and Dire, were purposively sampled to represent different sources of water, where Dire represents a *Tula*-well ecosystem and Yabelo a non-*Tula*-well ecosystem. From each district, three Pastoral Associations (PAs) were sampled (Figure 1). From the district data profiles, it was estimated that 200 to 400 households may dwell in each PA. The presumed proportion of households (80%) diversifying livestock species and practicing other adaptation strategies to climate change with a 95% confidence interval and 5% margin of error were considered as parameters of interest for estimating the required sample size. This was estimated to be 240 households, which were equally distributed between districts (120) and among PAs (40). The sampling of households from village or encampment settings was systematic and random, every fourth household being sampled based on an identified sampling frame during site selection and the pre-test phase conducted in August 2011. Any selected household was replaced by the next household in a village in cases of absence during the first visit. As our study focused on different aspects of livestock households without livestock were excluded. No household deliberately refused to participate in the survey. Subsequently, a semi-structured questionnaire survey involving 242 households was administered between August and December 2011.

The questionnaires focused on household's socio-demographic variables, livestock holdings, livestock diversification and food security indicators. A household was regarded as 'diversified', if cattle were kept with camels and at least one species of small ruminants, or otherwise regarded as 'non-diversified'. Using the *Gada* timeline, herders' perceptions on temporal changes of pastoral diets in relation to climate variability were documented. Household food insecurity situations were retrospectively assessed during the six months, between April and September 2011. This period was characterized by food shortage due to failure of the short rains in 2010 followed by late onset and subnormal long rains in 2011. Among the sampled households, 28 of them (11.6%) had received food aid, which has focused on very poor and destitute groups, during the drought phase before September 2011. A modified household food insecurity access scale (mHFIAS) was derived from summation of the seven indicators listed briefly hereafter (Coates et al. 2007). These are whether or not a household worried about food shortage, amount of food consumed was below normal (desired quantity), food was not preferred type (substandard for the community), adults or children skipped one or more meal occasions, and adults or children did not eat for a whole day. Meal skipping by adults and young children (5 to 15 years) was differentiated to get an impression of problem severity. The three frequency responses to an indicator were no (coded=0), yes for a couple of days (coded=1) and yes for a couple of weeks (coded=2). Finally, household food insecurity situations were assessed using the mHFIAS, the length of food shortage period (months) and livestock off-take (livestock sales) in tropical livestock units (TLU). Livestock off-take was regarded as proxy measure for food access, which most likely increase with off-take. Livestock conversion factors to TLU were 1.0, 0.7, 0.5 and 0.1 for head of camel, cattle, donkey and small ruminants, respectively (Jahnke 1982).

3.2.3 Dietary data collection

A longitudinal survey of 242 households was conducted at the beginning (September 2011) and end (December 2011) of the short rainy season. The household's head, his wife (one of his wives) and their children above 15 years of age were included in the survey. One or more individuals who were present in the home during the first visit were interviewed twice to assess the seasonal patterns of dietary diversity. Subsequently, dietary data of 339 individuals were collected, using the 14-food group model according to the FAO guidelines for measuring individual dietary diversity (FAO 2007).

Using a 24 hours recall, respondents were asked to list and qualitatively describe all the food items they had consumed, at home and outside home, during the previous 24 hours. Foods consumed on local feast occasions such as "*Jilaa"* were noted, but excluded from the analysis as food consumption is likely to vary on those occasions. Mixed dishes were described by listing all the ingredients used in meal preparation. The quantity of each ingredient in the meal was then estimated using households' measures in order to designate the meal as belonging to single or multiple food groups. Milk consumption, in the form of family tea (15-25%), mixed with water or whole milk, was recorded in locally used cups (*"Koki"*) and then converted into milliliters (ml). Attention was given to certain items that may not be spontaneously recalled, such as animal fats (sheep tai1, camel hump), butter, oil or secondary ingredients such as small amounts of meat, vegetables and spices. Both questionnaire and dietary diversity surveys were assisted by two trained persons with first degrees, speaking the local language (*Afaan Oromo*).

3.2.4 Statistical analyses

Socio-demographic data, perceived trends of climate variability, food insecurity and their impacts on human wellbeing over the five designated *"Gada"* periods were descriptively summarized by their frequencies and percentages. Dietary diversity data were summarized by terciles of the 14 food groups (FAO 2007). Then an ordered logit model was used to analyze terciles of dietary diversity for household and individual level predictors as follow:

$$y_{ij}^{*} = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \beta_3 x_{3ij} + \beta_4 x_{4ij} + \beta_5 x_{5i} + \beta_6 x_{6ij} + \beta_7 x_{7ij} + \beta_8 x_{8ij} + \beta_9 x_{9ij} \quad (1)$$

where y_{ij}^{*} is the latent value of dietary diversity tercile of the j^{th} individual (y_{ij} =1 for lower tercile if y_{ij}^{*} ≤0, y_{ij} =2 for medium tercile if 0< y_{ij}^{*} ≤μ1, y_{ij} =3 for upper tercile if y_{ij}^{*} > μ1), β_0 is the intercept, $\beta_1 - \beta_9$ are regression coefficients, $x_1 - x_9$ are vectors of explanatory variables with x_{1ij} is livestock diversification (x_{1ij} =1 for species diversity and 0 otherwise), x_{2ij} is per capita cattle holdings (x_{2ij} =1 for >1.41 cattle and 0 otherwise), x_{3ij} is household farmland size (x_{3ij} =1 for >0.5 hectares and 0 otherwise), x_{4ij} is off-farm income (x_{4ij} =1 for having an off-farm income and 0 otherwise), x_{5i} is the district (x_{5ij} =1 for Yabelo and 0 for Dire), x_{6ij} is family size (x_{6ij} =0 for <7, i=1 for 7–10, and i=2 for >10 persons), x_{7ij} is polygamy (x_{7ij} =1 for polygamous family and 0 otherwise), x_{8ij} is age of the jth individual (x_{8ij} =0 for 15–25, i=1 for 25–50 and i=2 for >50 years), x_{9ij} is gender of the j^{th} individual (x_{9ij} =1 for male and 0 for female). The model fit was assessed by a score test for the proportional odds assumption. Mean and median values were reported for livestock off-take (in TLU), number of food shortage months per year, mHFIAS, number of consumptions per day, amount of daily milk intake (ml) and the dietary diversity score. The variables were used to compare livestock diversifications, using the Wilcoxon rank sum test as most of them skew on normality tests. Wilcoxon rank sum test, a non-parametric test equivalent to the two sample t-test, compares the underlying distribution of a response variable between two independent variables. We further selected three variables namely mHFIAS, number of food shortage months and livestock off-take as proxy measures for household food security assessments and analyzed for household level predictors (described in equation 1) by a fitting general linear model as follows:

$$y_{ij} = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \beta_3 x_{3ij} + \beta_4 x_{4ij} + \beta_5 x_{5j} + \beta_6 x_{6ij} + \beta_7 x_{7ij} + e_{ij} \quad (2)$$

where y_{ij} is the observation of the j^{th} household, β_0 is the intercept, β_1 - β_7 are regression coefficients, x_{1ij} is livestock diversification, x_{2ij} is per capita cattle holdings, x_{3ij} is household farmland size, x_{4ij} is off-farm income, x_{5ij} is the district, x_{6ij} is family size of j^{th} household, x_{7ij} is polygamy, whereas e_{ij} is the error term assumed to be normally distributed. In the course of data analysis, data transformation (square root) and exclusions of outliers based on residual distribution were performed in order to fit the model. The mean values were then back-transformed from square root values for simplicity of interpretation. All analyses were performed using SAS version 9.3 (SAS Institute Inc. 2012).

3.3 Results

3.3.1 Socio-economic characteristics of the survey households

The socio-demographic information showed that the majority of the sampled households (78%) were monogamous, while the rest were polygamous. The median number of people per household was 10 (3 to 27 people). A household consisted of either members of one family, or an extended family, if the livelihood of parents and their children's household depended on a pooled resource, particularly livestock. The mean age of household heads and respondents to the dietary diversity survey were 56.6 and 36.7, respectively. Literacy levels among the household heads were very low (13%), while the majority of households (83%) had at least one person who attended primary or secondary school.

Almost all investigated households in Borana depended on livestock production and opportunistic crop cultivation (91%), while about one-third engaged in non-pastoral activities. Cattle were the predominant livestock species, being kept by all households, while considerable proportions of households also kept goats (94%), sheep (85%), chickens (50%), camels (40%) and donkeys (37%). The average TLU per household and per capita were 19.1 (1.6 to 106.5) and 1.9 (0.2 to 14.2), respectively. Respondents mentioned that milk production for family consumption and cash income from animal sales were the two major purposes of keeping livestock species. There was a growing interest among herders towards camel keeping with the exception of some constraints including financial limitations and lack of knowledge of camel husbandry. Household involvement in camel keeping has shown a swift increase over the last three decades, from 6% (14 out of 242) in 1980 to 40% (97 of 242) in 2011. Increased drought recurrences and bush encroachments were cited as major factors behind growing interest in camel production.

Maize, haricot beans, wheat and sorghum were the major cultivated crops, maize and beans being the most important crops for human consumption. Respondents indicated that grain produced from own farm could feed the family for two to four months period but that a larger share of their cereal staple came from outside, particularly the market. Cereals, milk, beans and, to some extent meat and vegetables, dominated household diets. Respondents cited *"Badalla"* (*Buluka*) as the most commonly consumed local dish (30.3%), followed by milk as family tea (28.3%) and other cereal preparations (28.7%). *Badalla* is prepared from coarsely milled maize which is boiled with beans, vegetables, cooking oil, spices, milk and sometimes even meat, depending on availability. Household heads (58.6%) ate more frequently outside the home than their spouses (31.6%). Both household heads and their wives reduced their own consumption to act as a buffer against short food supply for their children. Some respondents mentioned cultural restrictions against the consumption of certain animal foods such as chicken and eggs (28%), as well as camel meat and milk (5%). They considered chicken as wild birds and reared them mainly for income generation from selling eggs. Similarly, *"Karayu Barre"* and *"Oditu"* (i.e. *"Qallu"*- the ritual leaders) rejected the consumption of any camel products.

3.3.2 Perceived trends in climate change, food security and human wellbeing

Climate variability and its impacts on livestock and their livelihoods were the most frequently mentioned changes by the Borana community. According to respondents, recurrent droughts (89%) and associated livestock losses (72%) have increased from the *"Gada"* period of *"Jilo Aga"* (1976-1984) to *"Guyo Goba"* (2008-2016). Conversely, most interviewees indicated that trends in rainfall (92.1%), milk production (93%), and milk and meat consumptions (90.1%) were declining (Table 3.1). From their perception of dietary trends, it is evident that herders were aware of the changing patterns of milk consumption to cereals as a staple food in their diet. They were further concerned about the adverse effects of dietary changes and food insecurity on human wellbeing. These include a perceived decrease in child growth performance (78.5%), decreased adult height (74%) and a decline in adult body condition (81.8%). For example, respondents perceived that they were of thinner and shorter stature compared to the earlier generation before the *"Gada"* of *"Jilo Aga"* (1976-1984).

Table 3.1 Perceived trends of climate variability, food security and their impacts on human wellbeing over four to five "*gada*" periods in Borana, Ethiopia

Parameters	Respondents' perception					
	Increase		No change		Decrease	
Drought recurrence	216	(89.3)	23	(9.5)	3	(1.2)
Rainfall	4	(1.7)	15	(6.2)	223	(92.1)
Livestock loss to drought	175	(72.3)	38	(15.7)	3	(1.2)
Milk production/family	0		17	(7.0)	225	(93.0)
Milk in diet	16	(6.6)	8	(3.3)	218	(90.1)
Meat in diet	17	(7.0)	7	(2.9)	218	(90.1)
Cereals in diet	193	(79.8)	23	(9.5)	26	(10.7)
Child growth	37	(15.3)	15	(6.2)	190	(78.5)
Adult body condition	21	(8.7)	23	(9.5)	198	(81.8)
Adult height	17	(7.0)	45	(18.6)	180	(74.4)

Values are given in number of responses and their percentages in brackets, a "*gada*" period, serving as local time calendar, has duration of eight years.

Increased climate variability and drought recurrence caused food insecurity among respondents. The failure of short (September to November) and long rains (March to May) led to the 2010/2011 drought, which consequently resulted in household food insecurity following the drought event (Table 3.2). As a result, most of the households worried (91.7%) about the adequacy of their food and had subnormal consumption in terms of desired amount (84.4%) and acceptable standard (88.1%) of the food. The survey results showed that 78.1% of adults and 63.0% of children skipped one or more meals a day due to food shortage. Some respondents (14.5%) reported deprivation of food for the whole day, which is an indicator of hunger. Meal skipping by children and fasting the whole day were among the major risks mentioned by respondents. This had further consequences on school attendance, as 13% of the survey households reported occurrences of school dropouts among their students. The problem becomes more serious when the distances to schools are longer than two hours travel time.

Table 3.2 Summary of food insecurity indicators for the period of extreme weather conditions (April to September 2011) in Borana (n=242)

Variable levels	Respondents' view*					
	No		Yes, for couple of days		Yes, for couple of weeks	
Fear of food shortage	20	(8.3)	15	(6.2)	207	(85.5)
Food quality substandard	29	(12.0)	41	(16.9)	172	(71.2)
Food amount subnormal	38	(15.7)	32	(13.2)	172	(71.2)
Adults skipped meal	53	(21.9)	45	(18.6)	144	(59.5)
Children skipped meal	87	(36.0)	84	(34.7)	71	(28.3)
Adults didn't eat the whole day	206	(85.1)	35	(14.5)	1	(0.4)
Children didn't eat the whole day	239	(98.8)	3	(1.2)	0	

* Values are given in number of responses and their percentages in brackets.

3.3.3 Food security indicators and their determinants

Analysis of household food security indicators showed that livestock diversification and increase of per capita livestock holdings were significantly associated with improved household food security. Generally, non-diversified households were significantly more vulnerable to food insecurity with longer periods of food shortage than those households involved in livestock diversification (Table 3.3). The latter had a higher livestock off-take than the former, ensuring better access to food. Large family size (> 10 persons), polygamy and those having off-farm income and farmland size above 1.0 hectare were found to be better-off at least with one indicator compared to the other categories. Similarly, those respondents living in Yabelo district were found to have shorter period of food deficit and higher livestock off-take than those in Dire.

3.3.4 Dietary Diversity of the survey respondents and influencing factors

Table 3.4 displays the overall and seasonal dietary diversity score based on the 24 hours dietary recall survey. Dietary diversity was generally low. Most individuals (81.3%) had consumed one to three food groups and only 18.7% of them had a relatively more diversified intake (4 to 8 DDS). Significant differences in dietary intake were observed from the beginning (September) to the end (December) of the short rainy season ($z = -6.02$, $P < 0.001$). The mean dietary diversity of individuals in lower and upper terciles was increased by 18.8% and 11.6%, respectively. There was a 20% reduction in the proportion of individuals in the lower terciles, which had increased those in medium and upper terciles by 15% and 4%. Similarly, the median DDS had increased from 2 to 3 food groups (data not shown). Dietary intake improvement also holds true for specific food groups such as milk (29%) and vegetables (25%).

Table 3.3 Predictors of household food insecurity in Borana of Ethiopia

Independent variables and their levels	[2]Number of households	(%)	[1]Least square means and their significance levels		
			[3]Food insecurity scale (n=233)	[4]Food shortage period (n=232)	[5]Livestock off-take (n=239)
LS diversification					
No	145	(59.9)	6.3[a]	2.9[a]	4.0[a]
Yes	97	(40.1)	4.4[b]	2.3[b]	5.3[b]
TLU per capita					
≤ 1.41	121	(50.0)	6.8[a]	2.9[a]	2.9[a]
> 1.41	121	(50.0)	4.4[b]	2.0[b]	6.3[b]
Farm land size					
< 0.5 hectare	104	(43.0)	6.3[a]	2.9[a]	3.6[a]
0.5 – 1.0 hectare	89	(36.8)	5.3[b]	2.6[ab]	4.4[a]
> 1.0 hectare	49	(20.2)	4.4[c]	2.3[b]	5.3[b]
Off-farm income					
No	172	(71.1)	6.3[a]	2.6	5.3[a]
Yes	70	(28.9)	4.8[b]	2.6	4.0[b]
District					
Yabelo	129	(53.3)	5.3	2.3[a]	4.0[a]
Dire	113	(46.7)	5.8	2.9[b]	4.8[b]
Family size					
< 7	44	(18.2)	5.8	2.9[a]	2.9[a]
7-10	108	(44.6)	5.3	2.6[a]	4.8[b]
> 10	90	(37.2)	4.8	2.0[b]	6.3[c]
Polygamy					
No	189	(78.1)	7.3[a]	3.2[a]	3.6[a]
Yes	53	(21.9)	4.0[b]	2.0[b]	5.3[b]

TLU: tropical livestock unit, LS: livestock, [a,b,c] means with different superscriptions within variable levels in a column vary significantly ($p<0.05$), [1]least square means were back transformed from square root values, [2]Household number varies depending on removal of outliers, [3]Food insecurity scale ranging from 0 to 14 (i.e. the larger the scale, the higher the food insecurity), [4]Food shortage period in months per year, [5]livestock off-take per year in TLU.

Table 3.4 Overall and seasonal dietary diversity scores (DDS) by terciles in Borana, Ethiopia (n=339)

DDS Terciles	September	December*	Overall	
	Mean DDS (%)	Mean DDS (%)	Mean DDS (%)	Median (range)
Lower	1.6 (58.7)	1.9 (39.8)	1.7 (49.3)	2.0 (1–2)
Medium	3.0 (24.5)	3.0 (39.5)	2.0 (32.0)	3.0
Upper	4.3 (16.8)	4.8 (20.6)	4.6 (18.7)	4.0 (4–8)

Dietary diversity score ranging from 1 to 14 food groups, * dietary diversity differ significantly between September and December ($z = -6.02$, $P < 0.001$).

Figure 3.1 shows the proportion of individual dietary diversity distributions by their respective terciles. Household consumptions relied heavily on cereals such as maize and to some extent wheat, served with some vegetable sauce and family tea (15-25% milk content). Thus, at least half of the respondents in all of the three DDS terciles have consumed milk products. Additionally, oil-fat and legumes and to some extent vegetables and flesh meat were consumed by those in the upper tercile. Milk was mostly consumed in the form of family tea or mixed with water. Some respondents reported that they did not consume dairy products (25%), while far more reported consuming no vegetables (93%) and no meat (96%). None of them also ate fruits, organ meats, eggs and fish. In general, dietary diversity is very poor with overall median and mean food groups of 3 (range 1 to 8) and 2.7, respectively. About 25% (September) and 11% (December) of the interviewees could not even attain their dietary desire of three meals a day.

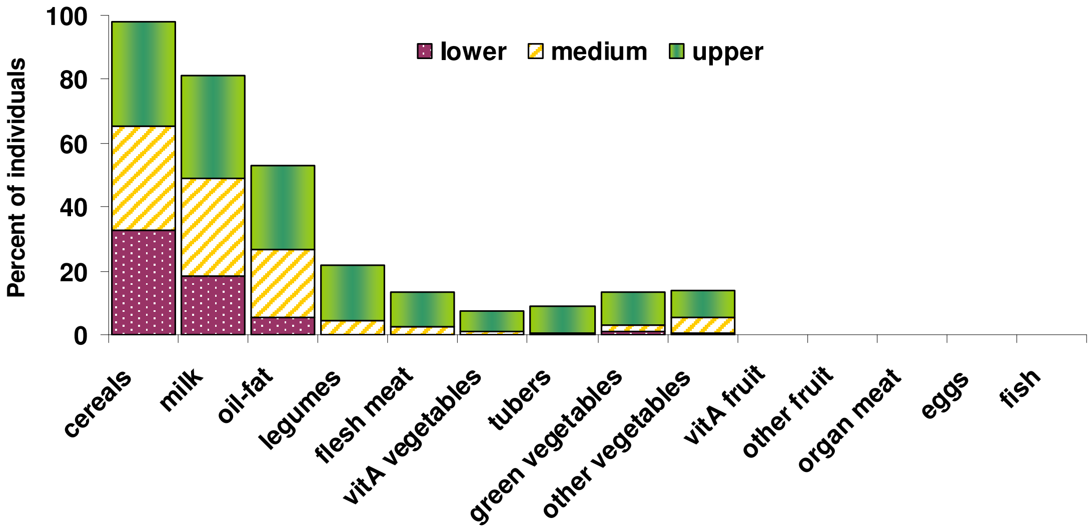

Figure 3.1 Proportion of individuals in each terciles by food group consumption in Borana

Table 3.5 shows the effects of different socio-economic factors on the individual's dietary diversity. Dietary diversity varied highly significantly with per capita livestock holdings, species diversification, family size and gender. For a unit increase in livestock species diversification, the odds of the upper tercile versus the combined medium and low terciles were 1.8 times greater (with the other variables held constant in the model). Similarly, the likelihood of being in the upper versus medium-low DDS terciles was 2.5-fold higher for households having more than 1.41 TLU per capita compared to those with 1.41 or less TLU per capita. Males had twice the chance of eating more diverse diets than females. Likewise, as one goes from smaller to larger family sizes, the likelihood of being in the upper tercile versus the low tercile is almost two-fold higher. In contrast, district, farm land size, off-farm income, polygamy and the age of individuals did not show any significant effect on dietary diversity.

Table 3.5 Effects of socio-demographic factors and livestock diversification on dietary diversity

Variables and their levels		Lower DDS (%)	Medium DDS (%)	Upper DDS (%)	Odds ratios (P-value)
District					
	Yabello	24.0	18.1	10.9	
	Dire	25.2	13.9	7.8	0.7 (0.054)
Family size (persons)					
	< 7	10.3	5.5	2.5	
	7 - 10	25.4	14.5	8.0	1.4 (0.135)
	> 10	13.6	12.1	8.3	2.3 (0.001)
Polygamy					
	No	40.3	25.8	13.9	
	Yes	9.0	6.2	4.9	0.9 (0.692)
Age group (year)					
	15 - 25	12.7	8.7	4.6	
	25 - 50	23.9	15.3	10.8	1.2 (0.359)
	> 50	12.7	8.0	3.4	0.8 (0.284)
Gender					
	Female	20.6	10.8	3.8	
	Male	28.6	21.2	14.9	2.0 (0.000)
Off-farm income					
	No	36.1	22.9	13.9	
	Yes	13.1	9.1	4.9	1.1 (0.602)
Farm land size					
	< 0.5 hectare	21.7	15.3	7.2	
	0.5 – 1.0 hectare	18.4	11.4	6.8	0.8 (0.357)
	> 1.0 hectare	9.1	5.3	4.7	1.1 (0.833)
TLU per capita					
	≤ 1.41	31.4	12.4	6.3	
	> 1.41	17.8	19.6	12.4	2.5 (0.000)
Livestock diversification					
	No	37.8	19.6	8.4	
	Yes	11.5	12.4	10.3	1.8 (0.001)

DDS: dietary diversity score, note that pooled data of the two periods were used to analyze dietary diversity terciles against different factors, Odd ratio (OR) is a measure a strength of association between predictor and response variables (OR=1 no association, OR>1 positive association, OR<1 negative association), score test for the proportional odds assumption shows that the model fairly fits the data (P=0.2608).

3.3.5 Livestock species diversification as predictor of food security indicators

Livestock species diversification was used to predict different variables of food security relevance i.e. livestock off-take, length of food shortage, mHFIAS, eating occasions, daily milk intake and dietary diversity (Table 3.6). The results showed that those households practising diversification had significantly higher mean TLU off-take (7.4 vs. 4), milk consumption (213.8 ml vs. 146.2 ml) and DDS (3.1 vs. 2.4) than non-diversified ones. Likewise, diversified households had significantly shorter periods of food deficit (2.3 vs. 3.8 months) and a lower mHFIAS (5.5 vs. 8.7) than non-diversified households. The latter experienced more severe hardship for longer periods than their counterparts. Differences in number of meals, milk consumption and dietary diversity between the two groups, however, were insignificant at the end of the short rainy season in December. An increase in DDS between the beginning and end of the rainy season was higher for the non-diversified households than their counterparts, while milk consumption had significantly increased for both groups (data not shown). It is worth noting that the Wilcoxon rank-sum test compares the underlying distribution of a response variable between two groups, but not necessarily their means or medians. For instance, the test gave significant difference between the distributions of meals per day of diversified and meals per day of non-diversified households, where their medians are similar (Table 3.6). This is due to the fact that about 20% of the non-diversified households had actually less than three meals per day corresponding to 10% of households with livestock diversification.

Table 3.6 Differences in household food security as a function of livestock species diversification in Borana

Variables	Non-diversified (n=145)§		Diversified (n=97)		Z-value	
	Mean	Median	Mean	Median		
Livestock off-take in TLU	4.0	3.3	7.4	7.0	-5.9	**
Food shortage period (months)	3.8	3.0	2.3	2.0	5.7	**
Household food insecurity scale	8.7	9.0	5.5	6.0	7.2	**
Av. milk consumption (ml)	146.2	72	213.8	108	-6.4	**
Milk consumption in Sep (ml)	33.7	0	134.4	90.0	-9.7	**
Milk consumption in Dec (ml)	258.6	180.0	293.1	180.0	-1.5	
Av. dietary diversity score	2.4	2	3.1	3	-7.5	**
Dietary diversity in Sep	1.9	2.0	3.3	3.0	-10.1	**
Dietary diversity in Dec	2.9	3.0	3.0	3.0	0.2	
Av. number of meals per day	2.8	3.0	2.9	3.0	-3.1	*
Number of meals in Sep	2.7	3.0	2.9	3.0	-3.7	**
Number of meals in Dec	2.9	3.0	2.9	3.0	-0.3	

§ n=223 for non-diversified and n=116 for diversified in cases of number of meals, milk and dietary intake per day which were based on number of individuals, ml: milliliter, Av: average, Sep: September, Dec: December, Z-value with asterisk vary significantly (* p<0.05), ** p<0.01).

3.4 Discussion

Livestock production is the foundation of livelihood in Borana with cattle being the most highly valued animals and a characteristic of social identity (Tache and Sjaastad 2010). A significant shift from centuries-old socio-cultural cattle pastoralism to multiple species herding was observed with a growing tendency of keeping camels and goats in the herds. Convergence of different environmental drivers such as climate variability and rangeland ecosystem changes which were perceived to have impact on cattle production, have compelled herders to diversify into more tolerant livestock species. Existing evidence (Solomon et al. 2007; Megersa et al. 2008) also suggests that camel production is gaining importance in Borana on account of increased drought recurrence (Desta and Coppock 2002), bush encroachment and reduced grazing capacity (Angassa and Oba 2008). Similarly, climate risks and ecological change drivers have been linked to the expansion of camels into the territories of communities with sedentary life and cattle based livelihoods in West Africa (Faye et al. 2012). Milk production is becoming the rationale of camel ownership in the study area contrary to previous assumptions that regarded the main function of camels as pack animals (Cossins and Upton 1987; Coppock 1994). Most respondents considered and recognized camels to be important in diversification. They believe the economic and environmental merits of camels as being complementary to other livestock species as also reported by Doti (2010). Camels feed on higher strata of plants, which make them less competitive with other livestock species for feed. Their ability to utilize scanty vegetation, while still producing milk that partially fills the food deficit gap during extended dry periods probably reflects their strategic importance in the Borana pastoral system.

Sheep and goats are the second most abundant livestock species, representing 14% of the total TLU, which is twice the proportion of an earlier report of 7.4% (Cossins and Upton, 1987). Small ruminants play a vital role as a major source of meat for domestic consumption, and in meeting small and immediate cash needs. Goats outnumber sheep by a ratio of 1.9 to 1. Goat milk is an important food for children during dry periods and for adults as family tea, in times of shortage.

For the Borana people, sheep milk is less important even though sheep are highly valued during cultural and ritual ceremonies.

The present findings show an increasing trend of households' involvement in both livestock and crop production (91%), while only a few households (9%) solely remain pastoralists. There has been a considerable change in cropping over time. Coppock (1994) reported that about 45% of the Borana pastoralists were involved in crop cultivation in the early 1990s but this had increased to 95% in a report by Tache and Oba (2010). The communities' motivation to become involved in crop cultivation is believed to be as a means of poverty alleviation and linked to the detrimental effects of increased climate variability and droughts on livestock holdings (Desta and Coppock 2004; Berhanu et al. 2007; Solomon et al. 2007). In line with this, an increase in farmland size was found to improve food security (Table 3.3). Farmland size was also reported to be positively correlated with increases in total grain harvest but it was found to vary with wealth rank, in favor of the wealthy group (Tache and Oba 2010). This may cast doubt on the suitability of plot size as an independent predictor of food security in pastoral areas, particularly under extreme weather conditions given its high vulnerability to rainfall deficit. Farming and pastoralism appear to be complementary in view of the household's food supply. Cultivation reduces the pressure on livestock off-take during a year with normal rain and swiftly alleviates post drought food shortage once the rains begin (Desta and Coppock, 2004). Given the present low level of livestock holdings (1.9 TLU per capita on average) with which sustainable pastoralism is unlikely (Tache and Sjaastad 2010), coexistence of cropping and livestock production seems inevitable for sustenance of local livelihoods. Yet, the long-term impact of competition for land use, especially in fertile valley bottomlands, is still uncertain (Berhanu et al. 2007). Appropriate integration of cropping into livestock production will be required.

Interviewees' perceptions indicate that trends in milk production and its use for human consumption are dwindling, the underlying factors being decline in cattle holdings and their productivity per head (Table 3.1). As a result, the traditional use of milk by the local people as the family's staple food has been eroded, giving rise to a monotonous cereal-based diet and compromising their nutritional wellbeing. Respondents consider that this alteration of diet has brought about poor growth in children and stunting and poor body condition in adults. Similar observations were made in Kenya by Fratkin et al. (2004) who found that milk intake had a significant effect on children's weight and height. According to Hoppe et al. (2006), milk provides energy, protein, many micronutrients and bioactive substances with growth-promoting abilities. The same authors further suggested that the effect is more evident in populations dependent on typical cereal staples in which addition of milk more likely supplies deficient nutrients that are important for growth. Thus, it is not surprising that the change in pastoralists' staple from milk to cereal adversely affects their nutritional status, particularly children and women, who are the most vulnerable members of the society.

Climate variability and change affect food security of a given region in several ways ranging from impacts on availability to access through effects on food prices and purchasing power (Gregory et al. 2005). Droughts have repeatedly hit the Borana plateau, causing huge mortality in livestock and heightening hardships in humans (Cossins and Upton 1988; Desta and Coppock 2004; Angassa and Oba 2007; Doti 2010). Likewise, failure of short and long rains during 2010/2011 had adverse effects on household food security. A higher proportion of households with subnormal consumption (84%) and meal skipping (78%) suggest the existence of severe food insecurity during the study period (Table 3.2). For instance, the traditionally uncommon "black tea" without milk had often been served alone instead of a main meal. Similarly, a study by Regassa and Stoecker (2012) showed that over 70% of their sampled households in southern Ethiopia had compromised culturally accepted standards of food quality. They also reported that the majority of households (64%) skipped meals occasionally out of which 32% skipped dinner. Meal skipping among young children is the most pressing issue and is indicative of the depth of food insecurity in the area as a cultural norm in Borana is that young children are given priority and receive available food first. We also found that food insecurity had a negative effect on school attainments (13% dropouts), which diminishes the career prospects of pastoral children. Overall, as found by other authors, food insecurity does affect the growth and wellbeing of young individuals (Fratkin et al.

2004), as well as their academic performance and future careers (Jyoti et al. 2005; Belachew et al. 2011).

In Ethiopia, seasonal food insecurity resulting from low-input farming, poor markets and rural infrastructure, and other socio-economic variables (Ferro-Luzzi et al. 2001; Regassa and Stoecker 2012), is triggered by climate shocks and further exacerbated by market failures (Devereux 2009). According to Desta et al. (2011), periods of food shortage in Borana extend from November to March, peaking between January and March when over 90% of their food comes from sources other than their own farms/herds, mainly from the market. During the present study period, however, drought has altered the pattern and magnitude of food shortage, extending it to August, after which it gradually declined. Seasonal food insecurity occurs as a downward cyclical pattern of availability and access to food in the study area. Food shortage coincides with depletion of household resources for access to food and unfavorable terms of trade between livestock and staple cereals. Forced off-take of animals, which are also in poor condition substantially drops their price, leading to dwindling purchasing power. In times of drought and food shortage, increased off-take is obligatory to meet the household's demand for food grain and to minimize animal losses caused by drought. This suggests that livestock off-take could be regarded as a proxy measure of food access by households in pastoral areas, particularly during the dry period, when the largest proportion of revenues from livestock sales is spent on food grain purchase (Berhanu and Fayissa 2010). From our results, it is apparent that those households involved in livestock diversification had a significantly higher off-take and thereby improved their access to food (Tables 3.3 and 3.6). Hence, the more diversified the livestock, the shorter the period of food deficit and the lower the magnitude of food insecurity the households experience.

Lower dietary diversity and milk intake during the lean period in September compared to the harvest period in December (Table 3.4) is in line with the observation of Becquey et al. (2012) in Burkina Faso. Savy et al. (2006) have also reported a similar pattern of seasonal dietary change between the beginning and end of the cereal shortage season elsewhere. Such a difference could be attributed to the crop harvest (i.e. maize and haricot beans), the access to some vegetables (local kale variety) and an increase in milk consumption. Unlike milk consumption, a significant increase in seasonal changes of dietary intake was observed for the non-diversified households as compared to their counterpart. This could suggest that an increase in milk intake, a favorite staple food, might not result in increasing dietary diversity and hence differential effects of livestock diversification on the dietary diversity are more evident in times of food deficit compared to 'normal' periods.

A low level of dietary diversity is most likely a key indicator of food insecurity in the study area, where the great majority of households (81%) are consuming only one to three food groups (Table 3.4). There is almost no intake of some micronutrient rich food groups such as fish, eggs, organ meat and vitamin A rich fruits and vegetables, signifying a potentially high risk of certain micronutrient deficiencies in the study area. While fish, fruits, vitamin A rich vegetables and tubers are not part of their diet and access to such food groups largely depends on a cash economy and availability in local markets, food preferences had a major role on the consumption of eggs. Addressing the dietary transition through interdisciplinary and intercultural collaboration deserves due attention for effective promotion of nutrition and health. Previous reports (FAO 2004; Sadler et al. 2009) have also indicated a low level of fruit and vegetable intake by pastoralists. The observed low level of mean DDS (2.7) in the present study is much lower than the reports from some rural communities in other African countries: 5.9 in Nigeria (Ajani 2010), 3.4 to 3.8 (Savy et al. 2006) and 7.8 (Torheim et al. 2004) in Mali. Low levels of dietary diversity among east African pastoralists have been ascribed to a high dependence on milk products as sources of energy and nutrients (FAO 2004; Sadler et al. 2009). According to a study in Borana, nearly everyone consumes milk, cereals being the second most consumed food (Villa et al. 2011). In contrast, the present study indicates that cereals are most commonly consumed in the study area, whereas about half of our respondents reported consuming milk mainly as family tea. Rather, our results are comparable with a report from Somalia (FAO 2004), where cereals remain the most common food group consumed, followed by meat, beans, and milk. As one moves from the lower to the upper dietary diversity terciles, oil-fat, legumes and flesh meat are included in the diversity (Figure 2), suggesting that the nutritive value of diets increases with dietary diversity, similar to previous reports elsewhere (Sadler et al. 2009; Ajani 2010; Oldewage-Theron and Kruger 2011).

The prevalence of food insecurity varies considerably among different socio-economic groups in Ethiopia (Ferro-Luzzi et al. 2001; Villa et al. 2011; Regassa and Stoecker 2012) and elsewhere in Africa (Garratt and Ruel 1999; Torheim et al. 2004; Savy et al. 2006). Increase in per capita livestock holdings predicated improved household food security and dietary diversity in this study as found in a previous report from Ethiopia (Ferro-Luzzi et al. 2001). Large herd size certainly contributes to food security through food supply, source of income, as a hedge against risks and as a means of capital accumulation that can be exchanged for food in times of deficit (Doti 2010). Households with off-farm activities (28.9%) had significantly lower mHFIAS but with lower livestock off-take, which may indicate the role of alternative income sources in alleviating food insecurity, while reducing the pressure on livestock off-take. But this factor had no effect on dietary diversity. Off-farm income opportunities, particularly through labor migration is vitally important for the Borana area as declining per capita livestock holding cannot support surplus household labor. Unskilled labor migration from the Ethiopian Borana (Berhanu and Fayissa 2010; Tache and Oba 2010) is lower than that of Borana in Kenya (Doti 2010). This could be linked to under development of rural towns in Ethiopia which could have absorbed unskilled surplus labor in the area and loosened ties of pastoral communities in Ethiopia to livelihood opportunities in major cities of the country (Devereux 2009). However, the current progressive trend in school enrollment, improved access to education and investment in human capital development have improved prospects of minimizing population pressure and supporting the local economy.

Large family size and polygamy positively affected food security (Table 3.3) contrary to other studies in which family size (Garratt and Ruel 1999; Becquey et al. 2012) and polygamy (Nanama and Frongillo 2012) were found to have an inverse relationship with food security. The authors of these studies found that higher numbers of household members negatively affected food security, particularly in urban settings where food comes from sources other than own farm and income of households strongly determines their ability to acquire food. Family size has general implications for household labor resources and consumption. In the context of pastoral societies, family and herd size grow in a subsistence manner for labor and food supply. Herd growth requires a large input of labor possibly leading to an extended family and polygamous marriage, and thus positively affects consumption.

A higher dietary diversity for male than female individuals was observed, similar to previous reports from Ethiopia (Belachew et al. 2008) and Mali (Torheim et al. 2004). The probable explanation could be that males, especially household heads, have higher chances of eating outside the home and are traditionally favored in the reception of the first and larger shares of food compared to their spouses. There is also a general accordance among the respondents that females (spouses) are the ones who receive less food and thus suffer most during periods of food shortage. However, a gender reverse scenario was previously reported from the same study area in which intra-household allocation of food favored daughters and disfavored sons (Villa et al. 2011). The reason given was that young men were most likely involved in herding at remote locations in times of stress where the food variety is often limited. Given the complex nature of gender relations and intra-household allocations, it is worth noting that differences in food security might exist among women in different marriage forms. Although the present study did not consider seniority of women within polygamous households, a senior (first) wife is culturally more favored in the Borana community and is thus likely to be better-off compared to her junior peers. Similarly, a study in Burkina Faso found that women, who ranked first or second in polygamous households were less food insecure compared to their junior counterparts (Nanama and Frongillo 2012).

In the present study, diversification of livestock species was associated with shorter periods of food deficit, better dietary intake and lower magnitude of household food insecurity (Tables 3.3 and 3.6). Generally, livestock diversification significantly affects off-take and consequently improves access to food. Thus, multiple species herding does not only offer food products but also more ample choices for off-take, which can be liquidated in times of shortage and can smooth consumption. Increased off-take improves purchasing power and food access, which ultimately fulfills the food requirements of the family. Regassa and Stoecker (2012) have also reported that household food security is influenced by the number of livestock species owned. In Chad, Bleich et al. (2005) demonstrated the potential of livestock diversification in contributing to food security and income of poor households. The success in Chad was attributed to differences in market values and disease resistance of the animal species. Different species of animals vary considerably with regard to water and feed requirements, and resistance to drought and disease (Doti 2010). As a result, herding of multiple livestock species is presently drawing attention as an indigenous adaptation strategy to climate change and disease episodes (Morton and Barton, 2002; Galvin et al. 2004; Speranza 2010).

Results of this study show that livestock diversification is important and contributes considerably to increased milk consumption and dietary diversity. For instance, camel and goat milk play a key role in replacing cattle milk in family's diets in dry spells, as noticed during field observation. Existing information on daily milk off-take of camels in Borana (Megersa et al. 2008) indicates that between 4.3 and 7.6 liters can be obtained during the dry and wet seasons, respectively. Hence, addition of camels to cattle and small ruminant composites certainly makes a significant contribution to food security besides its economic and ecological advantages. Due to their slow breeding and low reproductive rates, camels are not as efficient for off-take as they are for milk production. In this respect, small ruminants are complementary to camels. Likewise, Doti (2010) pointed out that camels are tolerant to drought and may sustain household food supply while small ruminants, given their high fecundity and hardiness to drought, play a role in speeding up post drought recovery. While diversification is a "noble strategy", labor inputs, stocking investment and other management issues need to be taken into consideration. In general, livestock diversification plays a vital role in ensuring food security under a changing climate in Borana.

3.5 Conclusions

This study shows that Borana herders experience a high level of seasonal food insecurity and low dietary diversity. There is also a general accord among the respondents that there is a downward trend in consumption of milk and meat. We can conclude that food security and dietary intake vary considerably among different socio-demographic factors of which livestock diversification showed a significant difference across different variables of food security relevance. Overall, our results shed light on future prospects of livestock diversification in ensuring household food security under looming climate change in Borana.

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4 Livestock diversification: an adaptation strategy to climate and rangeland ecosystem changes in southern Ethiopia

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Chapter 4 Livestock diversification: an adaptation strategy to climate and rangeland ecosystem changes in southern Ethiopia

Abstract

Pastoral cattle production in southern Ethiopia is becoming increasingly vulnerable to impacts of climate variability and rangeland resource degradation, giving rise to livestock diversification as an adaptation strategy. Using a household (n=242) survey among herders, the relative functions, adaptability and vulnerability of four livestock species, and factors influencing livestock diversification were analyzed. All of the respondents owned cattle, while 94%, 85% and 40% kept goats, sheep and camels, respectively. The stated major drivers of livestock diversification were recurrent droughts, bush encroachment, increased vulnerability of cattle and growing demand for adaptive species. Inadequate knowledge of camel husbandry and high initial stocking costs were highlighted as the major constraints. Function patterns varied considerably among livestock species, with milk production and animal sales being of paramount importance, reflecting the dominance of subsistence objectives over mere production goals of the herders. Based on a set of nine adaptive traits, camels were ranked highest, with regard to six traits (tolerance to heat stress, drought, water scarcity, feed shortage, coping with bush encroachment and walking ability), but were ranked least for pre-weaning survival rate. Cattle were ranked first for their tick resistance and tolerance to heavy rain, but last for five other traits. Species vulnerability to the 2010/2011 drought also corroborated the adaptability rankings with cattle being the most vulnerable to drought followed by sheep, while camels are the most tolerant. The average mortality rate differed significantly among the livestock species (P<0001) with cattle having 4.1, 2.9 and 2.5 times more death incidents compared to camels, goats and sheep, respectively. Livestock diversification and camel ownership varied significantly with family size and per capita holding of cattle, implicating the influence of demographic and economic factors on adoptions. Multispecies herding emerged as the dominant local adaptation strategy likely because, besides offering a variety of functions, it enhances resilience of households to climate change by broadening on the set of other existing strategies.

Keywords: Adaptability; Multispecies Herding; Production Objectives; Vulnerability; Borana

4.1 Introduction

In East Africa, climate change is linked to declining precipitation and changing rainfall patterns, and increased drought frequencies (Williams and Funk 2011; Williams et al. 2012). The changing patterns of climate and extreme weather conditions, in particular uneven distribution of precipitation and recurrent droughts, have already adversely impacted livestock keepers in the region (Speranza 2010; Silvestri et al. 2012; Catley et al. 2013). Pastoral societies are among the most vulnerable to climate change due to their relatively low adaptive capacity, highly risk-prone and less resilient production environments (Morton 2007; Speranza 2010; Ouma et al. 2011). Climate change and variability present a major challenge to livestock production in the arid and semi-arid environments, through their impacts on pasture production, water availability, disease risks and thermal stresses (Thornton et al. 2009; Nardone et al. 2010). Consequently, the lower the productivity and grazing capacity of rangelands, the higher the nutritional stresses that animals are likely to suffer, further exacerbating the existing vulnerability of pastoral systems (Morton 2007; Thornton et al. 2007; 2009). Among the factors that amplify the detrimental effects of climate change, recurrent droughts are perhaps the most crucial, because droughts adversely affect pastoral livestock production, including the Borana of southern Ethiopia (Desta and Coppock 2002; Speranza 2010; Angassa and Oba 2013). Drought cycles frequently affect the Borana rangeland, causing substantial livestock losses, particularly of cattle (Desta and Coppock 2002; Angassa and Oba 2013).

Until the 1980s, the Borana rangelands were in good condition and the production system was regarded as one of the most productive pastoral system in East Africa (Cossins and Upton, 1987). Oba *et al.* (2000) described the Borana rangelands as heterogeneous in soil types and vegetation cover with great suitability for grazers, which may elucidate why cattle pastoralism has been a centuries-old mainstay of the Borana community (Cossins and Upton 1987; Coppock 1994). More recent accounts indicate that the rangeland has been degraded in quality and shrunk in size, due to invasion of woody plants, decline of herbaceous biomass and fragmentation of communal grazing areas (Dalle et al. 2006; Solomon et al. 2007; Homann et al. 2008). Accordingly, increased climate variability compounded with rangeland resource degradation might have exacerbated cattle vulnerability to climatic risks, putting enormous pressure on the traditional cattle keeping pastoralists.

Cattle are generally the livestock species most sensitive to adverse effects of climate change (Seo et al. 2010; Lesnoff et al. 2012). They have slow recovery times after severe droughts, averaging 10 to 15 years (Cossins and Upton 1988). Recovery can be further prolonged, if interrupted by other climatic shocks, which are most likely to occur under scenarios of more frequent droughts (Lesnoff et al. 2012). Lunde and Lindtjørn (2013) have demonstrated that the highest vulnerability to climate variability is found in arid environments. In line with this, several studies have documented herders' responses to changing environmental conditions, such as pursuing alternative livelihood strategies (Doti 2010), crop farming, diversification of herd composition or switching to other species (Seo et al. 2009; Faye et al. 2012). Accordingly, an increased shift from vulnerable to adapted species, from cattle to goats (Seo et al. 2009) and from cattle to camels in Africa (Faye et al. 2012), or from cattle to sheep in Latin America (Seo et al. 2010) have been reported.

Differences among livestock species in their tolerance to drought, heat stress, water and feed shortages offer the possibility to choose species that are better adapted to changing environmental conditions (Seo et al. 2009; Speranza 2010). Besides acting as a buffer against climatic and disease risks, species diversification also endows herders with different complementary functions and rangeland resource uses (Seo et al. 2009; Doti 2010). Adoption of different agricultural practices and technologies has socio-economic dimensions (Yengoh et al. 2009). The decision of herders to keep different livestock species can also be influenced by their socio-demographic characteristics, economic factors, the optimal benefits, and the potential risks and uncertainties involved in doing so. Livestock diversification by herders in southern Ethiopia is also expected to be an outcome of similar dynamics. Understanding the potentials and constraints of multispecies herding as an adaptation strategy might thus provide decision makers with an improved basis for the design of livestock development strategies and the enhancement of adaptive capacity. The present study therefore investigates the functions and adaptability of different livestock species, and factors influencing livestock diversification in southern Ethiopia. To address these objectives, we analyzed different data sets including history and reasons of livestock species diversification, perception of herders on environmental changes, functions and adaptive traits of the livestock species.

4.2 Methods

4.2.1 Study area

The study was conducted in Dire and Yabelo districts in the Borana zone of Oromia Regional State, southern Ethiopia (Figure 1.1). The Borana lowland has an annul average rainfall and temperature ranging from 300 mm to 600 mm and from 19°C to 26°C, respectively. Rainfall distribution is bimodal, with the long rains falling from March to May and the short rains from September to November. The traditional *"Tula"* well complexes are the backbone of the pastoral production system serving the community as permanent water sources (Coppock 1994). Detail descriptions of the Borana production system have been given elsewhere (Cossins and Upton 1987; Coppock 1994; Desta and Coppock 2002; Homann et al. 2008). Pastoral livestock production is the main livelihood of the people, with increasing engagement in crop production and other livelihood activities.

4.2.2 Major livestock species kept in Borana

The Borana cattle breed is the shorthorn zebu cattle with a light grey body and a dark grey coat color around the dewlap and the neck region (Alberro 1986; Coppock 1994; Haile et al. 2011). The Borana cattle are endowed with the ability to withstand periodic shortages of water and feed, and can endure walking long distances. Cows have a good longevity, maternal ability and herd instinct (Haile et al. 2011). Most of the surveyed households kept a larger proportion of the Borana cattle than other breeds, although it was also common to find one or more highland zebu cattle in the herds, with a higher proportion in Yabelo than in Dire.

The most common sheep breed is the well known Blackhead Persian or Somali Blackhead sheep. They are hornless with black head color that makes a startling contrast to their white bodies (Yami and Merkel 2008). Along with sheep, the long-eared goats with short hair and a smooth white coat color are also kept. They are also well adapted to arid environments of the Borana and Ogaden region (Yami and Merkel 2008). The common camel types are the large Somali camel type, locally known as *"Horki,"* and a smaller sized type *"Gelab"*, as well as intermediate sized ones that are assumed to be a result of crossing the two types (Coppock 1994; Megersa et al. 2008).

4.2.3 Data collection

Details on the sampling methods have been given in Megersa et al. (2014a). Therefore, only those aspects of the methods that were not covered in the previous study are highlighted hereafter. Questionnaire surveys were administered to the 242 households between September and December 2011 to generate data on households' socio-demographic and economic variables, livestock holdings and species composition, major factors driving or restraining livestock diversification. Livestock species diversification was regarded to have occurred at the household level if a household keep at least three species i.e. cattle and camel together with at least one species of small ruminants. Diversification of livestock species was reconstructed for the period covering 1976 to 2011 using the Borana "gada" time calendar. The herders' perceptions of changes to rangeland and climate as well as livestock production were also recorded. Respondents were asked to answer questions related to changing trends in rainfall, temperature, drought frequency, pasture availability, grassland and bushland cover, and livestock species diversification by choosing one of the following options: (1) increasing, (2) decreasing, or (3) no change.

Herders were asked to rank purposes (utilities) of keeping livestock species according to predetermined reasons such as milk production, meat production, cash revenues from sales of live animals, socio-cultural functions, draught power and manure. Socio-cultural functions included cultural gifts, dowry, ceremonial slaughtering, social security and redistribution. Draught power, including traction, crop threshing and transportation services, was not considered for small ruminants. Similarly, herders were asked to compare four livestock species (cattle, camel, goat and sheep) against a set of nine traits that are considered to be important in adapting to changing environmental conditions based on FAO descriptions (2008). Additionally, six group discussions were used to capture different aspects related to livestock production, and trends in rangeland and climatic conditions. Mainly qualitative information was generated from the discussions and used to supplement the household survey results.

4.2.4 Statistical analyses

General characteristics of the surveyed households and perceptions data were descriptively summarized. Frequency responses for stated driving and restraining forces of livestock diversification were graphically plotted. Analyses of ranked data on the functions of a particular livestock species as well as the comparison of the four livestock species based on a set of nine adaptive traits were performed by two methods. First, a rank normalization was performed by converting ranks into standardized values [0, 1], with values close to zero and one indicating that a variable was ranked least and highest, respectively (Ouma et al. 2011):

$$\text{Normalized rank} = 1-\left(\frac{(rank - rank_{\min})}{(rank_{\max} - rank_{\min})}\right) \qquad (1)$$

where rank is the position of a variable in the order of ranking, and $rank_{\min}$ and $rank_{\max}$ are the lowest and highest positions in the ranking by a respondent, respectively. Then, normalized ranks were averaged for each variable and plotted for visual comparisons.

Second, ranked data were further analyzed to detect significant differences among the variables using an exploded logit model. Manure as a purpose of keeping livestock species was excluded from the analysis because of its extremely low ranked values. An exploded logit model regards the probability of any ranking of the alternatives from best to worst as a product of first choice probability for successive remaining alternatives (Skrondal and Rabe-Hesketh 2003). Rankings can be successively obtained by choosing the best preference first, and thereafter the second choice is selected from the remaining alternatives, and so on, until the worst choice remains. Allison and Christakis (1994) have developed a method for the analysis of ranked data using the PHREG (proportional hazards regression) procedure of the SAS System based on a random utility model.

Suppose respondent *i* derives a certain utility U_{ij} from each livestock function *j*, in which U_{ij} is the sum of a systematic component μ_{ij} and a random component e_{ij}, i.e. $U_{ij} = \mu_{ij} + e_{ij}$. If the error term e_{ij} is assumed to be independently and identically distributed with extreme value distribution, the systematic component can be modeled as:

$$\mu_{ij} = \beta_j x_i \quad (2)$$

where β_j is a row vector of coefficients, the values of which vary over the livestock functions and one of which is set to be 0, x_i is a vector of predictors that describe the i^{th} respondent, but do not vary across the functions. Accordingly, we fitted a model to the ranked data (without ties) in the PHREG procedure (SAS Institute Inc. 2012). The SAS macro %MULT was used to display significant mean differences by a letter display (Piepho 2012), with a common letter indicating non-significance of a difference between means. Similarly, the four livestock species were compared in terms of the nine selected adaptive traits.

Household level differences in vulnerability expressed as the mean mortality rate (during the 2010-2011 drought) among the four livestock species were assessed by fitting a generalized linear mixed model (GLIMMIX) with a negative binomial error distribution and a log link function. The logarithm of herd size at the onset of the drought was used as an offset variable. The linear predictor was (apart from the offset):

$$\eta_{ij} = \beta_0 + \beta_i \quad (3)$$

where η_{ij} is the linear predictor of the i^{th} species (*i* = cattle, camel, goat, sheep) belonging to the j^{th} household that died in the drought, β_0 is the general mean, β_i is the effect for the i^{th} livestock species. The expected count of the i^{th} species and j^{th} household is modeled by the logarithmic link function as:

$$\log(\mu_{ij}) = \log(h_{ij}) + \eta_{ij} \quad (4)$$

where h_{ij} is the i^{th} herd size (offset variable). Scaled deviance and residual diagnostics were used to assess model fit.

Similarly, GLIMMIX was used to discern factors influencing the adoption of livestock diversification after checking the distribution of residuals for normality as follows:

$$y_{ij} = \alpha + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \beta_3 x_{3ij} + \beta_4 x_4 + \beta_5 x_{5ij} + \beta_6 x_{6ij} + u_i + e_{ij} \quad (5)$$

where y_{ij} is the species diversity (1 to 4 species) of the j^{th} household in the i^{th} village (six levels), α is the intercept, β_1 - β_6 are regression coefficients, x_{1ij} is a dummy variable for off-farm income (x_{1ij}=1 if the j^{th} household receives an off-farm income and 0 otherwise), x_{2ij} is a dummy for household farm size (x_{2ij}=1 if the household farm size > 0.5 hectares and 0 otherwise), x_{3ij} is a dummy for the age of the household head (x_{3ij}=1 if the age of the j^{th} household head $\geq$ 55 years and 0 otherwise), x_4 is a dummy for the district (x_4 =1 if district is Yabelo and 0 for Dire district), x_{5ij} and x_{6ij} are family size and per capita cattle holdings by the j^{th} household, whereas u_i and e_{ij} are the random effects of the i^{th} village and the error term, respectively. Other variables such as herding labor source, gender and literacy of household heads were excluded from the final model due to small sample sizes and non-significance. None of the interactions between variables were significant so that these were excluded from the final model.

4.3 Results

4.3.1 Household characteristics

Table 4.1 presents major characteristics of the interviewed households. The results show that the average family size was 10 and most of the household heads were men with average age of 56 years. The proportion of households engaged in crop cultivation was higher in Yabelo than in Dire (99% vs. 81%). Relatively more households in Dire earned part of their income from off-farm sources compared to Yabelo.

Table 4.1 General characteristics of surveyed households in Yabelo and Dre districts

Characteristics	Levels/ units	Yabelo				Dire			
		N	Percent	Mean	SD	N	Percent	Mean	SD
Gender of hh head[a]	male	116	89.9			95	84.1		
Age of hh head	year	129		56.4	14.2	113		56.4	12.8
Family size		129		10.3	4.3	113		9.4	4.1
Farmland size	hectare	128		0.7	0.4	92		0.5	0.4
Off-farm income[a]	yes	18	14.0			52	46.0		
Herding labor source[a]	family	108	83.7			90	79.6		
Literacy[a]	literate	21	16.3			11	9.7		
Livestock species									
Cattle		129		21.6	20.9	113		17.7	18.3
Cattle per capita		129		2.1	1.9	113		1.9	1.7
Other cattle breed[b]	yes	62	48.1			20	17.6		
Camel		63		5.1	5.2	34		5.0	4.7
Goat		120		19.4	20.6	108		14.9	17.5
Sheep		105		11.2	9.0	102		8.6	7.5
Donkey		50		2.9	2.5	40		0.9	1.7
Chicken		59		6.3	3.4	63		3.0	3.5
No of ruminant spp[c]		129		3.2	0.8	113		3.2	0.6
Livestock per family	TLU[d]	129		21.2	19.8	113		16.7	16.1

N: number, SD: standard deviation, hh: household, [a] dummy variable, travel time to nearby town is a round trip in hours, [b] other cattle breed in herds indicates the highland zebu cattle, [c] ruminant species include cattle, sheep, goat and camel. [d] TLU: tropical livestock unit which counts 1.0, 0.7, 0.5 and 0.1 for head of camel, cattle, donkey and small ruminants, respectively.

The majority of the households (over 80%) relied on family labor for herding livestock while others used relatives as herders and only two households reported ever having hired labor. The literacy level among the household heads was generally very low (16.4% in Yabelo and 9.7% in Dire), but the majority of the households (83%) had at least one person, who attended primary or secondary school. Cattle were the dominant livestock species owned by all of the respondents. Most of the households kept a larger proportion of the Borana cattle, although it was also common to find one or more highland zebu cattle in the herds, with a higher proportion in Yabelo than in Dire. The main reasons mentioned for keeping the highland zebu cattle were that they were purchased at lower prices, received as gifts, or heritage from parents. In addition to cattle, a larger share of the households kept goats (94%) and sheep (85%) compared to chicken (50%), camels (40%) or donkeys (37%). The number of ruminant species per household averaged 3.2, with apparently higher average TLU livestock holding in Yabelo than in Dire.

4.3.2 Factors driving or restraining livestock diversifications

The herders showed a growing tendency to keep different livestock species, with an increasing shift towards camel husbandry. Livestock diversification, keeping cattle and camels with at least one small ruminant species, has increased markedly over the last three decades. For instance, diversification increased from 3% in 1976 to 17% in 1990, to 26% in 2000 and to 40% in 2011. The rate of adoption was particularly rapid between 1990 and 2011. The driving and restraining factors for the shift from pastoralism with cattle only towards multiple species are illustrated in Figure 4.1. An increased frequency of droughts, bush encroachment, vulnerability of cattle herds to climatic variability and demand for adaptive species were cited as the major driving factors. The two major restraining factors mentioned most frequently by the respondents and accounting for nearly 80% of the stated constraints were inadequate knowledge of camel husbandry and the high initial costs needed to establish a camel herd. For instance, about 8% of the households that adopted camels have lost them in part due to insufficient knowledge about camel health care and prevailing camel diseases. The remaining households mentioned cultural restrictions on consumption of camel products, landscape unsuitability and shortage of herding labor as reasons for not keeping camels.

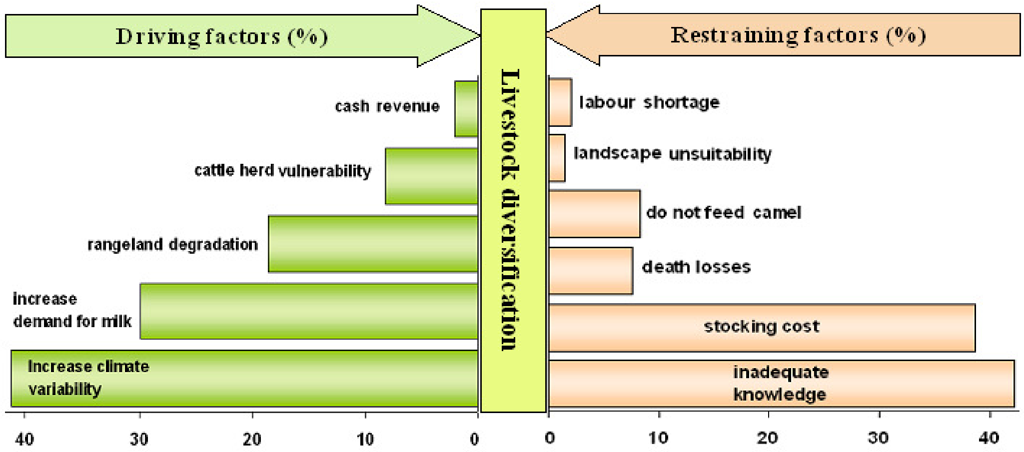

Figure 4.1 Stated driving and restraining factors of livestock diversification in Borana: the horizontal axis represent proportion of factors, while their lists were presented on vertical axis.

The stated drivers of multispecies herding were further grouped into "push and pull" factors with the former (68%) more frequently mentioned than the latter (32%). The "push" factors are those that might have compelled herders to look for another animal species or breed that adapts to and thrives in the changing environmental conditions better than cattle. These included increased climatic variability, cattle herd vulnerability, bush encroachment, decline in cattle holdings, herd productivity and fragmentation of grazing areas. The "pull" factors relate to the merits and attributes of the alternative animal species that could attract herders. These were high milk yield and revenue from camel sales, tolerance to drought, feed and water shortage, ample choices for off-take, and acting as a buffer against risks.

4.3.3 Herders' purposes for keeping major livestock species

The reasons for keeping livestock species varied considerably by species. Milk production for family consumption and cash revenues from live animal sales were the two major functions that animals are kept to fulfill except for sheep (Figure 4.2). Cash revenues, meat production and socio-cultural functions were the three major reasons for rearing sheep.

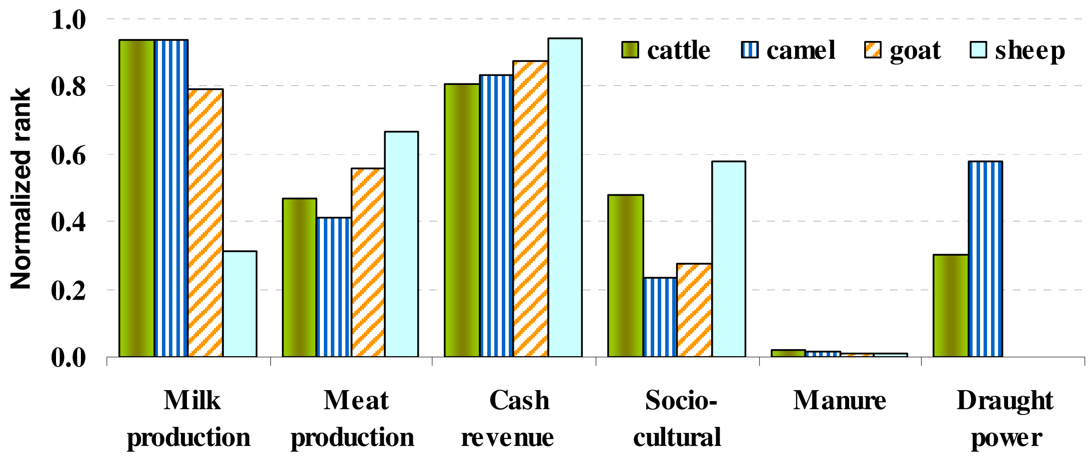

Figure 4.2 Purpose (utility) of keeping different livestock species in Borana

Highest normalized rank indicates best utility and vice versa, utilities do not include services for goat and sheep, socio-cultural functions include symbolic values, gift on cultural events, dowry, ceremonial slaughtering, social security and social status; draught power includes traction and transportation.

The use of manure was ranked lowest across all species, showing its negligible importance. Milk production was the best utility for cattle and camels. It was significantly different from the sales of live animal, the second best utility, which, in turn, differed significantly from the remaining alternatives (Table 4.2). Exponentiation of the estimated difference in utility between milk production and cash revenues for cattle (3.189 - 2.040 = 1.129; $e^{1.129}$ = 3.04), suggesting that cattle are three times more likely to be kept for milk production than for sales. They are also seven times more likely to be kept for cash revenue than for social functions and four times more likely to be for social functions than for draught power. Likewise, camels are three times more likely to be kept for milk production than for cash income, and ten times more likely to be kept for off-take than for transportation services. The difference between the best (sale of animals) and the second best utility is much higher for sheep (seven times) than for goats (about twice), indicating that sheep are mainly kept to meet household cash demands in the area. The least utilities were draught power for cattle, socio-cultural functions for camels and goats, and milk production for sheep.

Table 4.2 Differences among utilities of four livestock species kept by herders in Borana

Utility	Cattle	Camels	Goats	Sheep
Milk production	3.189[a]	6.501[a]	3.749[b]	-1.629[d]
Sale of animals	2.040[b]	5.509[b]	4.345[a]	2.413[a]
Socio-cultural functions	0.000[c]	0.000[e]	0.000[d]	0.000[c]
Meat production	-0.089[c]	1.619[d]	2.560[c]	0.460[b]
Draught power	-1.453[d]	3.152[c]	na	na

Values were given by least square means of estimated utility, utilities with common superscriptions in a column do not vary significantly ($p>0.05$), while alphabetical order indicates the relative importance of utilities, na: not applicable, socio-cultural functions, which was used as reference, include gifts on cultural events, dowry, ceremonial slaughtering, social security and redistribution, draught power include traction, transportation and crop threshing.

4.3.4 Adaptability of livestock species

A descriptive comparison of the four major livestock species based on nine traits considered important in adapting to changing climatic and rangeland conditions is displayed in Figure 4.3. Similarly, Table 4.3 presents the respective results of the proportional hazard regression for the overall as well as the individual trait level comparisons of cattle with other species. Out of the nine adaptive traits considered for the comparisons, camels were ranked highest with regard to six traits (tolerance to water scarcity, feed shortage, heat stress, drought tolerance, coping with bush encroachment, walking ability) and least for young survival rates. During group discussions, herders correspondingly highlighted that camel calf mortality particularly during the first three months of their life is a major problem. Cattle were ranked highest for their tolerance to heavy rains and tick resistance, and second best for long distance walking and young survival to weaning. But, they were also ranked lowest for five traits, comprising tolerance to water scarcity, feed shortage, heat stress and drought, and coping with invasive woody plants. Goats were chosen the second best for five out of nine traits and last for two of them. Sheep were ranked third for seven traits, first for young survival to weaning and last for their walking ability.

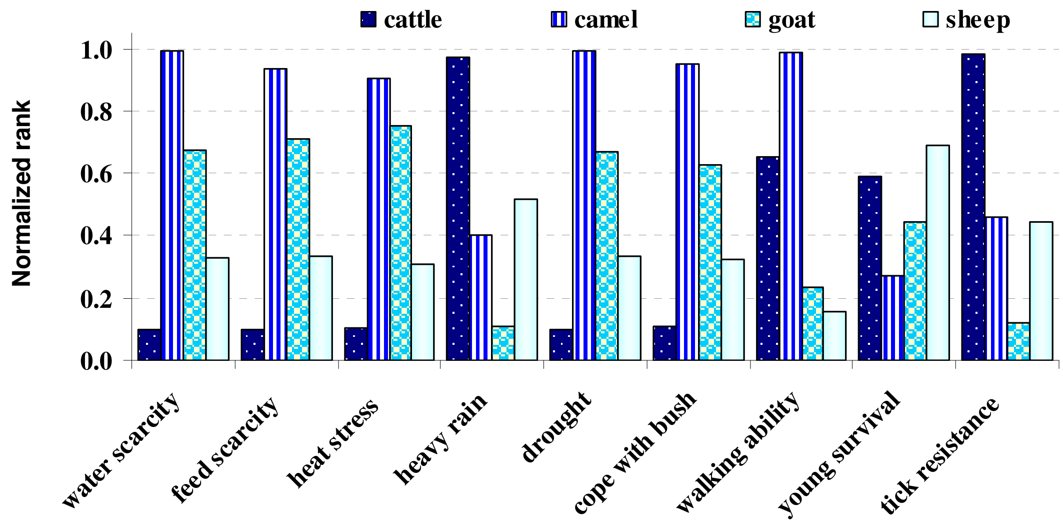

Figure 4.3 Comparison of livestock species by their adaptive capacity (highest normalized rank indicates utmost adaptive capacity)

The overall species level comparisons showed that camels were significantly ranked highest with 4.6, 2.7 and 2.1 times more adaptive capacity than cattle, sheep and goats, respectively. Goats were ranked the second best animals while cattle were ranked last in terms of adapting to changing environmental conditions. The comparison of the two cattle breeds showed that Borana cattle were ranked first for five traits compared to only one trait higher (tolerance to feed shortage) for the highland zebu (data not shown). Both breeds were regarded as equal for their tolerance to heavy rains, drought and young survival to weaning, indicating that the merits of Borana outweigh those of zebu cattle.

Table 4.3 Adaptability comparison of cattle with other species against nine adaptive traits

Comparison criteria		Camel	Goat	Sheep
At species level[a]				
	Cattle	1.518***	0.790***	0.532***
	Sheep	0.986***	0.258***	
	Goat	0.727***		
At trait level[b]				
Tolerance to water scarcity		13.552***	9.876***	4.378***
Tolerance to feed scarcity		9.308***	7.840***	4.090***
Tolerance to heat stress		9.153***	8.187***	2.521***
Tolerance to heavy rain		-3.674***	-4.942***	-3.026***
Tolerance to drought		14.371***	10.281***	4.788***
Coping with bush encroachment		5.927***	3.869***	2.109***
Walking ability		3.714***	-3.675***	-4.074***
Resistance to tick infestation		-3.927***	-5.245***	-3.842***
Young survival to weaning		-2.235***	-0.647***	0.901***

[a] Species were compared across the nine traits with values indicating differences of their choice least squares means, [b] while comparisons of cattle with other ruminants were performed at each trait level, and values were given as choice least squares means of estimates, with positive value indicating that other species are significantly better than cattle and vice versa (*** p<0.001).

4.3.5 Vulnerability of livestock species to climate variability: The case of 2010-2011 drought

Table 4.4 presents the comparative vulnerabilities of the four major livestock species: cattle, camel, goat and sheep to the drought of 2010/2011. The results show mean mortality rates of 6.5±1.4%, 9.1±0.9%, 10.5±1.2% and 26.4±2.4% for camel, goats, sheep and cattle, respectively. Cattle were thus found the most vulnerable species to droughts followed by sheep, while camels were relatively the most tolerant ones. The average mortality rate differed significantly among the four livestock species ($F_{3,771} = 29.2$, $P = 7.225 \times 10^{-18}$).

There was no significant difference between sheep and goats, and between goat and camels. Exponentiation of the differences in the logs of mortality counts show that cattle suffered 4.1, 2.9 and 2.5 times more deaths than camels, goats and sheep, respectively.

Table 4.4 Relative vulnerability of livestock species to climate variability: the case of 2010/2011 drought

Species	Exposure N (Mean±SD)[1]	Death N (Mean±SD)[2]	Mortality rate (%)	Regression estimates[3]
Cattle	242 (30.9±25.9)	193 (8.0±8.3)	26.4	-1.332[a]
Sheep	207 (14.1±10.9)	68 (1.5±3.1)	10.5	-2.254[b]
Goat	229 (22.4±22.1)	76 (2.0±4.0)	9.1	-2.398b[c]
Camel	97 (6.3±6.0)	17 (0.5±1.3)	6.5	-2.738 [c]

N: number of herds, [1]mean number of animals per herd exposed to drought, [2]mean number of animals died per exposed herd, SD: standard deviation of respective means, [3]least square means of estimates, [abc] estimates with a common superscript in a column do not differ significantly (α=0.05). Model fitness is acceptable with scaled deviance=729.3, df=771, value/df=0.946 and dispersion=1.7 i.e. the data are not much over dispersed.

4.3.6 Factors influencing livestock species diversification

Table 5 shows household level livestock diversification and its determinants. Family size and cattle per head had significant effects on multispecies herding. Both variables also significantly influenced adoption of camel husbandry, with the likelihood of adoptions increasing by 1.2 and 1.4 times per unit increase in per capita cattle holding and family size, respectively. Although, the average number of species kept in the two districts was rather similar, the proportion of households keeping camel was 19% higher in Yabelo than in Dire. The difference in camel holdings between the two districts was marginal (p=0.063) with Yabelo having 1.8 times greater odds of camel ownership compared to Dire. The variables off-farm income, farmland size and age of respondents did not show a significant influence on adoption of species diversification and camel husbandry.

Table 4.5 Factors influencing livestock species diversification and adoption of camel husbandry

Variables and their levels	Livestock species diversification (%)[a]					Adoption of camels
	One	Two	Three	Four	Coefficient	Coefficient [b]
Overall diversity	3.3	9.1	52.1	35.5	na	na
Camel in herds	0	2.1	9.3	88.7	na	na
District						
Yabelo	4.7	9.3	44.2	41.9	-0.064	0.576
Dire	1.8	8.8	61.1	28.3		
Family size						
average	8.6	8.1	9.2	11.5	0.053*	0.147*
Age of head hh (year)						
< 55	0.8	10.8	54.2	34.2		
≥ 55	5.7	7.4	50.0	36.9	-0.169	0.016
Cattle per capita						
average	1.2	1.2	1.8	2.6	0.100*	0.288*
Off-farm income						
no	2.9	8.7	52.9	35.5		
yes	4.3	10.0	50.0	35.7	-0.111	-0.125
Farmland size						
≤ 0.5 hectare	4.5	8.9	55.4	31.2		
> 0.5 hectare	1.2	9.4	45.9	43.5	-0.118	-0.295
Fitness statistics					0.47[c]	1.01[d]*

Regression coefficients with asterisks are statistically significant (* p<0.05), na: not applicable, [a] values are percent of respondents for categorical variables, whereas average for continues variables, [b] Regression coefficient is significant (* p<0.05), hh: household [c, d] the ratio of the generalized Pearson's χ^2 statistic to its degrees of freedom is acceptable i.e. close to 1, indicating the variability in the data has been fairly modeled and no much residual under or over dispersion

4.4 Discussion

This study mainly assesses the relative functions, adaptability and vulnerability of the four livestock species, and factors influencing household level species diversity. Similar to Oba and Tache (2010), we found that a high proportion of households in Borana are increasingly involved in both, livestock production and crop cultivation. The apparently higher proportion of households cultivating crops in Yabelo (99%) than in Dire (81%) may suggest slight differences in environmental suitability for crop and livestock production. Wet bottomlands and less variable precipitation in Yabelo may better suit for agro-pastoralism. Dire, by contrast, has plain landscapes and permanent water supply from "*Tula*" wells and is thus more suitable for livestock than crop cultivation (Coppock 1994; Oba 2000). Compared to Yabelo, more respondents in Dire had off-farm income sources due to the fact that Dire was severely affected by the 2010-2011 drought, compelling the herders there to seek for alternative livelihood sources (Megersa et al. 2014a). Still, livelihood opportunities are generally too few to absorb unskilled surplus labor in both districts, accounting for the lower labor migration from the area (Tache and Oba 2010) compared to northern Kenya (Doti 2010).

The dominance of the livestock species by cattle points to the traditional cattle pastoralism of the survey households (Cossins and Upton 1987; Coppock 1994). The higher proportion of households keeping the highland zebu cattle genetic resources in Yabelo than in Dire suggests the effect of geographical proximity to Guji area that facilitates the introduction of this breed (Homann et al. 2008). Apart from their low feed requirements, the highland zebu cattle do not seem to have other clear advantages which could motivate herders to prefer them to the Borana cattle. Desta et al. (2011) noted that farmers in south-western Ethiopia showed a higher preference for the local zebu than for the Sheko breed due to the lower feed requirement of the zebu despite Sheko's outperforming potentials. This emphasizes the importance of paying close attention to the advantages herders consider in deciding whether to keep specific breeds or species. In our study, however, the lower milk productivity and market value were reported as major shortcomings of the highland zebu. It has also been reported that under favorable rangeland conditions, the Borana herders prefer their original cattle over the highland breed (Homann et al. 2008; Zander 2011). Thus, there is no evidence for a general switch to this breed as an adaptation strategy to environmental changes. Recurrent droughts rather depleted the preferred Borana cattle population and forced the herders to restock their herds with the highland zebu, which were available in the local markets at relatively low prices (Zander 2011).

The observed proportion of households keeping different livestock species in the present study and the increasing trend over time is consistent with the findings of other studies in Borana. For instance, in a study by Solomon et al. (2007), all of their surveyed households owned cattle, 89.8% goats, 64.1% sheep and 46.2% camels. Zander (2011) reported all respondents to keep cattle, 57% sheep, 73% goats and 32% camels, while Homann et al. (2008) reported that 34% of the investigated households kept camels along with cattle. Environmental changes are likely to drive selection of animal species that are better able to adapt to the changing conditions and thus may alter household level species composition. The higher susceptibility of cattle to climate risks (Seo et al. 2010; Lesnoff et al. 2012; Lunde and Lindtjørn 2013) appeared to force herders to switch to more tolerant species such as camels (Faye et al. 2012). Thus, the observed shifts from cattle to camels in Borana, cattle to sheep in Latin America (Seo et al. 2010), cattle to goats (Seo et al. 2009) or cattle to camels in Africa (Faye et al. 2012) reflects the greater vulnerability of cattle herds and responses of herders to environmental changes. Adoption of camel husbandry showed a steep increase between 1990 and 2011, similar to the observation made by Homann et al. (2008). This could be linked to increased cattle vulnerability to climate variability (Angassa and Oba 2013) and a shift of rangeland herbaceous biomass to woody vegetation (Solomon et al. 2007).

While the involvement in camel production is increasing, inadequate knowledge of camel husbandry, financial shortages and other restraining factors were found to limit its adoption. High stocking costs generally hinder poor households from taking up camel production similar to the reason reported for not keeping cattle breeds with higher productive values in Kenya (Mwacharo and Drucker 2005). Camel production is a new business among the Borana herders and not yet as well embedded into their traditional husbandry practices as cattle, which could have implications on health status and performances of their herds (Homann et al. 2008; Megersa et al. 2008). Insufficient herding experiences have been associated with higher mortality rate and lower milk off-take in Borana camels than Gabra and Somali herds (Megersa et al. 2008). Therefore, a transfer of skills and knowledge from experienced camel herding neighbors, such as the Gabra, and the provision of adequate animal health services would be helpful in improving camel husbandry in the area.

Livestock diversification among the Borana herders connotes the adaptation measures to changing climatic and rangeland conditions, and thus represents a plausible compromise. Species heterogeneity may provide herders with the opportunity to utilize different vegetation resources, the ability to hedge against risks in addition to multiple functions (Doti 2010). Camels can reach the highest strata of plants and browse on a broad spectrum of vegetation, including thorny bushes, halophytes and aromatic species, which are often avoided by other livestock (Dereje and Uden 2005). Goats are able to forage in bipedal stance or climb a tree, thereby browsing the nutritious part of the plants such as fresh leaves and pods (Sanon et al. 2007). Small ruminants generally feed on leafy and brushy plants as well as shrubs that are invading the grasslands, which are either not palatable or noxious to cattle. Thus, they contribute to improved rangeland productivity and ecological stability (Rutter 2010). Additional economic benefits can also be derived from their difference in reproduction and price cycles which may offset the ups and downs of the other species' price cycles (Bleich et al. 2005; Doti 2010).

The production objectives stated by the respondents showed the multi-functionalities that livestock fulfill under extensive production conditions (Barrett 1992; Duguma et al. 2011; Ilatsia et al. 2012). The highest ranks given for milk production for camels and cattle, and second best for goats, reflect the essential role of milk as a favorite staple food in the diet of the people. This is in line with reports from elsewhere e.g. keeping cattle in Kenya (Mwacharo and Drucker 2005; Ilatsia et al. 2012), goats in Jordan (Tabbaa and Al-Atiyat 2009), and camels in eastern Ethiopia (Mehari et al. 2007). Milk production was ranked lowest for sheep as the Boranas rarely consume sheep milk (Cossins and Upton 1987). A study by Duguma et al. (2011) also showed that sheep milk is not utilized by communities in the mixed production system, while it was given the highest rank by Afar pastoralists in Ethiopia. Thus, values attached to different utilities for keeping an animal species vary considerably across cultures, agro-ecological zones and production systems (Desta et al. 2011; Duguma et al. 2011; Zaibet et al. 2011; Ilatsia et al. 2012; Ejlertsen et al. 2013).

The overall highest values attached to milk production and sales of live animals reflect the main feature of subsistence oriented production systems. In the pastoral production, supply of sufficient food for the family outweighs the production objectives of herders, while surplus animals are sold to fulfill the top necessities of households (Ilatsia et al. 2012). Pastoralists make varying degrees of decision on livestock marketing in order to satisfy their priority needs. Small ruminants, being highly prolific and able to quickly reach marketable size, are easily sold to meet small and immediate financial needs. Large animals such as cattle and camels are sold to fulfill large financial demands (Doti 2010). Hence, sheep and goats play a vital role in meeting various financial needs and reducing the pressure on cattle and camels. Small ruminants are therefore regarded as “guards” of the large stocks that prevent their depletion through off-take.

Although, livestock provide a wide range of socio-cultural functions, depending on cultures and species of animals, the economic valuation is rather difficult and values are often underestimated (Dovie et al. 2006; Swanepoel et al. 2010). Cattle and sheep play vital roles in the fulfillment of a set of socio-cultural practices of the community. In particular, cattle have historically been of the highest symbolic, social and economic value among the Borana, who consider cattle a heritage from their ancestors, while other animal species were acquired in due course. Cattle have plentiful functions including payment of dowry, symbolic gift, sacrifice for communal feasts and social obligations similar to reports elsewhere (Barrett 1992; Huyen et al. 2010). Considering the high values attached to cattle, Cossins and Upton (1987) have noted the existence of a limited possibility for diversifying into other livestock species.

Although camels have less value in the Borana culture (Homann et al. 2008) unlike for the Gabra and Somali pastoralists (Guliye et al. 2007), they are now regarded as vital animals for milk production and in improving household food security (Megersa et al. 2014b). Camels provide herders with routine transportation services such as water collection, carrying commodities between market destinations and home base, and transportation of household items during seasonal movements (Guliye et al. 2007; Mehari et al. 2007). Homann et al. (2008) suggested that the presence of camels enhances herd mobility and improves pastoral productivity. Camel meat is least preferred in the study area and slaughtering camel is not often by necessity even during festivity, except for emergency cases. Instead, small ruminants contribute significantly to the supply of meat for family and honored visitors (Doti 2010). In contrast to a mixed farming system elsewhere (Barrett 1992; Huyen et al. 2010; Swanepoel et al. 2010), the use of manure was found to be negligible in the area, even as fire fuel or in improving soil fertility. A heap of cattle manure near a house, however, may serve as sign of livestock wealth.

The adaptability and vulnerability evaluations of the four major livestock species have distinguished the extent of their relative fitness and adaptive capacity similar to observations made elsewhere (Oseni and Bebe 2010; Nkedianye et al. 2011; Catley et al. 2013). A comparative study (Catley et al. 2013) on drought related livestock mortality in pastoral areas of Ethiopia showed a higher mortality in cattle (2.2–34.9%) compared to small ruminants (6.5–23.3%) and camels (0–20.3%). Local species and breeds are generally believed to have evolved for centuries in their current eco-zones, and have subsequently developed a wide range of unique adaptive traits that enable them to perform under the prevailing environmental conditions (Hoffmann 2010; Mirkena et al. 2010). In particular, pastoral livestock are kept under harsh environments and are adapted to extreme climatic conditions, seasonal feed and water scarcities, poor nutritional quality, and high disease challenges (FAO 2008). Although indigenous animals are part and parcel of their ecosystem and are adapted to an array of stressful conditions, large genetic differences in terms of fitness and adaptation exist among animal species (Mirkena et al. 2010). The ability to adapt to and thrive in an extreme condition, which depends on complex interactions among anatomical, physiological and behavioral factors, provides an animal species a competitive advantage in the face of environmental changes (Hoffmann 2010; Mirkena et al. 2010). The variance in fitness offers an opportunity to select an animal species that fits well to the underlying condition and enhance the adaptability of livestock to environmental changes (Hoffmann 2010).

There exists dearth of literature comparing the adaptability of local animals sharing the same eco-zone, and available studies are mainly focusing on comparisons between local and exotic breeds (FAO 2008; Hoffmann 2010; McManus et al. 2009). Oseni and Bebe (2010) assessed the adaptability of livestock species regarding six climate change driven scenarios, and found camels to have the highest adaptability, while sheep and cattle had the lowest.

Tolerance to heat stress differs considerably among livestock species, with ruminants outperforming monogastrics (Renaudeau et al. 2012) while camels surpass other ruminants (Ouajd and Kamel 2009). Cattle appear to be highly vulnerable to climate change scenarios (Seo et al. 2010). For instance, thermal stresses impair the health and metabolic activities of the animals and heighten their water requirements (Nardone et al. 2010). Heat stresses also decrease the foraging time and distance covered by animals because distressed animals are likely to spend much of their time in the shades. The higher vulnerability of cattle to climate variability stems from their reliance on herbaceous pasture and frequent water intake (Hoffmann 2010; Lesnoff et al. 2012). Their shorter watering interval, 2-3 days compared to 4-5 days in small ruminants and 15 day in camels (Tolera and Abebe 2007), has negative effects on foraging distance, mobility and access to patchy vegetation away from water points. Animals with reduced water consumption can decrease their metabolic activities and feed intake, so that they can manage to survive feed scarcity (Mirkena et al. 2010). Camels tolerate dehydration and heat stress through their unique biological and behavioral characteristics, and their economical water utilization (Ouajd and Kamel 2009). Being browsers, camels and goats can cope with feed shortage better than grazers, and are able to survive drought periods.

As for adoption of other agricultural practices or technologies (Yengoh et al. 2009), livestock diversification also depend on demographic characteristics, socio-economic factors, the benefits and costs (inputs) of adoption. In light of this, significant effects of family and herd sizes on livestock diversification and camel ownership underline the importance of labor and financial inputs. In pastoral systems, the number of livestock and herding labor are two key variables that are strongly interrelated (Blench 2001). As herds grow, in size and composition, the labor inputs for their management increase. Hence, labor availability determines the number of animals to be kept by each household (Yi et al. 2008). In cases where herds grow beyond a size that can be managed by family labor, either herding service is outsourced or animals are temporarly distributed to poor households (Blench 2001). According to Næss (2010) livestock diversification and herd mobility are dependent on availability of large labor forces. Thus, family size, being the major labor pool, positively influences adoption of livestock diversification. For the Rendille camel pastoralists, however, wealth in livestock was found to have a stronger correlation with cattle keeping than labor supply (Næss 2010). Diversifying into herd composition, particularly camels, requires high financial input that most likely comes from cattle sales, explaining the relationship between cattle holdings and species diversity.

Marginal differences in camel keeping between Yabelo and Dire could be linked to differences in landscape suitability and vegetation type as camels prefer bushy landscapes, while heterogeneous vegetation mosaics suit small ruminant production (Oba 2000). Larger areas covered by grass in Dire reflect its better suitability for grazers (Oba 2000). Proximity to camel rearing ethnic groups (Gabra occupying northern part of Yabelo) and other factors such as religion may also play a considerable role in facilitating the adoption of camel husbandry (Coppock 1994).

4.5 Conclusions

The study showed that climatic factors and rangeland ecosystem changes were the major drivers of livestock diversification, while inadequate knowledge of camel husbandry and financial resources were identified as constraining factors. Different livestock species are kept to fulfill the livelihood priorities with subsistence objectives surpassing other production goals of the herders. Adaptability comparisons of the livestock species showed that camels had the highest level of adaptive capacity, followed by goats, while cattle and sheep were found to be the least adaptable species. Species vulnerability to drought also substantiated the adaptability rankings with cattle being the most vulnerable to drought followed by sheep, while camels were the most tolerant species. Livestock diversification varied significantly with family size and per capita holdings of cattle, pointing to the importance of labor and economic factors on adoption decisions. Multispecies herding would therefore seem a recommendable local adaptation strategy, which improves resilience to climate and rangeland cover changes through enhancing the adaptive capacity of existing practices.

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5 General discussion

5.1 Impacts of climate change on livestock production, and adaptability of livestock species

5.1.1 Trends in climate change and variability over the East African region

Previous climate predictions, which regarded the East African precipitation to be relatively in a stable regime with a long-term wetting (IPCC 2007), are in contradictions with the observations of this study (Chapter 2). Other findings also convincingly showed that the region is receiving less precipitation as climate change increases the sea surface temperature in the Indian Ocean (Funk and Verdin 2010; Williams and Funk 2010; Williams and Funk 2011). In line with this, the present study also showed a declining trend in rainfall in the study area (Section 2.3.4). The East African climate is regarded as one of the most complex (Omondi et al. 2012). The Inter-Tropical Convergence Zone that drives the bimodal rainfall pattern during its seasonal North-South movements (Ellis and Galvin 1994) is highly susceptible to the atmospheric and oceanic factors such as rising sea surface temperatures and the El Niño-Southern Oscillation (Omondi et al. 2012). This subsequently, affects the onset and cessation of the regional rainfall. More importantly, climate change likely exerts perturbation and amplifies the variability of the regional climate through progressive warming of ocean surface temperatures (IPCC 2007), thereby altering regional atmospheric circulations. Williams and Funk (2011) have ascribed a westward extension of the Walker circulation to rising of the Indian Ocean temperatures. Consequently dry air is being carried over East Africa and resulted in less precipitation. Several other studies showed that declining trends in rainfall, particularly in the major rainy seasons, have substantiated the existence of a strong link between a downward trend in precipitation and climate change in the region (Funk and Verdin 2010; Williams and Funk 2010; Rao et al. 2011; Omondi et al. 2012). Evidence for declining rainfall has been also documented for Ethiopia (Cheung et al. 2008; Viste et al. 2013). In particular, a considerable decrease in the long rains (March to May) between 1971 and 2010 was observed in the southern part of the country (Viste et al. 2013).

In addition to the decline in precipitation, drought frequencies have apparently also increased over time, occuring every four to six years (Figure 2.3). An earlier study similarly suggested the occurrence of vicious drought cycles once in every five to six years (Desta and Coppock 2002). As climate change advances, the frequency and intensity of droughts likely increase, posing challenges to pastoral livestock production (Thornton et al. 2009). The enormous livestock losses incurred during the recurrent droughts presents one of the most serious threats to pastoral livestock keepers in East Africa (Desta and Coppock 2002; Speranza 2010; Silvestri et al. 2012; Catley et al. 2013).

In contrast to the trends in rainfall, only minimal changes in temperature were observed, with a slight increase in the maximum daily temperature. But the minimum temperature was fluctuating without showing any clear trend (Section 2.3.2). Most of the studies conducted in Africa also give more emphasis to the trend and variability in precipitation (Funk and Verdin 2010; Williams and Funk 2010; Williams and Funk 2011; Omondi et al. 2012; Viste et al. 2013; Williams et al. 2012) compared to changes in temperature (Collins 2011). This could be due to the fact that changes so far observed in precipitation and its interannual variability were higher than those in temperature and thus more detrimental to the livelihoods dependent on rain-fed agriculture (Kotir 2011; Kassie et al. 2013). As temperatures only gradually increase at regional or global level showing less variability compared to rainfall, the negative effects on local herds may not be easily identifiable on basis of survey data and records of a focal area. In general, the study showed that the declining trends in precipitation and increasing drought recurrences were more evident than changes in temperature.

5.1.2 Adverse effects of climate change and its variability on livestock production

Climate change and variability pose numerous adverse effects on animals, both directly and indirectly. The direct impacts are related to the morbidity and mortality of animals caused by thermal stresses and extreme weather events. In arid and semi-arid environments, where high ambient temperatures prevail and the provision of artificial shade or alternative means of cooling are not feasible, a higher severity of solar radiation and thermal stresses on grazing animals can be anticipated (Nardone et al. 2010). The adversity of prolonged exposure to thermal stresses can be further worsened by the dry period's water shortage and low forage water content, as well as poor feed quality that reduces feed intake and increases fermentative heat (Nardone et al. 2010). Although the heat stress-induced impairments on feed intake, metabolic activity, immune system, growth, and reproduction and production performances of animals are indisputable, the measurement of such effects is practically difficult in extensive production systems (Thornton et al. 2009). In the present study, increased ambient temperatures were reported by most of the survey respondents (Table 2.1), but this perception was not well supported by the time series temperature data (Figure 2.1). Such differences between perceived and actual trends in some climate variables were also observed in Kenya (Rao et al. 2011). Discriminating the negative effects of increased temperatures on the wellbeing and performance of livestock is beyond the scope of the present survey results and needs a controlled investigation.

The indirect effects of climate change, through lowering feed and water availability especially due to droughts, appear to be currently more devastating to pastoral herds compared to the direct impacts. Although drought is one of the common risks with which pastoralists have a great deal of experience, its frequency and intensity in the course of climate change are increasing (IPCC 2007). The herder's perception (Table 2.1), patterns in precipitation anomalies (Figure 2.4) and the spectral analysis of the annual rainfall data (Figure 2.6) also suggest shortening intervals between droughts in the Borana area. Consequently, a downward trend in cattle holdings observed in this study reflects the effects of the underlying rainfall variability (Section 2.3.4). Recurrent droughts were evidenced to be the most harmful on pastoral livestock in Borana area (Section 2.3.3). Other reports also underline the detrimental effects of droughts on assets of pastoralists in Ethiopia (Desta and Coppock 2002; Angassa and Oba 2007; Catley et al. 2013), Kenya (Blackwell 2010; Speranza 2010; Nkedianye et al. 2011) and Tanzania (Galvin et al. 2004), while severe winters were shown to be equally harmful to pastoral herds in Mongolia (Begzsuren et al. 2004).

The 2010-2011 drought (Section 2.3.3) has caused a substantial decline of cattle herd sizes (45%) due to mortalities (26%) and desperate off-takes (19%). Similar reductions in cattle herds of this magnitude in the study area had been recorded in previous droughts (Cossins and Upton 1988; Angassa and Oba 2007; Tache 2008). A significantly higher mortality rate in Dire than Yabelo district corresponds to a lower precipitation in the latter district. As opposed to this observation, Nkedianye et al. (2011) reported a higher death rate from a region which had a relatively higher precipitation than its counterpart in Kenya and attributed this to higher stocking densities and a less drought tolerant cattle breed. Their analysis was based on annual rainfall anomalies which may not show the seasonal patterns of precipitation. Given the erratic nature of rainfall in arid regions in which a large share of the annual total can be received in a few days and lost rapidly through run-off and evaporation, seasonal amount and distribution is much more suggestive of rainfall deficits than the annual total (Ellis and Galvin 1994). The present study (Section 2.3.4) showed that total annual rainfall is not a good indicator compared to the seasonal distribution pattern in identifying deficits in precipitation that resulted from distribution failure. Hence, paying attention to the seasonal distribution of rainfall, especially in areas receiving bimodal rains, is vitally important in relating deficits to their negative effects.

Drought-related mortalities were higher among calves and breeding females compared to mature male animals (Section 2.3.3), thus altering herd structure and leading to slow rates of recovery (Cossins and Upton 1988; Oba 2001). The observed high proportions of mortalities among breeding females (46.1%), young animals (23.4%) and calves (21.7%) negatively affect calving rate and herd growth. Given the slow recovery time of cattle herds (10 to 15 years) after severe droughts (Cossins and Upton 1988), which is often further interrupted by new shocks, it is unlikely for most herds to resume to their pre-drought sizes. As climate risks become more frequent and severe, cattle herds lurch from one disaster to the next without any revival. According to Lesnoff et al. (2012), 20% of the herds failed to recover after a severe drought (75% herd reduction), while others were found to recover after 35 years when moderate calving and off-take rates were considered. The results of the present study (Section 2.3.4) also indicated a downward trend in cattle holdings over the last three to four decades, suggesting an increasing challenge for the sustainability of cattle pastoralism in Borana.

In addition to recurrent droughts, respondents have cited that bush encroachment is another challenge to cattle production in the study area (Section 4.3.2). An increasing vegetation shift, from grassland to bushland, has been previously reported in the study area (Solomon et al. 2007). A rise in atmospheric CO_2 concentration favors the dominance of C_3 woody plants over C_4 grass species due to a higher net photosynthesis in C_3 plants (Ward 2010). Extreme climatic events and stressful conditions may unevenly affect plant communities, disfavoring the herbaceous biomass, while facilitating the invasion of vigorous woody plants (Hiernaux et al. 2009). Decreasing precipitation negatively affects nitrogen cycle and reduces the amount of nitrogen available for plant uptake (Beier et al. 2008), which lowers the growth and nutritional quality of plants. Consequently, low levels of plant nitrogen content together with reduced levels of fermentable energy contents of forages indeed impair the rumen microbial population and their protein synthesis (Calsamiglia et al. 2010) thereby hampering the production and reproduction performances of ruminant animals such as cattle. Thus, climate change reduces the herbaceous biomass production and carrying capacity of rangelands (Morton 2007; Thornton et al. 2007), as well as the nutritional quality of pastures (Craine et al. 2010). This is consistent with the views expressed by the respondents of this study, who stated that climate variability and bush encroachment are among the challenges to cattle production in the Borana region (Section 4.3.2). The lower the feed availability and the nutritional quality of pastures the higher the impact on the productivity and health status of livestock (Thornton et al. 2009; Nardone et al. 2010). When animals suffer from nutritional stresses and energy deficits, they subsequently become vulnerable to extreme weather conditions.

5.1.3 Climate related vulnerability and adaptability difference among livestock species

The present study showed a significant difference among the four considered livestock species in their adaptability (Section 4.3.4) and vulnerability to climate risks (Section 4.3.5). Cattle were found to be the most vulnerable species to drought followed by sheep, while camels were relatively tolerant to climate challenges. A comparative study by Catley et al. (2013) on drought-related mortalities in Ethiopia showed higher mortalities in cattle (2.2–34.9%) than in small ruminants (6.5–23.3%) and camels (0–20.3%). Nkedianye et al. (2011) also reported apparently higher death rates among cattle (13–45%) compared to goats (22–35%) in Kenya. Similarly, relatively higher mortalities were also recorded in cattle (19%) compared to sheep (15%) and goats (13%) in Kenya (Homewood and Lewis 1987). The higher susceptibility of cattle to drought-induced starvation and dehydration is attributable to their dependence on herbaceous pastures and frequent water intake (Hoffmann 2010; Lesnoff et al. 2012). The short watering interval of cattle (Tolera and Abebe 2007) may also have impacts on their mobility and foraging distance away from water points. The vulnerability of cattle increases as climate gets drier and warmer (Seo et al. 2010; Lunde and Lindtjørn 2013).

Dromedary camels tolerate feed shortages, dehydration and heat stress (Section 4.3.4) due to their unique biological and behavioral characteristics, as well as their economical use of water (Bornstein 1990; Ouajd and Kamel 2009). According to Bornstein (1990), the capability of camels to withstand extreme environmental stresses is mainly on account of their resource use efficiency. They manage to survive dehydration by reducing water losses through feces, urine, respiration and skin evaporation (Bornstein 1990). Reduced water consumption decreases the metabolic activities and feed intake of animals such as camels, thus contributing to their drought tolerance (Mirkena et al. 2010). Being browsers, camels and goats can cope with feed shortages better than cattle, and manage to survive drought periods. They generally forage on a wide range of vegetation types, which are not utilized by cattle (Dereje and Uden 2005). Their long distance walking ability along with less frequent water consumption enables them to get access to distant vegetation (Table 4.3). During adequate feed availability, camels may store fat in their humps as a reserve energy supply that can be mobilized to buffer feed scarcity and to ensure survival of the animals during drought periods.

Sheep and goats are generally between cattle and camels in their ability to withstand drought-related starvation and dehydration (Section 4.3.4). Being small in body size and opportunistic in their feeding behavior, small ruminants easily meet their minimum feed requirements. They can feed on shrubs and invasive weeds, which are often avoided by cattle, and can thus better manage to survive periods of scarcity compared to cattle (Rutter 2010). Especially, goats can feed leaves and pods at higher foraging reach than cattle and sheep due to their bipedal standing and climbing abilities (Sanon et al. 2007). Contrary to the results of this study (Section 4.3.4), Oseni and Bebe (2010) reported equal vulnerability of sheep and cattle to feed and water scarcity. In general, this study showed that livestock species vary in their adaptation (Section 4.3.4) and vulnerability (Section 4.3.5) to climatic risks. Such differences among species in their adaptability may enhance the resilience to climate change and household food security (Hoffmann 2010; Mirkena et al. 2010).

5.2 Impacts of climate change on household food security among livestock keepers

Complex interactions of agro-ecological, socio-economic and biological factors may affect the stability of the three pillars of food security (availability, access and utilization) in a given region (Gregory et al. 2005; Pinstrup-Andersen 2009; Barrett 2010). Of the many factors, rainfall volatility and failures have been evident to threaten the livelihoods and food security of livestock keepers in East Africa (Galvin et al. 2004; Devereux 2009; Speranza 2010; Nkedianye et al. 2011). This study revealed that climate risks related livestock mortalities and declining herd productivity (Chapter 2) have aggravated household food insecurity (Chapter 3). As a result, a higher proportion of households had either subnormal consumption or has skipped one or more meal occasions (Section 3. 3.2). A decline in milk production and consumption has also been mentioned by herders (Table 3.1), which may result in food and nutrition insecurity, and deter the nutritional wellbeing of the people, particularly children (Fratkin et al. 2004). This condition appeared to be more severe in households, who are mainly keeping cattle and having less species diversity compared to their counterparts (Chapter 3).

Drought occurrence had impacts on food security in the study area through direct effects on livestock mortality and dropping production (Chapter 2), as well as dwindling herders' capacity for food access (Chapter 3). In pastoral regions, climate related food insecurity occurs as a downward pattern of availability and access to food (Devereux 2009). The short supply of own sources coincides with depletion of household purchasing power because of unfavorable terms of trade between livestock and food cereals. In times of drought, livestock off-take is primarily increased to meet the households' food requirements and secondly to minimize animal losses due to mortality (Desta and Coppock 2002; Berhanu and Fayissa 2010). Higher cattle off-take rates (18.9%) observed in this study, well above the average rate of 10% for a non-drought period (Berhanu and Fayissa 2010) also suggested escalating sales with drought (Chapter 2). On one hand, increased off-take positively affects food security, through improving the purchasing power and access to food. On the other hand, excess off-takes of animals that are in poor body condition saturate the market and lead to substantially dropping the prices. Herders trek long distances to the local markets with their weak animals. As markets are flooded with desperate sales, the weak animals are disposed at disadvantageous prices offered by buyers because herders are in urgent need of food and animals are too weak to come back to their villages. Furthermore, climate variability having negative impacts on crop yields increases the demand for staple cereals and escalates the costs of food grain, thereby diminishing the purchasing power of livestock keepers.

Pastoralists are often exposed to humanitarian crises owing to their unpredictable exposure to a multitude of risks such as climate shocks, disease episodes, resource conflicts, livestock raiding and market failures (Devereux 2006; Morton, 2007). According to Devereux (2006), recurrent droughts, land dispute conflicts and livestock market failures are the major sources of livelihood vulnerability among Ethiopian pastoralists. Resource conflicts are evidently induced by the effects of climate change and resource asymmetries, and further fueled by inappropriate resource rights protection and bad governance (Devereux 2006; Butler and Gates 2012). The fragmentation of natural resources into divergent uses e.g. grazing and cropping, reduces dry season grazing areas, and impairs pastoral ways of risk avoidance through herd mobility. This study indicated that delayed herd mobility, partly due to shrinkage of the dry season grazing areas, had contributed to increased livestock mortality during the 2010/2011 drought (Chapter 2).

Another source of pastoralists' vulnerability arises from their being victims of marginalization, exclusion, and misconceptions by the highlander policy making elites, who view pastoralism as a backward and unproductive way of life fated to extinction (Tache 2008; Berhanu and Fayissa 2010; Behnke and Kerven 2013). Although the present regional administration system, where the governance of pastoral areas is being handled by personnel of pastoral origin appears to be better than before, the dominance of other decision makers is still inevitable. Consequently, the prevalence of low levels of access to health services, education, infrastructure development and access to potable water add to food insecurity and vulnerability of pastoralists. Alternative livelihood sources other than pastoralism and crop cultivation are generally scarce, which otherwise could buffer seasonal food shortages. This study found that households with off-farm incomes were relatively better-off in terms of smoothing consumption (Chapter 3). Policy makers in Ethiopia often view pastoral territories as vast land without credible production and annex grazing areas for crop cultivation and large-scale irrigation projects. Unfortunately, these development options did not result in economic and environmental profitability over pastoralism (Behnke and Kerven 2013). It rather emerges as a barrier to livestock mobility, heightening vulnerability to climate risks and livelihood insecurities.

In pastoral areas, there exist different degrees of susceptibility to food insecurity due to pronounced gender asymmetries in intra-household allocation of food and access to health care, which usually favor male individuals over females (Devereux 2006). The present study also recorded a significantly lower dietary diversity among females compared to their male peers (Section 3.3.4). Conversely, Villa et al. (2011) reported a gender reverse scenario from the same study area, while comparing sons and daughters for dietary intake. The authors ascribed their results to the involvement of young men in herding livestock at distant pastures, where food diversity is limited. In a nutshell, vulnerability to food insecurity among livestock keepers has roots in economic marginalization in terms of market and infrastructure under development, socio-economic variables and gender dimensions, and is further exacerbated by climate shocks and market failures (Devereux 2009).

5.3 Adaptation strategies

5.3.1 Adaptation strategies of herders to climate change and its variability

Before discussing herders' adaptation strategies to climate change, it is helpful to give the contextual meaning of adaptation. Adaptation refers to the adjustments made in ecological, social, and economic systems in response to the imposed environmental conditions or challenges such as climate change (Nelson et al. 2007; Stringer et al. 2009). Adaptation is thus "the decision-making process and the set of actions undertaken to maintain the capacity to deal with current or future predicted change" (Nelson et al. 2007). Accordingly, livestock keepers have been carrying out a set of actions and adjustments in response to environmental changes, so that they can manage to minimize their vulnerability to challenges. Pastoralists live in fragile and harsh environments with unpredictable climatic conditions. Hence, they have adapted to environmental changes by their traditional strategies including mobility, herd splitting, increasing herd size and species composition, using traditional safety net system and engaging in other livelihood alternatives (Galvin 2009; Doti 2010). Especially, herd movement has been used for centuries as a flexible way of adaptation and risk reduction strategies (Oba 2012). Narratives of pastoralists' adaptation strategies emphasize the utmost importance of mobility in dealing with ecological sustainability, natural resource scarcity and spatiotemporal vegetation heterogeneity in addition to its role in minimizing risks (Galvin 2009; Oba 2012; Hurst et al. 2012; Krätli et al. 2013). As indicated in Chapter 2 of this thesis (Section 2.3.3), herd mobility has been considered to minimize the risks associated with the 2010/2011 droughts, although delays in taking measures have lowered the desired outcomes. It can be anticipated that herd movements out of the area could have reduced the extent of mortality losses, provided that herders were supported by weather forecast information and decisions were made in time. Mobility encompasses the socio-cultural (social organization, scouting, negotiation) and ecological (identification of ecological indicators and species-specific landscape) dynamics of pastoralism (Oba 2012). According to Krätli et al. (2013), herd movements can be triggered by both, the scarcity and relative abundance of natural resources. The latter strategy intends to optimize the nutritional wellbeing of animals and enhance herd productivity by accessing pastures of high abundance and nutritional quality (Krätli et al. (2013). Livestock keepers commonly practice herd movements aiming to cope with resource scarcity and reduce risks related to drought and disease occurrences. This strategy enables herders to cope with environmental challenges and natural resource scarcity, and thus enhance adaptation to climate change. Although the economic rationality and ecological suitability of mobility is plainly discussed in literature, it is increasingly coming under pressure of constraining factors e.g. socio-economic transformations, population pressure, climate change, and fragmentation of grazing areas (Desta and Coppock 2004; Galvin 2009). Hence, other forms of adaptation strategies are necessary in order to sustain livestock production and the livelihood of livestock keepers in arid environments.

In response to environmental changes, livestock keepers are adjusting their herd composition or shifting from susceptible to more tolerant species. Correspondingly, Chapter 4 of this thesis analyzed the rationality of livestock diversification among the cattle herding community in southern Ethiopia. The results showed that increased drought recurrences and cattle herd variability, bush encroachments, and the growing interest in keeping tolerant animals were among the major driving factors for livestock species diversification. Different scholars have also demonstrated how climate change and variability alter livestock species composition at household level (Seo and Mendelsohn 2008; Seo et al. 2009; Faye et al. 2012). According to Seo and Mendelsohn (2008), farmers switched from beef cattle to sheep and goat as climate got warmer and further shifted to goats in drier environments. Similarly, shifting from cattle to sheep was also observed elsewhere in Latin America (Seo et al. 2010). A study by Faye et al. (2012) showed the adoption of camel production to be on the rise among the communities with cattle-based livelihoods elsewhere in Africa. Hence, livestock diversification is increasingly recognized in the literature as a potential adaptation strategy to climate change (Galvin et al. 2004; Speranza 2010).

This study has also demonstrated the potential role of feed supplementation during drought periods in reducing death occurrences among cattle herds (Chapter 2). Some of the surveyed households selectively supplemented their animals with grasses and branches collected from bushes, and managed to reduce death losses due to the drought (Section 2.3.3). However, significant differences were not observed regarding purchases of commercial feeds (such as hay, straw and concentrate), the measures taken during the drought phase, perhaps due to late interventions having been likely implemented by herders who had already lost some of their animals. Thus, implementing early warning systems, reservation of supplemental feed for periods of scarcity and strategic feeding (supplementing selected animals) are of paramount importance in minimizing vulnerability to droughts. Supplementary feeds may include timely hay making from areas inaccessible to livestock (hilly or bushy landscape), preservation of crop residues and purchase of commercial feeds. Traditional grazing enclosures *"Kallo"* reserved for calves, sick and lactating animals, are also one of the coping strategies practiced to alleviate feed shortage (Solomon et al. 2007). According to a report by the World Initiative for Sustainable Pastoralism (WISP 2010), pastoralists in the Logone floodplain in northern Cameroon deal with feed shortages by pursuing both, transhumance and intensive management. They feed some of their animals in their villages with cotton seed cakes, bran and sorghum stalks during the dry period and send them back to the mobile herds when feed is sufficiently available. In another study (Tegegne et al. 2011), agro-pastoralists in eastern Ethiopia produce fodder on privately owned enclosures, which is then used in a cut-and-carry feeding system or by free grazing. According to the same study, the agro-pastoralists also efficiently utilize crop residues such as sweet sorghum stover, fresh leaves, stalks, tassels, head covers, dry leaves and cobs for regular feeding and fattening.

The adaptation measures of herders can be strengthened through backing up the existing strategies (livestock diversification, herd mobility and animal feed reservations) with improved livelihood opportunities, better access to markets, banking and rural financial services. This would enhance local capacities to adapt to climate change and mitigate its impacts (Desta and Coppock 2004; Morton 2007; Porter 2012). Increasing diversity in livelihood sources minimizes the total investment costs and risks associated with a single venture, thus contributing to improved adaptive capacity of livestock keepers (Hurst et al. 2012). As also indicated in Chapter 3 of this thesis and other similar studies (McCabe et al. 2010; Tache and Oba 2010), opportunistic crop cultivation is one of the most common practices in which pastoralists increasingly get involved in order to mitigate climate-related food shortages. Crop farming improves food supply when rainfall is adequate and alleviates post drought food shortage once rain onsets (Desta and Coppock, 2004). After the crop is harvested its residue can be used as feed or animals can also feed whatever comes up in cases of crop failure (Hurst et al. 2012). However, the long-term impact of competition for land use and its being not well imbedded into the natural resource management traditions of the Borana people is yet unclear, calling for proper integration of cropping and pastoralism.

The present study showed that off-farm income sources (28%) have a positive effect on household food security (Section 3.3.3). Off-farm income sources are vitally important in offsetting the declining per capita livestock holdings in the area, but such opportunities are scarce for pastoralists of the country (Devereux 2006; Berhanu and Fayissa 2010; Tache and Oba 2010). If at all existing, some locally available ones such as small business activities are mostly in the hands of non-pastoral people (Hurst et al. 2012). Reports show that non-farm earnings account for 25% of the total household income in pastoral areas (Berhanu et al. 2007) and 20-30% for the mixed farming system (Porter 2012). Off-farm income sources were found to vary with household economic status. Poor households mainly engaged in activities with low return such as casual labor, charcoal and firewood selling, petty trading and livestock brokerage activity, while few well to do families had investment in house construction and renting out (Berhanu et al. 2007). Hence, options for integrating pastoralists into other economic activities and markets to enhance their resilience to climate change are limited

5.3.2 Livestock diversification as a plausible adaptation strategy to climate change

The present study showed that the convergence of climate change and its variability, and rangeland ecosystem changes have posed considerable pressure on cattle production (Chapter 2), resulting in livestock diversification (Chapter 4). Keeping multiple species might be intended to fulfill the broad perspectives of herders, which may include the optimization of economic benefits, hedging against risks, ensuring food security and ultimately enhancing resilience to climate change. Multispecies herding provides households with numerous complementing functions. The utility patterns of different animals showed a considerable difference among the species in the study area, suggesting the role of different species in fulfilling different priorities of a household (Section 4.3.3). For instance, cattle and camels contributed much to the food supply in addition to providing draught power. Due to their tolerance to drought-related water and feed shortages, animals like camels and goats sustain household food supply during extended dry spells and play a vital role in replacing cattle milk in the family's diet. As small ruminants are highly prolific and reach maturity at an early age (Doti 2010), they are easily slaughtered for home consumption or sold to meet immediate financial needs of a household (Section 4.3.3). Hence, small ruminants play a vital role in reducing the pressure on cattle and camels. Cattle and sheep are deeply entrenched in the culture and tradition of the Borana people, thus they remain important in executing various socio-cultural practices.

Diversity in livestock species is not only improving food supply, but also offering households with more ample choices for off-take, which can be liquidated in times of shortage to smoothen consumption. In the present study, increased off-take was found to improve food access, ultimately enabling to meet the food requirements of the households (Section 3.3.3). Complementary economic benefits could be gained from differences in reproduction and price cycles, which may offset the ups and downs of the other species' market value. Correspondingly, differences among species in their market values and vulnerability to risks have also been reported to improve the livelihood of poor farmers in Chad (Bleich et al. 2005). A camel fetches more than three to four times the price of equivalent cattle, with even higher differences during dry periods, and hence can feed a family for a prolonged period. But camels are often sold late, preferably at six years of age in order to get maximum returns (Hurst et al. 2012). Given their slow reproduction and late maturity, camels are generally not as efficient for off-take as they are for continous food supply, and small ruminants best offset this deficit of camels.

The present study showed that cattle had the highest resistance to tick infestation and tolerance to heavy rains (flooding), while sheep were ranked best for young survival rate (Section 4.3.4). The relative superiority in tick resistance may heavily depend on the breed in combination with the actual level of infestation. Oseni and Bebe (2010) noted that cattle had the ability to withstand heavy rains and flooding owing to their swimming ability, while other species were immobile and could be easily be wiped out by floods. Camels are widely recognized to be better in their tolerance to thermal stresses than other livestock species (e.g. Ouajd and Kamel 2009). Cattle appear to be highly susceptible to heat stress and drought-induced feed and water shortages (Seo et al. 2010; Nardone et al. 2010; Lesnoff et al. 2012). They have shorter watering intervals (2-3 days) compared to small ruminants, while camels can go without drinking for two to three weeks (Tolera and Abebe 2007). Being browsers, camels and goats can cope with feed shortages better than grazers and are able to survive extended drought periods. This study showed that species vulnerability to climate risks varied significantly (Section 4.3.5) and reflected their relative fitness and adaptive capacity to environmental changes similar to the observations made elsewhere (Oseni and Bebe 2010; Nkedianye et al. 2011; Catley et al. 2013). A similar study in Ethiopia (Catley et al. 2013) showed that cattle incurred apparently higher mortalities (2.2–34.9%) than small ruminants (6.5–23.3%) and camels (0–20.3%). Therefore, differences among species in their tolerance to climatic and disease risks enable livestock keepers to hedge against risks and ensure survival under looming climate change.

Mixed species composition provides herders with the opportunity to utilize different ecological niches (Oba 2000; Doti 2010). Differences between the species' plant preferences and foraging behavior enhance the optimum use of vegetation resources and reduce the competition among animals. Diversity in species composition thus contributes to increase the carrying capacity and productivity of rangelands. This ultimately improves the economic return per unit of grazing area. Camels have generally the highest foraging height and browse on a broad spectrum of vegetation types, including thorny bushes, halophytes and aromatic species, which are often avoided by other livestock species (Dereje and Uden 2005). Goats have the second highest foraging reach, owing to their bipedal stance and tree climbing abilities, so that they can browse the most nutritious parts of the plants, such as fresh leaves and pods (Sanon et al. 2007). Small ruminants generally feed on leafy and brushy plants as well as shrubs that are either not palatable or noxious to cattle, and may contribute to improved rangeland productivity and ecological stability (Rutter 2010). In conclusion, livestock diversification in southern Ethiopia spells out the measures taken in response to changing environmental conditions and household food security.

5.4 Methodological approach

This study provides a systematic analysis of climate change impacts on cattle pastoralism and household food security, as well as the role of livestock diversification as an adaptation strategy of the Borana herders. The study was based on both qualitative and quantitative data. Methods of data collection included a household survey, a dietary diversity survey, participatory group discussions and the use of meteorological time series data of the study area. Semi-structured interviews, preceded by participatory discussions, were used to collect data from pastoral households on topics covering socio-economic and demographic variables, livestock holdings, species composition, and household food security. The interviews also included perceptions of herders towards climate change, changing trends in livestock production and key rangeland resources (water and pasture). Detailed descriptions of the methods were elaborated in the individual chapters (papers) of this thesis. A brief overview of the strengths and limitations of each method are given in the following subchapters.

5.4.1 Sampling methods

Sampling of a study population in terms of sample size adequacy and representativeness is a general prerequisite for any quantitative study (Marshall 1996). Probability sampling techniques such as random sampling of survey respondents is the ideal way to secure representative samples and to avoid biases. However, various factors including lack of complete household lists for a sampling frame, location of a selected household (household head) in a mobile and sparsely settled community, and possibilities of randomly picking an individual that doesn’t fulfill the survey’s requirements generally makes a random sampling approach difficult to implement in pastoral contexts. Tache (2008) also noted that random sampling often picked young individuals, who are not eligible for capturing long-term events and reconstructing herd histories. Accordingly, this study followed a mix of convenience sampling and systematic random selection as pragmatic compromise. Two districts and six pastoral associations were selected purposively. Subsequently, a systematic random sampling at every fourth household was approached to sample households from the selected villages based on the sampling frame identified during site selection and the pre-test phase in August 2011.

5.4.2 Questionnaire survey and group discussion

Questionnaire surveys and group discussions are the most commonly employed methods of data collection in participatory research. Both have their strengths and limitations, the combination of which may compensate the disadvantage of one method and improve the quality and validity of the information generated. Both are useful to get complete responses on the research inquiries, and are useful to explore information in-depth and to resolve conflicting issues (Harrell and Bradley 2009). Questionnaire surveys can be administered either through face-to-face interviews, or by self-administration depending on costs, facilities, characteristics of the target respondents, depth and scope of the survey questions, and more importantly the accuracy and credibility of the data generated. Personal interviews are more advantageous than self-administered questions in evaluating the validity of answers, ensuring all questions are answered by respondents and increasing clarity of questions to respondents, so that the accuracy and understandability of the answers is improved (Barriball and While 1994). Semi-structured interviews enable a researcher to further explore a given response through probing questions. Group discussions are useful in providing depth and insight, on account of collective knowledge and views, but have shortcomings in representing views of all respondents and in producing numerical data that fulfill statistical test requirements (Gill et al. 2008). They generally give a broad picture of the subject under investigation. Participatory discussion has various strengthes over the conventional focus group discussion regarding the identification and motivation of silent individuals to provide their views, as well as the generation of numerical data in terms of ranks or scores. However, it is more time consuming and requires a facilitator skilled in participatory tools and principles, in addition to limiting the the number of participants to be below 15 individuals (a manageable size). Due to the inquisitive nature of the pastoral people, individuals other than the selected ones (especially young people) were allowed to observe the discussion process without disturbing. It is also not uncommon to get opinions and suggestions from the observers when an issue is pressing and everyone likes to participate.

Interviews can be subjected to interviewer and respondent biases due to their interactions, thus demands good skill and expertise of the interviewer to offset biases. Being a cross-sectional representation of a time series dynamic reality, it also poses a challenge in terms of recalling past events and trends of changing conditions (Tache 2008). Herd history recalls were used to collect long-term cattle and camel herd data. Systematic approaches such as the use of a local time calendar, the "*gada*" calendar, and other known benchmark years for political, social, cultural and natural events are useful in assisting the reconstruction of the timeline events. Although herd history recalls may raise concerns with regard to the cognitive burden placed upon respondents, as well as the overall data accuracy and the time to be spent, recalls have been acknowledged in literature to be a suitable approach under pastoral conditions, where written documents often do not exist (Desta and Coppock 2002; Angassa and Oba 2007; Tache and Oba 2010; McCabe et al. 2010). The special values attached to livestock, particularly cattle, and the well-developed tradition of the Borana people to track animal inventories using the "*gada"* calendar are among the vital inputs that make such a method feasible (Desta and Coppock 2002).

The present study might have also benefited from two attributes: First, collecting data from the highly cooperative and knowledgeable Borana people contributed to the quality of the information generated. Second, the long-term experiences of the researcher with the community through frequent interactions during routine works, community trainings and repeated surveys on animal diseases raised familiarity with the culture, traditions and dialectical expressions of the people and have enabled to obtain reliable information. Familiarity with the culture of a given community or being a ‘cultural insider’ gives an opportunity to fully capture the concepts and opinions of the respondents without being modified in interpretations (Tache 2008).

5.4.3 Food security measurements

Food security is characterized by three dimensions: the availability of safe and nutritious food, economic and physical access to food, and biological utilization of the food consumed. Thus, there is no single tool to precisely measure the complex nature of food security (Pinstrup-Andersen 2009; Barrett 2010). Different indicators are used to collect data on food access and consumption information as a proxy for the actual caloric intake and diet quality. According to Barrett (2010), the choice among indicators involves tradeoffs and the underlying purpose of a research commonly determines the choice of indicators. In view of that, this study employed multiple indicators, i.e. dietary diversity score (DDS), household food insecurity access scale (HFIAS), periods of food shortages and livestock off-takes to investigate the food security situation in the Borana area. Livestock off-take was regarded as a proxy measure of the household’s food access because in pastoral areas the largest proportion of revenues comes from livestock sales and is spent on food grain purchases (Berhanu and Fayissa 2010).

HFIAS and DDS have been widely applied to measure different aspects of food security (Becquey et al. 2010; Thorne-Lyman et al. 2010; Regassa and Stoecker 2012) and were reported to perform well in approximating diet adequacy and assessing household food insecurity (Becquey et al. 2010). The association between dietary diversity and nutrient adequacy ratios suggests dietary diversity to be a simple, but good indicator of food security (Kennedy et al. 2011; Oldewage-Theron and Kruger 2011). Still, these measurements have also limitations in view of the multidimensionality of food security. DDS reflects a snapshot of economic access to a variety of foods and intake of dietary diversity (Kennedy et al. 2011) while HFIAS indicates prevalence of food insecurity (access) over a couple of weeks (Coates et al. 2007). Access to available food has gender and cultural relations that account for differentials in intra-house allocation, thus measurement of household level food availability does not ensure access by every individual member (Negin et al.

2009). As biological utilization of the food consumed also depends on non-food factors e.g. hygiene, access to potable water, health conditions and knowledge of an individual on basic principles of nutrition, measures of dietary intake may not always indicate the nutritional security of an individual (Negin et al. 2009; Barrett 2010). Therefore, a combination of different proxy measures is useful in supplementing the limitations of different indicators in estimating food security at household or individual levels.

5.4.4 Assessment of impacts of climate change and its variability in a given region

According to IPPC (2007), detection of climate change is the process of demonstrating a change in a climate variable that is significantly different from its natural variability. Such measurable changes in rainfall, temperature, and extreme events like droughts, floods, storms and heat waves, have also quantifiable impacts on the phenology (life cycle), abundance and distribution of plants and animals. Accordingly, long-term changes in temperature and precipitation patterns are commonly used as indicators for regional climate change and its impact assessment. Available literature shows greater incidences of precipitation changes in the East African region (Funk and Verdin 2010; Williams and Funk 2011; Omondi et al. 2012; Viste et al. 2013; Williams et al. 2012) compared to changes in temperature (Collins 2011; Kassie et al. 2013). The rationale behind such disparity lies in the higher volatility of rainfall that decisively affects the vast majority of the population, who rely upon rain-fed agriculture (Kotir 2011; Kassie et al. 2013). Chapter 2 of this thesis presents assessments of the interannual variability and trends in long-term temperature and rainfall of Dire and Yabelo districts, using monthly climate data acquired from the Ethiopian National Meteorology Agency (1970 to 2009) and the Yabelo Research Center (2010 to 2011). The National Meteorology Agency data set had some missing values, which were filled by averaged records of the Southern Rangelands Development Unit. Assessments of climate change generally require long-term climate records of multiple stations, which could be a concern regarding the sufficiency of the meteorological data sets used in this study. Nevertheless, proper analysis of the available records of the two districts was considered to be sufficient to show the trends in rainfall and temperature, and their relation to herd changes.

5.5 General conclusions

Based on herders' perceptions and empirical data, the present study provided evidence of climate change and its consequent impacts on cattle production and household food security in a pastoral region of Ethiopia. The study has further investigated the role of livestock diversification as a local adaptation strategy in improving food security and enhancing resilience to climate change. Accordingly, the study results revealed that both the standardized anomalies of annual precipitation and cattle holdings showed a downward trend. The spectral analysis of the annual rainfall suggested a quasi-periodic cycle of about 8.4 years in the annual rainfall with droughts to recur at leas once in every half cycle of 4.2 dry years. Hence, the cattle herd anomalies appeared to reflect the patterns in interannual rainfall variability. The Borana herders suffered heavy cattle losses and severe food insecurity in consequence of increased climate variability. As a result, the traditional cattle-based livelihood system is under increasing pressure from climatic and rangeland ecosystem changes, giving rise to livestock diversification as an adaptation measure. Species diversity is intended to fulfill a broad spectrum of the herders' livelihood priorities. The objective to ensure household food security was found to prevail over other production goals of the herders. Livestock diversification indeed significantly improved dietary intake and household food security. Owing to differences among species in their tolerance to climate change driven stressors, complementary economic benefits and variations in their feeding behavior, multiple herding appears to be the most plausible strategy at hand. This should in fact be considered in light of the strengths and limitations of any adaptation strategy. For instance, the major barriers cited for camel ownership were high initial cost of stocking, and inadequate knowledge in camel husbandry and health care. Hence, promotion of multispecies herding thus should take those hindering factors into account and look for exit strategies. Crop cultivation is also widely practiced as a livelihood diversification. Although crop production improves food supply for families and the residues can be used as animal feed, its land resource use is often in conflict with pastoral livestock production. It becomes a barrier to mobility and takes over the dry period grazing area and therefore needs proper integration. Additionally, supporting local strategies with improved livelihood diversification opportunities, access to markets and rural microfinance augments local adaptive capacities. Adoption of early warning systems, through improving the delivery of weather forecast information, inducing early livestock off-take and timely feed resource mobilization ahead of drought occurrences, certainly reduce the livestock asset losses associated with climate risks. Well integrated early warning and weather index-based livestock insurance systems could produce synergies in climate-related risk management.

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6 General summary

Climate change is one of the key environmental stressors in arid and semi-arid environments, causing changing precipitation patterns, extreme weather events and rising temperatures. Such changes negatively affect surface water availability, pasture productivity and the rangeland ecosystem. The resulting reduction in the carrying capacity and resilience of rangelands hamper the productivity of pastoral herds. In particular, heavy livestock losses associated with recurrent droughts pose serious threats to pastoral livelihoods and food security in southern Ethiopia. The sensitivity of pastoral livestock to climate change and variability varies considerably among animal species. Cattle are generally the livestock species most susceptible to water and nutritional stresses engendered by climate change, because they are strongly dependent on herbaceous pasture and frequent access to drinking water, which in turn are highly sensitive to variation in precipitation in dry Savannas. Thus, the traditional cattle based Borana livelihood systems are coming under increasing pressure, leading to livestock species diversification as an adaptation strategy. Nevertheless, there is still a lack of empirical studies showing to what extent climate change has impact on pastoral cattle production and household food security under rangeland conditions. Analyses that attempt to document trends in climatic variables and their influences on cattle herd dynamics, household food security and the efficacy of herders' adaptation strategies would thus deepen our understanding of the effects of climatic change and variability on the resilience of pastoral livelihoods. This study therefore aimed at investigating regional manifestations of climate change and variability, and their impacts on cattle production and household food security, as well as the role of livestock species diversification as a local adaptation strategy in the Borana pastoral system of southern Ethiopia.

The methodological approach involved the use of multiple methods and data sources, including questionnaire surveys, participatory discussions and meteorological records for the study region. Accordingly, a total of 242 households in Yabelo and Dire districts of the Borana area were surveyed between August 2011 and December 2011 to generate data on household socio-economic variables, household food security indicators, livestock production, livestock holdings, species composition, functions and adaptability of different livestock species. The study also included herders' perceptions on climate change and its impacts, and household-level livestock mortalities due to the 2010/2011 drought. By the use of a local time calendar, cattle herd histories were reconstructed for a period spanning five major droughts (between 1980 and 2011) to depict patterns of cattle population dynamics relative to interannual rainfall variations. Additionally, data on individual dietary diversity were collected from 339 respondents at the beginning and the end of the short rainy season. Monthly average rainfall and temperature data for the study region, covering the years from 1970 to 2011, were obtained from the National Meteorology Agency of Ethiopia and Yabelo Research Center. Besides descriptive analyses and non-parametric tests, a range of statistical models were applied to different data sets using the SAS version 9.3 (SAS Institute 2012). These included general linear models, generalized linear mixed models, generalized additive models, ordered and binary logit models, and a proportional hazard regression model.

Analysis of the data on herders' perceptions showed that rainfall was perceived to become more unpredictable with lower amounts and shorter durations, while temperature and the frequency of droughts have increased. Similarly, cattle holdings and their productivity were perceived to show a downward trend, as well as milk consumption patterns, resulting in dietary changes. The perceived effects of climate changes on cattle herds were well corroborated by empirical evidence. The changes in herd size were significantly correlated with changes in rainfall. This suggests that the downward trend in cattle herd sizes reflected a similar underlying pattern in the interannual variation in rainfall. Seasonal rainfall patterns revealed that sequential failures of the short and long rains were often associated with droughts. The spectral density analysis of rainfall data revealed a quasi-periodic pattern in annual precipitation, suggesting drought recurrences roughly once in 4.2 dry years. The 2010/2011 drought caused massive cattle losses, with mortalities varying significantly by district, herd size and feed supplementation. In general, the analyses showed that climate change and variability are having impacts on cattle production, portending a precarious future for the sustainability of cattle pastoralism in southern Ethiopia.

Analysis of the data on food security showed a high prevalence of food insecurity (78%) and low dietary diversity, with the majority of households (81%) merely consuming one to three food groups. A large number of the respondents consumed no fruits, vegetables (93%) and meat (96%), suggesting a high risk of micronutrient deficiencies given the declining trend in milk intake. Livestock diversification was found to be a principal factor affecting household food security and individual dietary diversity. Those survey households keeping multiple species had significantly shorter food deficit periods, lower food insecurity scale values and a higher average livestock off-take than the non-diversified ones. Households with large herd sizes, farmland size and large family sizes, or households having off-farm income sources were also found to be relatively better-off compared to their counterparts.

Analysis of data on livestock species composition showed that all of the respondents were keeping cattle, while 94%, 85% and 40% kept goats, sheep and camels, respectively. Recurrent droughts, bush encroachment, increased cattle herd vulnerability, and thus the growing demand for adapted animal species, were the major drivers of livestock diversification. As major constraints to diversification, herders mentioned inadequate knowledge of camel husbandry and high initial stocking costs for herd establishment. The importance of livestock functions varied considerably among the species with milk production and cash revenues from live animal sales being generally of highest importance. Adaptability assessments on basis of nine adaptive traits showed that camels had the highest adaptive capacity, followed by goats, while cattle were the least adapted species. Species vulnerability to drought also reflected the adaptation patterns with cattle being the most vulnerable to drought followed by sheep, and camels being the most tolerant species. Accordingly, cattle suffered two to four times more mortalities during the 2010/2011 drought compared to sheep, goats and camels. Livestock diversification varied significantly with family size and per capita cattle holding, pointing to the influence of demographic and economic factors on adoptions.

The results of the present study show that climate change and its variability poses serious challenges to cattle production, with recurrent droughts causing enormous cattle mortalities and worsening household food insecurity. The adaptation measure of herders through diversification of herd composition was found to alleviate food insecurity and reduce vulnerability to periodic climatic shocks. In order to further enhance herders' adaptive capacity, the implementation of adaptation strategies aiming at proactively reducing vulnerability to climatic risks and enhancing ex-post risk management capacity are vitally important. The adoption of early warning systems through improved delivery of weather forecast information, inducing early livestock off-take and timely feed resource mobilization, as well as the introduction of weather index insurance are among the measures recommended to enhance resilience to climate change. Livestock diversification and off-farm income were among the factors associated with improved food security, and deserve to be strengthened. Furthermore, diversity in herd composition, while undeniably providing complementary economic and ecological benefits, as well as a buffer against risks, appears to be the most pragmatic current strategy. Nevertheless, further research will be required to appropriately match livestock species diversity with the necessary inputs and the prevailing rangeland conditions such as landscape and vegetation suitability, carrying capacity, and ecological stability.

7 Zusammenfassung

Der Klimawandel zählt zu den hauptsächlichen Verursachern von Umweltstress in ariden und semi-ariden Gebieten in Form von veränderten Niederschlagsmustern, extremen Wetterereignissen und steigenden Temperaturen. Derartige Einflüsse verändern die Verfügbarkeit von Oberflächenwasser, beeinflussen die Produktivität von Weideland und das Grasslandökosystem. Die hierdurch entstehende Abnahme der Tragfähigkeit und Belastbarkeit der Weiden vermindern die Produktivität pastoraler Tierhaltung. Insbesondere hohe Tierverluste durch wiederkehrende Dürreperioden stellen eine ernste Bedrohung der pastoralen Lebensgrundlage und Ernährungssicherheit im südlichen Äthiopien dar. Die Sensibilität von Nutztieren gegenüber Klimavariabilität und Klimwandel unterscheidet sich beträchtlich zwischen verschiedenen Tierspezies. Rinder gelten im Allgemeinen als besonders anfällig für durch den Klimawandel herbeigeführte Wasserknappheit und Futtermangel, weil sie stark von Weidefutter und regelmässigem Zugang zu Trinkwasser abhängig sind, dessen Verfügbarkeiten in trockenen Savannengebieten wiederum durch grosse Nierderschlagsschwankungen stark variieren. Daher gerät die traditionelle Viehhaltung als Lebensgrundlage der Borana unter zunehmenden Druck und führt zu einer Diversifizierung der Tierarten als Anpassungsstrategie. Nichtsdestotrotz gibt es nach wie vor einen Mangel an empirischen Studien, die aufzeigen, in welchem Ausmaß der Klimawandel die pastorale Tierhaltung und Ernährungssicherheit beeinflusst. Der Versuch den Einfluss von Klimavariablen auf die Herdendynamik, die Ernährungssicherheit einzelner Haushalte und die Wirksamkeit von Anpassungsstrategien der Tierhalter zu beschreiben, würde demnach zu einem besseren Verständnis über das Ausmaß der Klimaauswirkungen auf die Widerstandsfähigkeit der pastoralen Lebensweise beitragen. Die vorliegende Arbeit hatte daher zum Ziel, regionale Ausprägungen der Klimaveränderung und Variabilität und ihren Einfluß auf die Rinderproduktion und Ernährungssicherheit, sowie die Funktion der Diversifizierung der Tierarten als lokale Anpassungstrategie im pastoralen System der Borana in Südäthiopien zu untersuchen.

Die methodische Vorgehensweise beinhaltete mehrere Methoden und Datenquellen, darunter Fragebogenerhebungen, partizipative Gruppendiskussionen und meteorologische Aufzeichnungen der Untersuchungsregion. Dementsprechend wurden in den Distrikten Yabelo und Dire insgesamt

242 Haushalte in den Monaten August bis Dezember 2011 befragt, um Daten zu sozioökonomischen Variablen, Indikatoren zur Ernährungssicherheit der Haushalte, Tierhaltung, Artenzusammensetzung, Funktionen und Anpassungsfähigkeit verschiedener Tierspezies zu sammeln. Die Studie erfasste ebenso die Sichtweise der Tierhalter in Bezug auf den Klimawandel und seine Einflüsse, sowie Daten zu Tierverlusten der einzelnen Haushalte während der extremen Dürre 2010/2011. Schwankungen in den Rinderbeständen wurden mittels eines lokalen Kalendars für eine fünf Dürreperioden umfassende Zeitspanne (zwischen 1980 und 2011) rekonstruiert, um Zusammenhänge zwischen der Herdendynamik und der Niederschlagsvariabilität schematisch darzustellen. Zusätzlich wurden zu Beginn und am Ende der kurzen Regenzeit Daten zur Ernährungsdiversität von 339 befragten Personen gesammelt. Die monatlichen Niederschlagsmengen und Durchnittstemperaturen von 1970 bis 2011 in der Untersuchungsregion wurden von der äthiopischen Agentur für Meteorologie und des Forschungszentrums in Yabelo bezogen. Neben einer deskriptiven Analyse und nicht-parametrischen Tests sind eine Reihe statistischer Modelle für unterschiedliche Ausgangsdaten in SAS 9.3 (SAS Institute 2012) angewandt worden. Hierzu zählten allgemeine lineare Modelle, generalisierte lineare gemischte Modelle, generalisierte additive Modelle, Ordered Logit- und binäre Logitmodelle, sowie ein Porportional Hazards Regressionsmodell.

Die Auswertung der Daten zur Sichtweise der Tierhalter zeigte, dass Niederschläge als weniger vorhersehbar wahrgenommen wurden, bei gleichzeitig geringeren Niederschlagsmengen und kürzeren Regenzeiten, während die Temperaturen und die Häufigkeit von Dürreperioden zugenommen haben. In ähnlicher Weise wurde bei Tierzahlen und der Produktivität der Herden ein deutlich rückläufiger Trend bemerkt, wie auch beim Konsum von Milch mit entsprechenden Ernährungsumstellungen. Die beobachteten Klimafolgen für die Rinderherden liessen sich durch empirische Daten belegen. Veränderungen in den Herdengrössen waren signifikant mit Veränderungen in den Niederschlägen korreliert, was vermuten lässt, dass die rückläufige Entwicklung der Herdengrössen einem ähnlich zugrunde liegendem Muster folgte, wie die zwischenjährlichen Schwankungen der Niederschläge. Die saisonalen Niederschlagsverteilungen zeigten, dass das sequenzielle Ausbleiben der kurzen und langen Regenzeiten häufig in Zusammenhang mit Dürreperioden steht. Die Spektralanalyse der Niederschläge ließ ein quasiperiodisches Muster in den jährlichen Niederschlägen erkennen, was auf wiederkehrende Dürreperioden etwa alle 4,2 trockenen Jahre hinweist. Die Dürre 2010/2011 führte zu massiven Verlusten bei Rindern mit signifikanten Unterschieden zwischen Distrikten, Herdengrößen und Futterergänzungen. Im Allgemeinen haben die Auswertungen gezeigt, dass sich Klimavariabilität und Klimawandel auf die Rinderhaltung auswirken und auf eine bedenkliche Zukunft des Pastoralismus in Südäthiopien hindeuten.

Die Ergebnisse zur Ernährung zeigten eine grosse Verbreitung von Ernährungsunsicherheit (78%) und eine geringe Ernährungsdiversität, wobei die Mahlzeiten eines Großteils der Haushalte lediglich auf ein bis drei Nahrungsgruppen basierten. Eine große Anzahl der Befragten konsumierte keine Früchte, Gemüse (93%) und Fleisch (96%), was das Risiko eines Mangels an Mikronärstoffen begünstigt, wenn man den gleichzeitgen Rückgang im Milchkonsum berücksichtigt. Die Diversifizierung der Tierarten war der wichtigste Einflussfaktor der Ernährungssicherheit der Haushalte und der individuellen Ernährungsdiversität. Diejenigen Haushalte mit verschiedenen Tierarten hatten signifikant kürzere Zeiträume mit Nahrungsmangel, geringere Nahrungsmittelunsicherheit und durchschnittlich höhere Entnahmeraten von Tieren als die nicht-diversifizierenden Haushalte. Haushalte mit grösseren Herden, mehr Fläche und grösseren Familien, oder auch Haushalte mit Nebenerwerbseinkommen befanden sich in durchschnittlich besseren Verhältnissen als ihre Kontrahenten.

In Bezug auf die Tierartenzusammensetzung hielten alle Befragten Rinder, sowie jeweils 94%, 85% und 40% der Haushalte Ziegen, Schafe und Kamele. Wiederkehrende Dürreperioden, Verbuschung der Weiden, sowie eine erhöhte Anfälligkeit der Rinderherden und der damit einhergehende wachsende Bedarf an agepassten Tierspezies waren die treibenden Kräfte der Diversifizierung der Tierarten. Als wichtigste Einschränkung einer Diversifizierung nannten die Tierhalter unzureichende Kenntnis der Kamelhaltung und hohe Erstinvestitionskosten für den Aufbau der Herden. Die Wichtigkeit der Tierfunktionen unterschied sich erheblich zwischen den einzelnen Spezies, wobei der Milchproduktion und Einnahmen aus Lebendtierverkäufen insgesamt die höchste Bedeutung beigemessen wurde. Die Beurteilung der Anpassungsfähigkeit anhand von neun Adaptationsmerkmalen ergab, dass Kamele die grösste Anpassungfähigkeit besitzen, gefolgt von Ziegen, während Rinder die am wenigsten angepasste Tierart darstellten. Die Vulnerabilität der Tierarten gegenüber Dürren spiegelte das Adaptationsmuster wider, bei dem Rinder, gefolgt von Schafen, am stärksten verwundbar gegenüber Dürren waren, und Kamele die Tierart mit der grössten Toleranz darstellten. Dementsprechend erlitten Rinderherden im Vergleich zu Schafen, Ziegen und Kamelen zwei bis vier Mal höhere Mortalitäten während der extremen Dürre 2010/2011. Die Diversifizierung der Tierarten unterschied sich signifikant nach Familiengrösse und Rinderbesitz pro Kopf, was auf den Einfluss von demographischen und ökonomischen Faktoren hinweist.

Die Ergebnisse der vorliegenden Studie zeigen, dass Klimavariablität und Klimawandel eine grosse Herausforderung für die pastorale Rinderhaltung darstellen und wiederkehrende Dürren zu enormen Tierverlusten führen, wodurch sich die Ernährungssicherheit der Haushalte verschlechtert. Der Anpassungsmechanismus der Tierhalter durch Diversifizierung der Tiere in den Herden konnte die Ernährungsunsicherheit mildern und die Verwundbarkeit gegenüber klimatischen Schocks reduzieren. Um die Anpassungsfähigkeit von Tierhaltern zu erhöhen ist die Implementierung von Strategien zur zielgerichteten und vorausschauenden Reduktion der Vulnerabilität gegenüber Kimarisiken und die Lesitungsfähigkeit eines ex-post Risikomanagements äußerst wichtig. Die Einführung von Frühwarnsystemen durch eine verbesserte Überlieferung von Wettervorhersagedaten, die eine frühzeitige Verringerung der Herdengrössen und die rechtzeitige Bereitstellung von Futterressourcen induzieren, wie auch die Einführung von index-basierten Wetterversicherungen gehören zu den empfohlenen Maßnahmen, um die Widerstandsfähigkeit gegenüber dem Klimawandel zu stärken. Die Diversifizierung der Tierarten und Nebenerwerbseinkommen gehörten zu den mit erhöhter Ernährungssicherheit assoziierten Faktoren und verdienen weitere Unterstützung. Weiterhin scheint die Diversität der Herden neben des offensichtlich komplementären ökonomischen und ökologischen Nutzen, sowie der Funktion eines Risikopuffers, die derzeitig pragmatischste Strategie darzustellen. Dennoch wird weitere Forschungsarbeit notwendig sein, um die Diversität der Tierspezies in geeigneter Weise den notwendigen Produktionsmitteln und den vorherrschenden Weidebedingungen, wie die Eignung von Landschaft und Vegetation, Tragfähigkeit und ökologische Stabilität, anzupassen.

CURRICULUM VITAE

I. PERSONAL DATA

Name:	Bekele Megersa Bati
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II. UNIVERSITY EDUCATION

- PhD candidate in Agricultural Sciences, University of Hohenheim, Institute of Animal Production in the Tropics and Subtropics (2010–2013)
- MSc (Master of Science) in Veterinary Epidemiology: Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit, Ethiopia (2003–2004)
- DVM (Doctor of Veterinary Medicine): Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit, Ethiopia (1990–1996)

III. PROFESSIONAL EXPERIENCES

- August 2005 to Present: Working as Academic Staff at Hawassa University, School of Veterinary Medicine. Major duties including teaching, research activities and advising undergraduate students.
- September 2004 to August 2005: Worked as Veterinary Epidemiologist at Oromia Pastoral Development Commission, Oromia Regional State
- September 1996 to August 2002: Worked at different levels in Borana zone: as veterinary practitioner, zonal veterinary service team leader; and as deputy head of animal production and health division of the Agriculture Department of Borana zone.

IV. LIST OF PUBLICATIONS

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