Understanding Resilience Pathways to Climate Change in a Changing Rangeland Environment amongst Pastoral Societies of Afar Region, Ethiopia

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DECLARATION

I, Muluken Mekuyie Fenta, declare that the thesis that I herewith submit for the doctoral degree **Doctor of Philosophy in Disaster Management** at the University of the Free State, is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education.

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Muluken Mekuyie Fenta Date

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Prof. Andries Jordaan Date

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DEDICATION

This thesis is dedicated to pastoral communities of the Afar region who managed the inhospitable environment over hundreds of years and contributed a lot to the country's economy, despite the fact that they are the most marginalised people in Ethiopia.

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LIST OF ABBREVIATIONS AND ACRONYMS

A	Assets
AC	Adaptive capacity
ACCRA	African Climate Change Resilient Alliance
ANRS	Afar National Regional State
APS	Access to public services
ARS	Afar Regional State
CV	Coefficient of Variation
DFID	Department for International Development
DPPC	Disaster Prevention and Preparedness Commission
DRMFFS	Disaster Risk Management and Food Security Sector
DTR	Diurnal temperature range
ETB	Ethiopian Birr
EWI	Early Warning Information
FAO	Food and Agriculture Organisation of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FHH	Female-headed households
GDP	Gross Domestic Product
GoK	Government of Kenya
HIV/AIDS	Human immunodeficiency virus infection / Acquired immunodeficiency syndrome
IFA	Income and food access
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel in Climate Change
KMO	Kaiser_Meyer_Olkin
MEA	Millennium Ecosystem Assessment
MENR	Ministry of Environment and Natural Resources
MHH	Male-headed households
MLR	Multiple linear regression
MoARD	Ministry of Agriculture and Rural Development
NGO	Non-Government Organisation
NMA	National Meteorological Agency, Ethiopia
NMSA	National Meteorological Services Agency, Ethiopia
OLI	Operational Land Imager
PAR	Pressure and Release
PCA	Principal Components Analysis
PCI	Precipitation Concentration Index
PENHA	Pastoral and Environmental Network in the Horn of Africa
R	Resilience
RDPS	Rural development policies and strategies

REGLAP	Regional Learning and Advocacy Programme for Vulnerable Dryland Communities
RI	Resilience index
S	Stability
SNNPR	Southern Nation, Nationalities and Peoples Region
SPI	Standardised Precipitation Index
SSN	Social Safety Nets
SPSS	Statistical Package for Social Sciences
TIRS	Thermal Infrared Sensor
TLU	Tropical Livestock Unit
UNDHA	United Nations Department of Humanitarian Affair
UNDP	United Nations Development Programme
UN-EUE	United Nations Emergencies Unit for Ethiopia
UNFCCC	United Nations Framework Convention on Climate Change
UN OCHA	United Nations Office for the Coordination of Humanitarian Affairs
VIF	Variance inflation factor
WISP	World Initiative for Sustainable Pastoralism
WRI	World Resources Institute
dec^{-1}	Per decade

LIST OF CHEMICAL SYMBOLS AND UNITS OF MEASURE

°C	degrees Celsius
CO_2	carbon dioxide
ha	hectare
km^2	square kilometre
masl	metre above sea level
mm	millimetre
N	nitrogen

DEFINITION OF KEY TERMS

Adaptive capacity: The capability of a system, institutions, individuals and other organisms to adjust to potential harm, to exploit opportunities, or to react to outcome of hazards (Intergovernmental Panel in Climate Change [IPCC], 2014).

Climate change: An alteration in the conditions of the climate that can be distinguished (for example, by utilising statistical tests) by alterations in the mean as well as the inconsistency of its properties, and that perseveres for a long-term period, normally for decades or more (IPCC, 2007).

Exposure: The presence of livelihoods, individuals, environmental services and assets, biological communities, and infrastructure, or economic, social, or cultural assets in places that could be negatively impacted by a hazard (IPCC, 2014).

Mitigation: Defined as any continuous exertion attempted to reduce a hazard risk through the decrease of the probability and the outcome of that hazard's risk (Coppola, 2011).

Rangelands: All lands that are not dense forests, crop land, barren or covered with solid rock, concrete, or ice. It includes grasslands, woodlands, and shrub or bushlands (Roselle *et al*., 2009).

Resilience: The capability of a social and ecological system to absorb a range of perturbations and to support and build up its central structure, function, character, and responses through either a bounce back or reorganisation in a new situation (Folke, 2006; Gunderson and Holling, 2002; Holling, 1986; Walker *et al.*, 2004).

Sensitivity: Denotes how much the social and ecological system, asset or species is influenced, either harmfully or usefully, by climate change and variability (IPCC, 2014).

Vulnerability: Refers to the characteristics of an individual or group and their circumstances that impact their ability to expect, adapt to, resist and bounce back from the effect of a characteristic risk (Blaikie *et al*., 1994).

ABSTRACT

Change in climate and climate extremes are increasingly being acknowledged as a vital challenge to pastoral production systems. The resilience of pastoral households to climate-induced shocks depends on the knowledge, skills of households and assets. The present study was conducted in the Southern Afar region in Ethiopia to understand the resilience of pastoralists to climate change and variability in a changing rangeland environment. This study used the Mann-Kendall statistical test, the Sen's slope estimator test and the Standardised Precipitation Index to analyse the trends of climate change and variability and the annual and seasonal anomalies of rainfall, and assess the severity of droughts in the study area. A household questionnaire survey and focus group discussion were employed to collect primary data at household level. A total of 250 pastoral households were sampled using stratified random sampling. The data obtained were analysed using descriptive statistics, principal component analysis and linear regression, as well as Tobit models. In addition, satellite image analysis and field observation were used to analyse the land-use/land-cover changes in the Southern Afar region.

The results indicated a significant declining and increasing trend of Sugum (spring) season and Karma (summer) season rainfall, respectively in the study area. However, significant trend was not observed for long-term annual rainfall. The coefficient of variation of seasonal rainfall ranged from 25.2 to 42.7, indicating the strong variability of rainfall among the seasons. Precipitation Concentration Index values also indicated a strong, irregular distribution of rainfall in the study area which was more irregular in the Gewane than in the Amibara district. Analysis of the Standardised Precipitation Index indicated that the total percentage of dry years (negative anomalies of rainfall) ranged from 53.3% (at Amibara) to 43.3% (at Gewane), implying more drought periods in the Amibara than the Gewane district for the observation periods. However, the percentages of extreme drought years were from 6.7% (at Amibara) to 10% (at Gewane). The research has confirmed a significant increasing trend of monthly, seasonal and annual temperatures for the period 1983–2014. The results also indicated that the mean annual temperature of the Southern Afar has increased by 0.67 °C dec^{-1}*which is almost twice the national increase. Due to the unreliability and erratic nature of rainfall and recurrent droughts in the region, pasture and water availability became scarce and livestock assets and productivity reduced to a high degree, the income and asset ownership of households declined and the market price of livestock decreased, while the price of grain food increased. Due to deepening of poverty in the Southern Afar region, the informal safety net/mutual support system was eroded and individualism was increased. Furthermore, the pastoral households pursued different strategies to adapt/cope with climate-induced shocks and stresses. The most important strategies deployed by the local people included mixing livestock–crop farming, mobility,* *changing herd species composition and herd splitting, reduced consumption, remittance, cash-for-work, charcoal burning and firewood selling and food aid. The indigenous early warning system and mutual support among the extended families, neighbours and community were still significant to enhance the resilience of the pastoral households, though the indigenous early warning system was not integrated into the formal early warning system and the informal safety nets were eroded.*

The results further indicated that agro-pastoral households were more resilient than pastoral households to climate-induced shock. Furthermore, households in the Gewane district were more resilient than those in the Amibara district. In addition, female-headed households were less resilient than male-headed households. The findings further indicated that irrigation crop farming, livestock ownership, education level, per capita income, mobility and herd splitting, herd composition change, labour, remittance, food aid, access to credit, market and formal early warning information had a significant impact on the resilience of households to climate-induced shocks and stresses. The findings of the household vulnerability analysis indicated that 28.8%, 53.6% and 17.6% of pastoralists were highly vulnerable, moderately vulnerable and less vulnerable, respectively, to climate-induced shocks and stresses. The most important drivers that determine the vulnerability level of households were gender, age and marital status of the household, household size, educational level, extension services, farming experience, early warning information, livestock asset, irrigation farming, non-farm income, livestock mobility, radio ownership, distance to market and veterinary clinic, access to credit and agricultural inputs, the number of sick family members, the number of months with food shortages during the normal season of the year and number of dependents in the household. The results also indicated that substantial loss of grassland cover (64.5%), moderate decline of cultivated land (24%) and a dramatic increment of shrub and bushland cover (114.3%) occurred between 1985 and 2015. Consequently, access to rangeland resources and farmlands for pastoralists was highly restricted, putting the pastoral communities under increasing threat. The identified drivers of land use/cover changes in the order of decreasing influence were the invasion of Prosopis juliflora, climate change, and variability, government intervention, and population growth.

If enhancing the resilience of pastoral households is the final aim, the government and other partner organisations should focus more on long-term strategic livelihood interventions than on emergency relief interventions by equipping the local people with the capability to manage and respond to climate-induced shocks and stresses in the early stage of the crisis. Furthermore, the decision makers should develop a policy for controlling P. juliflora and ensuring accessibility of the rangeland to grazing and strengthening of the customary institution for effective management of rangeland resources.

Keywords: Climate change, Land use, Livelihood, Rainfall, Resilience, Vulnerability

Chapter 1
INTRODUCTION

1.1 Background

In recent decades, the human and natural systems in all continents have been impacted by change in climate and climate variability. Rising temperatures and long-term alterations in all elements of the climate system is caused by continued emission of greenhouse gases, increasing the probability of the occurrence of severe, widespread and irreversible impacts on people and ecosystems (Intergovernmental Panel in Climate Change [IPCC], 2014a). According to IPCC (2013), global temperatures have been increasing since the late nineteenth century, the last three decades have been characterised by increasing trends of temperature in comparison to all previous decades, and the first decade in the twenty-first century has been the hottest decade in history. Since 1950, the world's average temperature has risen by 0.72 °C.

Climate change impacts weaken and even reverse the progress made in improving the socio-economic welfare of most African countries. The negative influences of climate change can be exacerbated by the existing mounting poverty, human diseases and the increasing population (IPCC, 2014a). According to Yanda and Mubaya (2011), the incidence of climate shocks such as droughts and floods are the features of the climate in African countries. The current and predicted climate influences indicate that a severe impact will be observed more in Africa than in other continents, as the livelihoods of African people are mainly based on rain-fed agriculture and due to low incomes and its geographic exposure. Deressa and Hassan (2009) also stated that Africa contributes the least to global carbon emissions, though the region is anticipated to be severely harmed by the impacts of climate-induced shocks and stresses.

The spatial and temporal variability of rainfall is the feature of rainfall in Eastern African countries (Hession & Moore, 2011; Rosell & Holmer, 2007). Furthermore, a continuous reduction in rainfall numbers was detected recently (Liebmann *et al.*, 2014, Tierney *et al.*, 2015). Consequently, the people whose livelihood is mostly dependent on rain-fed agriculture, is becoming under great pressure (Conway & Schipper 2011, Hawinkel *et al.*, 2016). Studies indicated that dry seasons in East Africa are linked with negative Indian Ocean Dipole (IOD) events and/or La Niña, while wet seasons are related to positive IOD events and/or El Niño (Funk *et al*., 2008; Schreck & Semazzi, 2004; Williams & Funk, 2011). The findings reported by Lyon and DeWitt (2012) indicated that rainfall has declined in the months of March to May over East Africa. Furthermore, a declining trend of rainfall has been observed during the months of June and September in most regions of the Great Horn of Africa (Williams *et al.,* 2012). Change in climate was predicted and it was indicated that temperatures would increase at a faster rate than that of the previous years and more rainfall variability would be expected over East Africa (Williams & Funk, 2011). According to Barros *et al.* (2014), temperature could rise by 2 °C by the mid-twenty-first century and by 4 °C close to the end of the twenty-first century in Africa compared to other countries in the globe. East African countries are very susceptible to climate-induced shocks and stresses such as droughts and climate variability (Anyah & Semazzi, 2007). According to Anyah and Semazzi (2007), extreme climatic events affected the livelihoods of most East African countries in the late 1970s, causing extensive famine in the sub-region.

Like other African countries, the agricultural sector in Ethiopia is very prone to the impacts of climate-induced shocks and stresses such as droughts and climate variability since the country's livelihood is mostly based on rain-fed agriculture (Conway 2000; Hulme *et al.,* 2001; Seleshi & Sanke, 2004). Frequent droughts and floods are the main hazard risks to rural livelihoods in the country. The incidences of droughts have been increasing mostly in the pastoral communities of the country (Ferris-Morris, 2003). According to Funk *et al.* (2005), precipitation in Ethiopia is anticipated to decrease and become more uneven in the future. Climate extremes such as more intense and prolonged droughts and floods could happen in Ethiopia due to climate change and variability (United Nations Development Programme [UNDP], 2008). The findings reported by Haile (2005) also indicated that erratic monsoon rainfall would negatively harm the well-being of most people in Ethiopia as the country pursues a climate sensitive agriculture. It was also reported that the occurrence of one year of severe drought in Ethiopia caused consumption depression for two or more years after the severe drought (Dercon, 2004). Although the pattern and trends of climate change and variability and its impact varies across districts, regions and countrywide, most studies on the trends of change in climate and variability and its impact have been conducted at national level in the country. According to Tadege (2007), the average maximum temperature has risen by 0.1 °C per decade and a rise of the average minimum temperature was observed in the range of 0.25 °C–0.37 °C per decade, while McSweeney *et al.* (2010) observed a rising mean annual temperature trend of 0.28 °C per decade throughout the country. Temperature trends also revealed that seasonal variability and increased temperature were observed during the summer season, which has risen at a rate of 0.32 °C per decade (McSweeney *et al.,* 2010). Overall, the findings indicated that a persistent increasing temperature trend was observed in the previous decades in Ethiopia. Furthermore, the National Meteorological Services Agency [NMSA] (2001) revealed a decreasing rainfall trend in the southern and northern parts of Ethiopia, while an increasing rainfall trend have been observed in the central part of the country. However, Osman and Sauerborn (2002) showed a decreasing rainfall trend in the central parts of the country. Although Seleshi and Sanke (2004) reported a decreasing rainfall trend in the south, southwest, and eastern parts of Ethiopia, neither Cheung *et al.* (2008) or Seleshi and Sanke (2004) observed any rainfall trend in the central regions of the country. Similarly, Verdin *et al.* (2005) showed a decreasing rainfall trend in the southwestern and eastern parts. Generally, no consistent pattern or trends of rainfall were observed across the country.

On the other hand, rangeland degradation has become the most serious problem in the century, especially in pastoralist areas due to changes in climate and anthropogenic activities (Millennium Ecosystem Assessment [MEA], 2005). Climate extremes such as increased temperature, drought and floods caused deterioration of rangeland resources which led to scarcity of pasture and water in pastoral communities. Consequently, competition for scarce resources had increased, which led to violent conflicts among different ethnical groups of pastoral households (Nori & Davies, 2007). Pastoralists inhabiting an enabling policy environment and free from negative external interference are supposed to be adaptive to climate-related shocks and stresses (Kirkbride & Grahn, 2008; Nassef *et al*., 2009). The reaction of pastoralists in this case depends on a variety of their indigenous adaptation mechanisms/strategies. However, marginalisation of pastoral communities, which has been continued for a long time and inappropriate interventions by the government, have eroded their indigenous adaptive strategies and made them more susceptible to the increase in climate-induced shocks and stresses, though they were adapted for decades in their inhospitable environment (Kirkbride & Grahn, 2008) The possible adverse influences of climate-induced hazards on the livelihood of pastoralists can be exacerbated by non-climatic factors, including shrinking of rangelands, increasing population and poor governance practices (Birch & Grahn, 2007; Hassan, 2010). The extent of climate-related hazard risks may vary from place to place. Therefore, it is reasonably essential for research to put emphasis on pastoral communities to provide significant information for decision makers and enhancing resilience of pastoralists.

The poor and most vulnerable pastoralists are already feeling the twin effects of climate-induced shocks and stresses and rangeland degradation. Rangeland degradation is another disaster risk for the sustainability of pastoral livelihoods (Abate *et al.*, 2010). Persistent decrease of rangeland ecosystem goods and services links rangeland deterioration to loss of welfare (MEA, 2005). The rangelands of Ethiopia, which are below 1 500 m elevation, are considered as the traditional pastoral territory. However, due to expansion of sedentary agriculture, agricultural projects, national parks inside the rangeland and encroachment of unwanted plant species and conflict over the rangeland resources have reduced the total area of the rangeland and contributed to mismanagement (Abate *et al.*, 2010; Tesfaw, 2001). Internally and externally driven changes are features of pastoralism and can be best explained as a system in shift. However, the driving factors are not the same in all pastoral communities and, hence, the rate of the system transitions also varies from place to place. The degradation and shrinkage of rangelands, decline of livestock assets and inappropriate governmental intervention forced herders to leave pastoralism and see other livelihood options such as charcoal making, crop farming and other economic activities. These factors systematically affect the trends of land-use/land-cover in East Africa (Beyene & Korf, 2008; Lambin *et al.,* 2003).

1.2 Statement of the Research Problem

In pastoral communities of Ethiopia, climate-induced shocks and stresses such as droughts, rising temperature and irregular rainfall-reduced pasture and water availability and lead to animal loss through hunger and disease (Conway, 2000). The weather-related natural disasters frequently occurred in pastoral areas of Ethiopia, which has been further exacerbated by the depletion of the natural resources and destruction of ecosystems due to anthropogenic activities (Tadege, 2007). Ethiopia is particularly very susceptible to drought, making drought the utmost significant disaster influencing the country over time (Seleshi & Sanke, 2004). Rainfall anomalies and the delayed onset of the rainy season, along with rising temperatures, lead to impoverishment of grassland, lack of livestock feed and water and heat stress to livestock. This has, in turn, increased the mortality rate of herds, susceptibility of livestock to disease and emaciation as a result of the long distances they travel in search of pasture and water (Muluneh & Demeke, 2011). Although the drought may occur all over the globe, in general its harm is not as intense as in Africa, particularly in Ethiopia (Funk *et al*., 2008; Seleshi & Sanke, 2004; Williams & Funk, 2011). Droughts, heat waves and floods have increased in Ethiopia over the past decades. Excessive floods due to the high intensity of rainfall in the Ethiopian highlands caused loss of life and damaged properties of the people who inhabited the arid and semi-arid areas (Tadege, 2008).

It has been observed that although change in climate is happening all over the world, its influence and extent differ across multiple levels and scales. Its impacts are not the same at district, regional, national and global level. Although changes in climate and climate extremes will be the greatest challenge for people in Ethiopia, few studies have been undertaken in the country concerning resilience to climate change. Most of this literature has only investigated seasonality, poverty and food insecurity (Dercon & Krishnan, 2000). However, studies conducted expressly in the context of farmers' vulnerability and resilience to climate change and climate variability is limited. Deressa *et al.* (2008) assessed the vulnerability of households to climate-induced shocks and stresses at national level in Ethiopia. However, insights into vulnerability/resilience to climate perpetuation vary with the scale of analysis. Resilience to climate-induced shocks assessed at national level can conceal variations in local resilience of households (Parkins & MacKendrick, 2007). Accordingly, this national-level (macro-scale) assessment by Deressa *et al.* (2008) could have overlooked variations in vulnerability at the local level since the vulnerability level may vary even among households at district level. Households at district level can vary in terms of level of food insecurity, coping and adaptation capacity, access to credits, public services, safety nets and natural resources. In such conditions, variability at local level is usually ignored in nationwide resilience and vulnerability studies. Therefore, it is difficult to precisely understand the spatial aspects of households' resilience from nationwide resilience assessments. This shows the significance of scale in resilience studies and ensures the necessity of resilience study at micro-level.

A study at district, regional, national and global level is essential to integrate worthwhile adaptation strategies in the development policy. The reason for this is that adaptation/coping capacities to climate change and variability can vary at all these levels, taking into account their level of income, local exposure, and education level to mention but a few. It is on the basis of these premises that the present study needs to understand the resilience/vulnerability of pastoralists to climate change and climate variability in a changing rangeland environment in the Southern Afar region of Ethiopia.

On the other hand, due to the alarming reports on degradation of rangelands in pastoral communities, studies on rangeland of pastoral societies is of much more concern. Shifts of rangelands to other land use/cover changes have been observed in pastoral communities, mainly linked to changes in climate and climate variability, human population growth and establishment of new invasive species (Homewood, 2004; Sala *et al.*, 2000; Vetter, 2005). According to predictions by Grau and Aide (2008), the man-made influences on natural resources between 1950 and 2050 are probably to be the worst in human history. Lambin *et al.* (2003) also reported that land use/cover change is a much complex process triggered by the coupled effects of climatic and non-climatic factors.

Most studies in the area of land-use/land-cover changes and its drivers were conducted in the highland areas of Ethiopia, which cover nearly 40% of the total area of the country (Dessie & Kleman 2007; Tefera, 2011), while limited information is available about the trends of land-use/land-cover changes and its drivers in arid and semi-arid areas of the country where land-use/land-cover change is believed to be a rapid process (Hurni *et al.,* 2005). Pastoralists in the Afar region depend mostly on livestock and livestock products where feed resources of livestock are mostly limited by land-use/land-cover changes. Likewise, the Afar pastoralists have been experiencing considerable erosion of their main livelihood strategy, pastoralism, over the past 40 years (Keeley *et al.,* 2014). This is due to the persistent allocation of their dry season grazing areas, particularly following the Awash River, for large-scale commercial farms, wildlife reserves and urban settlement (Mohammed, 2004). Hence, assessing and monitoring land-use/land-cover trends and its drivers in arid and semi-arid rangelands of the Afar region are vital to understand its influence on rangeland resources. Recently, the Afar people have also experienced recurrent droughts, population pressure, expansion from neighbouring cultivators and pastoralists (such as the Issa Somali) and invasive plants (Rede, 2014). However, there is scant information concerning the land-use/cover changes, its drivers and how pastoralists are impacted by land-use/cover changes. Thus, in addition to understanding the resilience of pastoralists to climate-induced shocks and stresses, the present study was also conducted to address the trends of land use/cover changes, drivers, and their impacts in Southern Afar pastoralists.

1.3 Research Questions

This study was led by the following research questions:

i. What are the trends of climate variability and change in the Southern Afar region?
ii. What are the local people's perception about the region's climate change and variability and its impacts, their adaptation/coping mechanisms and livelihood resources and well-being trends?
iii. What is the resilience status of the Afar pastoralists to climate variability and change impacts?
iv. What are the factors that aggravate the vulnerability of the Afar pastoralists to climate change and variability?
v. What are the trends of land-use/land-cover changes of Southern Afar's rangelands, drivers and their impacts on people's livelihood?

1.4 Hypotheses

Given the information to the statement of the research problem, this study is guided by the following hypothesis:

i. Climate change and variability is happening in the Afar region and are negatively affecting the livelihoods of the pastoralists.
ii. Resilience of the pastoralists to climate change and variability is becoming eroded and unevenly distributed across livelihood groups, districts and the gender of household heads.

iii. The accelerated pace of climate-induced shocks and stresses and land-use/land-cover change exceeds the resilience of pastoralists.
iv. Increasing vulnerability in the Southern Afar communities is driven by both climatic and non-climatic factors.

v. Rangelands are greatly changed to other land-use/cover types and threatening Southern Afar pastoralists.

1.5 Objectives

The study aimed at understanding the resilience of pastoralists to climate change and variability in a changing rangeland environment in the Southern Afar region, Ethiopia. The sub-objectives of this study were as follows:

i. Determining the trends of climate variability and change in the study area.
ii. Assessing the perceptions of the local people towards climate variability and change, and trends of livelihood resources and well-being.
iii. Assessing the impact of climate-induced shocks and stresses on livelihoods of pastoralists and their adaptation/coping mechanisms.
iv. Assessing the vulnerability of pastoralists to climate-induced shocks and stresses.
v. Determining the resilience status of pastoralists to climate-induced shocks and stresses.
vi. Analysing the trends of land-use/land-cover changes, drivers and their impacts on the livelihood of Afar pastoralists.

1.6 Significance of the Study

The present study offers scientific knowledge about the resilience of the pastoralists to climate-induced shocks such as droughts and floods, and stresses including climate variability and change. The study also helps to understand the indigenous adaptation/coping mechanisms deployed by pastoral households to adapt/cope with climate shocks and stresses which may be useful to integrate their indigenous knowledge in the development policy of the government for sustainable development of pastoralists. The study also informed decision makers about which groups of pastoral households are vulnerable to climate change and variability and this is important to give priority for the most vulnerable social groups during development interventions. The government of Ethiopia developed policies and strategies to ensure sustainability of the environment and climate change adaptation and mitigation; hence, the present study offers important policy recommendations that will help in the achievement of the aforementioned policies and strategies of the Ethiopian government.

1.7 Limitation of the Study

Due to constraints arising from poor infrastructure, security problems, harsh climatic conditions and time shortage, it was difficult for a single researcher to address all districts of the administrative Zone III--the present study area which is one of the five zones of the Afar region of Ethiopia. Hence the research results were primarily based on data collected from randomly selected respondents in two districts. Though the present study analysed the trends of rainfall and temperatures in the study area, the study did not identify the causes of climate change and variability. Furthermore, this study determined the current status of the resilience of Afar pastoralists to climate-induced shocks based on cross-sectional data. However, due to a lack of panel data sets, the present study also did not analyse the dynamics of pastoral household's resilience to climate variability and change.

1.8 Structure of the Thesis

The thesis is structured in eight chapters. The first chapter describes the introduction of the study that includes the background, research problem, research questions, hypotheses and objectives of the study. Chapter 2 presents theoretical and conceptual frameworks which are the basis to construct the resilience framework for Afar pastoralists. Chapter 3 deals with the literature review about change in climate and its impacts, and an overview of pastoralism at global, national and regional level. Chapter 4 discusses the methodological approaches comprising a description of the study area, research design and data collection techniques and analysis. Results obtained from the study about trends of climate variables (temperature and rainfall) are presented in Chapter 5. Influences of climate shocks and stresses on pastoral livelihood, local people's adaptation and coping strategies, resilience and vulnerability status of pastoralists to climate shocks and stresses are discussed in Chapter 6. Chapter 7 discusses the findings on land-use/land-cover changes and its drivers and impacts on the livelihoods of pastoralists. Finally, summaries and conclusions of the study are presented in Chapter 8.

Chapter 2
THEORETICAL AND CONCEPTUAL FRAMEWORK FOR RESILIENCE

2.1 Introduction

In this chapter, the theoretical framework that guides the present study, the concepts and analytical tools that are applicable and indispensable for carrying out this study are discussed. Different resilience and vulnerability conceptual frameworks to understand and manage disaster risk and crises, how people derive their livelihood by drawing on or combining five types of capitals (human, social, financial, physical and natural) and the drivers and processes that affect resilience and vulnerability of the society are reviewed. Following these resilience/vulnerability conceptual frameworks from literature, a conceptual framework was developed to understand the resilience/vulnerability of Afar pastoralists to climate change and variability. The climate-induced shocks and non-climatic factors that affect the resilience of Afar pastoralists and the possible livelihood outcomes have been hypothesised on the resilience framework.

2.2 Theoretical Framework

The present study followed the *adaptive cycle* theory described by Chapin *et al.* (2009). All systems undergo disruptions, for instance, disturbance of the forest system through fires, economic failures, and occurrences of war, policy changes and industrial plants that lead to alterations in important system characteristics. Changes that happen during the critical stages disturb the long-term steadiness of systems and, qualitatively, such alterations can have various influences on the ecology and social systems than do temporary variability and slow alterations (Chapin *et al.*, 2009). According to Holling (1986), adaptive cycles offer a framework for explaining the importance of disturbance in environmental and social organisations. Adaptive cycles include system disruption, reorganisation, and renewal. In an adaptive cycle, a system may undergo some form of disruption and either renew to a uniform state or be altered to any new state (Holling, 1986, Walker *et al.*, 2004). Using a forest ecosystem analogy, Chapin *et al.* (2009) explained the main stages of adaptive cycles and how the theory can be employed to characterise disruptions that a given system experience. According to Chapin *et al.* (2009), the beginning of an adaptive cycle in the forest ecosystem, called *release phase*, occurs due to a severe fire that can kill all the trees, leading to a sudden alteration among the components of the forest system such as loss of trees, reduction of productivity and increasing run-off to streams. This phase can happen in a moment of time or within days and completely decreases the structural complexity of the system.

The next phase following the *release phase* is the *renewal phase*. For instance, after disturbance of a forest, new policies may be developed and seedlings may be established to restore the forest ecosystem. Throughout this stage, a number of activities are anticipated to occur and the system after disturbance may be comparable to the previous one or it may be developed to another type of state which is different from the previous one, called the *regime shift*.

Alongside this short-term opportunity for alterations, the forest undergoes a *growth phase* for many years, when ecological resources are introduced into living entities, and policies become regularised. The nature of the renewing forest system is mainly influenced by the species and regulations that are formed during the regeneration period (Chapin *et al.*, 2009). During the growth phase, the forest is comparatively unaffected to potential agents of disruption. The large amount of water content and limited biomass of the early-successional forest system, for instance, make renewing forests comparatively incombustible.

The fourth phase of an adaptive cycle is *conservation phase*, the stage in which the forest progresses into the stable state and the exchanges among elements of the system become to be more specific and complex (Chapin *et al.,* 2009). Accessibility of light and nutrients decreases, which leads to specialisation among plants to use various light environments and various fungal associations to obtain nutrients. The authors further reported that in the policy realm, the comparatively stable state of the forest directs to management decisions that are intended at sustaining this steadiness to offer expectable forms of forest services and goods. The forest becomes more vulnerable to disturbing factors such as fire, drought, and alterations in the local economy due to the increased linkage and interdependence between social and ecological variables and, hence, another *release phase* may be initiated again if such changes are significantly large.

Chapin *et al*. (2009) fundamentally offers a more acceptable approach of defining the adaptive cycle theory by taking the forest ecosystem analogy. According to Gunderson *et al*. (1995), the sequence of the phases of the adaptive cycles – release, renewal, growth, and conservation can be used to deal with several types of social and ecological systems, such as national economies, cultures, lakes, governments and business, though the sequence of the phases of adaptive cycles is never constantly similar. From a management point of view, the most vital experience in managing adaptive cycles, sets up social and ecological systems to be especially susceptible, therefore, prone to change to another state in light of unsettling influence (Holling & Meffe, 1996; Walker & Salt, 2012).

On the other hand, it is suggested that systems develop their own vulnerabilities during the conservation phase. During this stage, decision makers usually attempt to decrease persistent alterations in the process of the ecosystem; consequently, slight disturbances are controlled to promote the activities of the management goals. Release and crisis offer significant chances for alteration (Berkes *et al.,* 2002; Gunderson & Holling, 2002). Certain alterations may be unwanted such as expansion of invasive species and change in political administrations that bring social inequality, though some changes may be necessary. Emphasising the significance of efficient use of the concept in the management of natural resources, Chapin *et al*., (2009) reported that acknowledgement of these altering components of a system through the perspective of an adaptive cycle reveals that efficient long-term management and policy-making must be profoundly adaptable, looking for windows of opportunity for positive strategy changes.

2.3 The resilience concept and its components

Resilience is the capability of a social–ecological system to continue after a shock and reorganise, while sustaining a fundamentally similar function (Folke, 2006; Holling, 1986; Walker *et al.* 2004).

Recently, a broader concept of resilience has been developed. The idea of resilience was initially used by Holling (1986) to define ecosystem resilience and has currently been applied in other contexts, progressively in social sciences, to explain people or household resilience (Levin *et al.,* 1998). Assuming the wide variety of resilience thoughts, it is complicated to detect common characteristics; however, nearly all descriptions stress the ability for effective adaptation against shocks. Norris *et al.* (2008) suggested that an overall agreement occurs on two significant characteristics of the resilience definitions, namely: (i) it is better conceived as a capability or a process than as a result; (ii) it is well-conceptualised as adaptability than steadiness. A first step in the direction of understanding the resilience concept in a learning environment is to discourse the important characteristics and regulations of the investigated system. In order to enhance a common understanding of resilience in the situation of diverse systems, Norris *et al.* (2008) have identified the most important principles, namely: (i) a changing environment is given, (ii) systems are too complex to know or map all interdependencies, and (iii) there is not only one stable state in reality – alteration is the common state. Resilience therefore, is a learning process and knows that no stable state exists in reality.

There are two contrasting resilience concepts. The first concept is described by Gunderson *et al.* (1995) as resilience in engineering, and by (Cutter *et al.,* 2008) as the ability to persist and survive with a disaster with slight influence and destruction. It includes the ability to lessen or evade damages, encompass the impacts of hazards, and bounce back with slight disturbances (Cutter *et al*., 2008). Rose (2009) also described it as the time taken by a system to recover to its earlier state after a disturbance. Furthermore, not only the time required for bouncing back, but also the pattern of bouncing back can be considered. According to the framework of engineering resilience, opportunities are not taken into account to adapt or learn from a previous disturbance and shift to an alternative state. On the other hand, the second resilience concept, called ecological resilience, is the amount of perturbation that a system can accommodate without redefining its structure and functions (Holling, 1986; Walker *et al.,* 2004). A concept regularly quoted when referring to resilience of an ecosystem is the *adaptive renewal cycle*, primarily developed by Holling (2001). The adaptive renewal cycle is an informative model, made from long-time measurements of ecosystem changes over time, such as the succession of species, in four phases of change forced by periodic disturbances and processes (Folke, 2006). Resilience refers to persistent or robustness of a system to disturbance and about the possibilities that disruption may lead to the occurrence of new trajectories. Therefore, resilience offers the ability of the system to adapt to disturbances that allows for sustainable development. It does not mean that resilience has always been a positive characteristic of the system (Folke, 2006).

According to O'Brien *et al.* (2004), adaptability, resilience, and vulnerability are highly interrelated and the difference between these terms is not clear yet for most researchers. Resilience and vulnerability are slightly broad theories, and the drivers regularly overlay, which makes the difference between them not understandable (O'Brien *et al.,* 2004). According to the IPCC (2007), vulnerability is the function of adaptive capacity (AC), sensitivity (S) and exposure (E). However, recently, resilience is interlaced with vulnerability and adaptive capacity and it has been discussed that resilience, as the all-encompassing idea, is a function of vulnerability and adaptive capacity (Wilson, 2012) as indicated below.

Resilience R = f (Adaptability A, Vulnerability V)

2.4 Conceptual Frameworks of Resilience and Vulnerability Assessments

2.4.1 Pressure and release model

Though many models have been proposed and advocated for understanding and managing disaster risk and crisis, researchers in social sciences have widely accepted the pressure and release model proposed by Blaikie *et al.* (1994). The model is mainly useful for understanding the various faces of interaction between factors of vulnerability and hazards. According to Blaikie *et al.* (1994), understanding vulnerability should go beyond the identification of vulnerability. It needs to understand the root causes of vulnerability and why a particular segment of the population suffers in every disaster. This model is broadly used to know the various levels of vulnerability over time. According to this model, *pressure* is produced by the vulnerability and influences of hazards. Blaikie *et al.* (1994) explained vulnerability in the model as composing of three levels, namely: root causes, dynamic pressure, and unsafe conditions.

The **root causes** of vulnerability are limited access to resources, structures, power, and ideologies. The root causes are the function of the economic and political structures of the society. The underlying causes are linked with the activities of the government and, ultimately, the police and military. The political and economic structure of a community also determines the sharing of power. As a result, marginalised people have less access to political power. The low level of accessibility due to less political power creates limited access to livelihood opportunities and resources, and low opportunity to be considered by the government to deal with hazard mitigation (Blaikie *et al.*, 1994). The **dynamic pressures** such as rapid population growth, epidemic diseases, rapid urbanisation and deforestation translate the root causes into vulnerability due to unsafe conditions. As a result, communities are incapable to survive within hostile conditions (Blaikie *et al*., 1994). The **unsafe conditions**, such as living in a hazardous place, incapability to construct quality houses, dependency on dangerous livelihoods and minimal food entitlements, are the driving factors in which vulnerabilities occurred over time and space in a combination of hazards (Blaikie *et al*., 1994). The *release* part of the model is incorporated to reverse the mechanism that translates the root causes of vulnerability into an unsafe condition (Blaikie *et al*., 1994). The main aim of the release model is to reduce disaster risk of the vulnerable people. The central weakness of the pressure and release model is that the development of vulnerability is not combined with the mechanisms in which natural hazards affect people.

2.4.2 Sustainable livelihood framework

The sustainable livelihood framework was developed in the area of development studies to provide a framework for disaster managers and development practitioners. It seeks to understand how persons or groups derive their livelihoods by drawing on or combining five types of capitals (human, social, financial, physical and natural). The sustainable livelihood framework begins with the vulnerability context (shocks, trends, seasonality) in which the society is living their everyday life, and the livelihood assets (human, natural, financial, social and physical capitals) that they possess. Then it looks at how civil society organisations, public and private institutions and processes that generate livelihood strategies that lead to livelihood outcomes (more income, enhanced welfare, reduced vulnerability, sustainable use of resources) (Department of International Development [DFID], 2011). Although the sustainable livelihood framework is a significant framework to understand the livelihood bases of communities and their vulnerability to shocks or stresses which affect the community's well-being, it does not place emphasis on informal institutions, but rather places more emphasis on formal institutions. The framework does not clearly address the coupled human–environmental systems.

2.4.3 Resilience conceptual framework

The resilience conceptual framework as developed and explained by Frankenberger *et al.* (2012 (Figure 2.1), was designed to give a comprehensive understanding of the drivers and processes that affect resilience and vulnerability of the society. In an altering social, economic and natural environment, this framework should finally help stakeholders indicate, estimate and model different vulnerability and resilience pathways in a community. According to Frankenberger *et al.* (2012), the components of the resilience conceptual framework include the following:

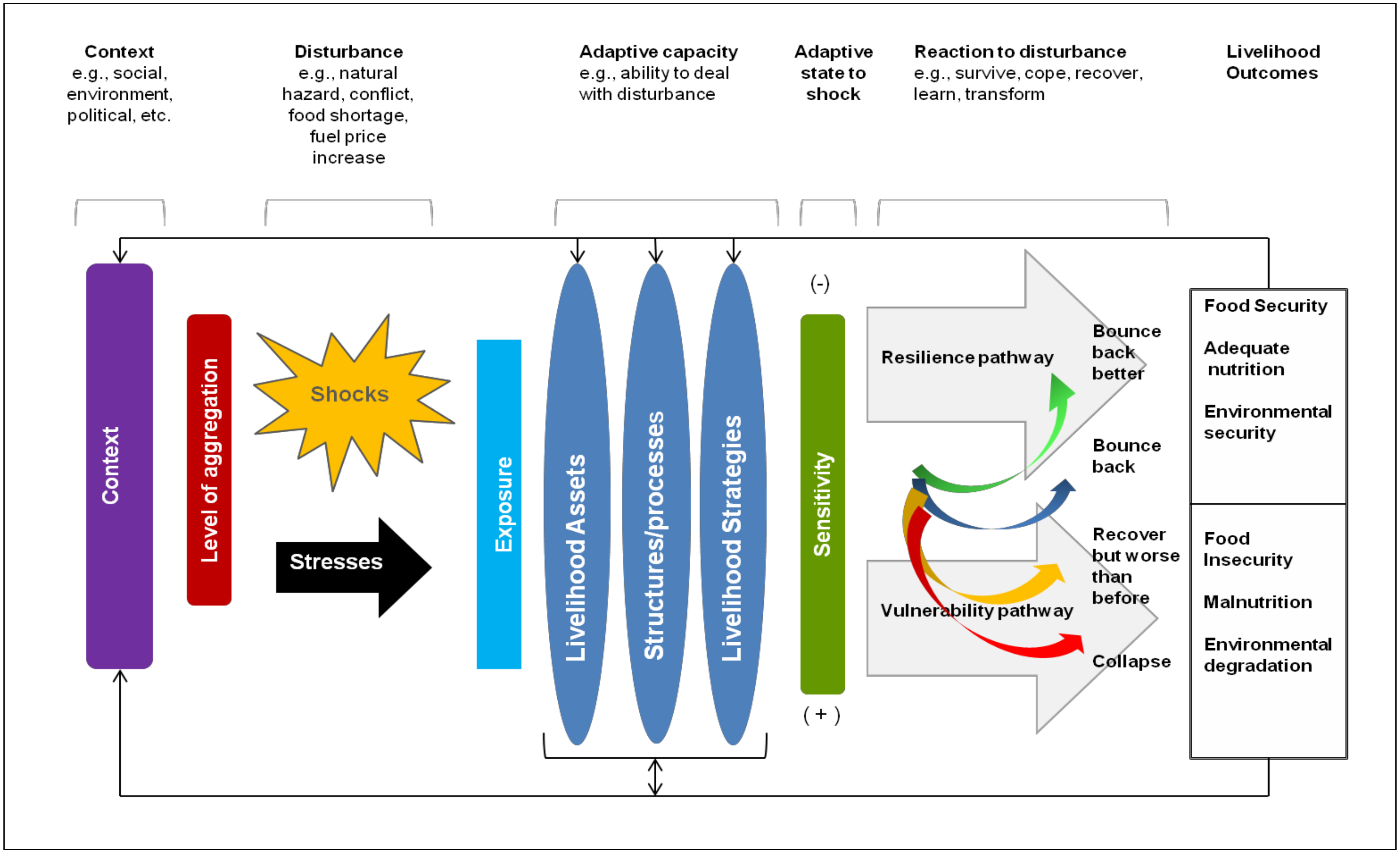
i. **Context**: Refers to social, demographic, environmental, economic, political, historical, conflict, policy conditions, and religions that disturb and are impacted by people resilience.

ii. **Disturbance**: Includes shocks (for example, droughts and floods), stresses (for example, political instability, price increases, environmental impoverishment, and climate change and variability).

iii. **Adaptive capacity**: Involves the ability of households to deal with disturbances such as livelihood assets, structure and processes, and livelihood strategies employed by households.

iv. **Vulnerability and resilience pathways**: The term ‘pathway’ refers to the concept that both resilience and vulnerability are reasonably seen as a process rather than static states. Households who are capable of managing shocks or stresses that they are exposed to and decrease their vulnerability, are less susceptible and are on a resilience pathway. However, those that have low adaptive capacity to deal with shocks and stresses are susceptible and are likely to follow a vulnerable pathway.

v. **Livelihood outcomes**: Refers to the household’s interests and needs that they intend to achieve. Resilient households will be capable to achieve the food security of its family, will have access to sufficient nutrition, will ensure availability of a secured environment, will be able to meet secured health and income, and will be capable to send their children to school. Vulnerable households experience insufficiencies or high risk of insufficiencies in these characteristics.



Source: Frankenberger *et al.* (2012:4).

Figure 2.1 Disaster conceptual resilience framework

Therefore, this resilience framework combines a framework of livelihoods, framework of disaster reduction, and components of a climate change approach to understand the basic causes of vulnerability of individuals to shocks and stresses. The resilience conceptual framework also helps to know how the socio-economic, environmental and political factors impact the resilience of the community and develop appropriate policies and strategies to address the critical problems.

2.5 Resilience conceptual framework for Afar pastoralists

The present study aimed at understanding the resilience status of pastoralists to climate-related shocks, such as droughts and floods, and climate stresses such as climate change and variability. This study also aimed at identifying the coping/adaptation strategies of the households in the Southern Afar region. Therefore, an attempt has been made to employ the conceptual framework developed by Frankenberger *et al.* (2012), with some modifications. The reformed conceptual framework and description of the elements of the framework for resilience that fitted to Afar pastoralists are described below.

The central focus of the conceptual framework was the social-ecological system connected by arrows (Figure 2.2). Decisions and actions emerging from the social system on how to use and manage the rangeland resources and services from the ecological system such as pastures and water, fuel wood, maintain a continuous and dynamic interplay between these tightly coupled systems. In the present study, this conceptual framework was designed to analyse the resilience of pastoral households, considering climatic and non-climatic drivers that are acting on the system. These drivers fall into four categories: (i) shocks and stresses; (ii) trends; (iii) institutions and policy, and (iv) adaption and coping strategies.

The shocks and stresses (drought, floods, livestock and crop loss, and illness) on the upper part of the framework in Figure 2.2 can shape and transform the livelihood strategies of pastoral communities in arid and semi-arid areas of the Afar region. Climatic extremes, particularly recurrent droughts, act on rangeland and result in depletion of water and pasture resources which are critical for pastoral production systems in arid areas of the Afar region.

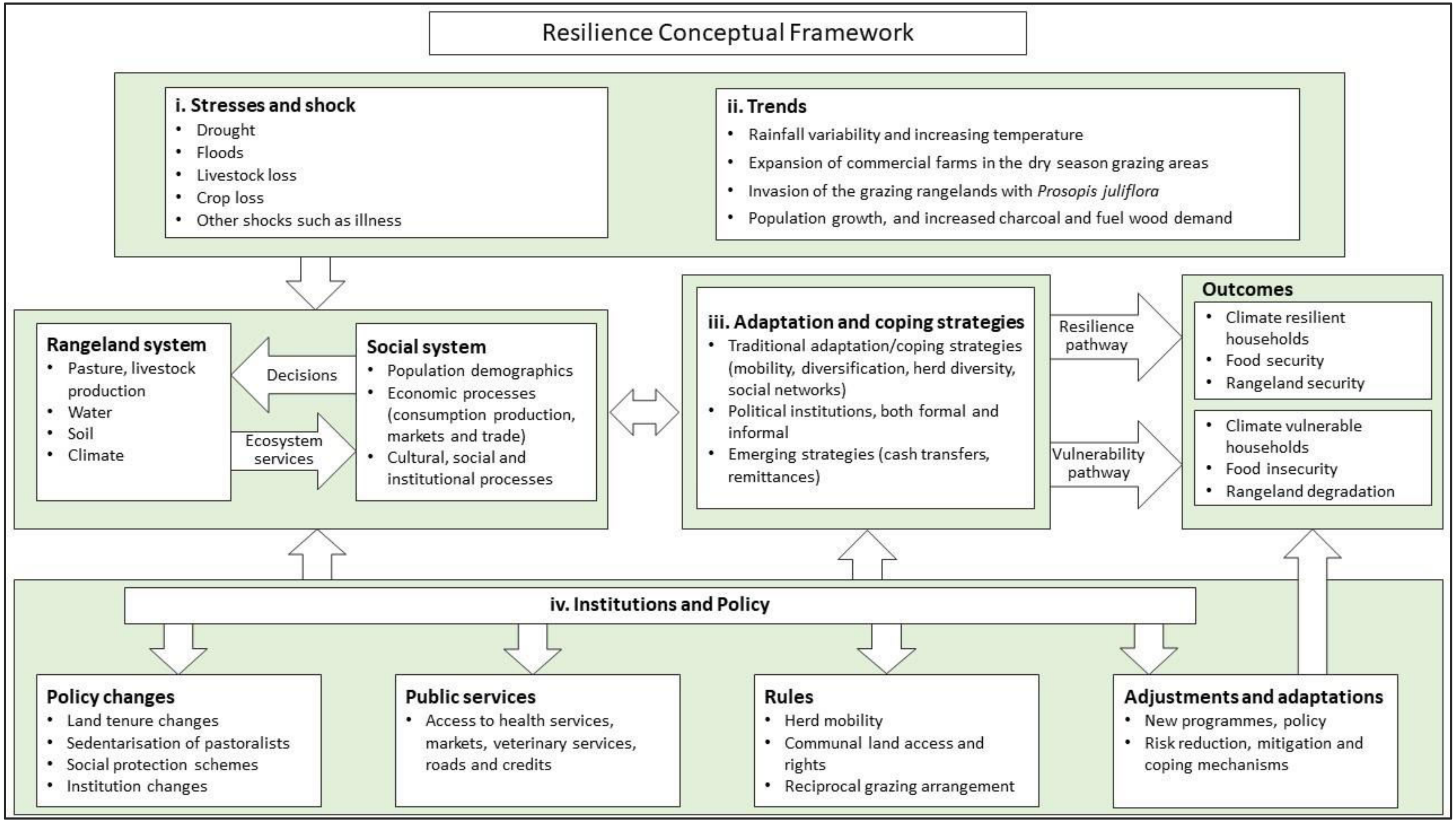


Figure 2.2 Resilience conceptual framework for understanding pastoralist's resilience to climate variability and change in the Afar region

The incidences of severe and recurrent droughts can result in the deaths of large numbers of livestock, resource-based conflicts, livestock disease outbreaks and environmental degradation, which in turn affects the resilience and well-being of the society (Woldetsadik & Hailu, 2011).

On the other hand, trends on the upper part of the framework (Figure 2.2), such as rainfall variability and increasing temperature, expansion of commercial farms in the dry season grazing areas, invasion of an alien shrub, *Prosopis juliflora,* on rangelands, and population growth, can affect the rangeland ecosystem services which in turn threaten the sustainability of pastoralism. Rainfall variability causes shortage of pasture, which in turn affects livestock assets. It can also lead to changes in rangeland species diversity, water resources and forage quality. The increasing temperature trends can also reduce the surface water which can compound the increased demand for water by livestock and humans. The increased temperature beyond its normal range can cause lignification of forages which affects the palatability and digestibility of forages. Temperature increments from the normal range can impact animal production. Warmer and drier conditions increase animal thermal stress with resultant declines in meat, dairy production and measure of animal success, such as conception rates (Easterling *et al*., 2007).

Furthermore, allocation of the dry season grazing areas along the Awash River for commercial farms can affect the resilience of pastoralists to climate variability, and change as their main strategy, *mobility*, might be restricted during dry seasons. *P. juliflora* expansions in the Afar rangeland also suppress palatable grass and browse species which further aggravates the influences of climate-related shock on Afar pastoralists. Many pastoralists own few livestock today than they did in the past due to degradation of rangeland resources as a result of climate extremes such as droughts and floods and non-climate drivers, for example allocation of prime grazing areas for commercial farming and urbanisation (Reid *et al*., 2008).

The other important trend, *population dynamics*, greatly alter the dynamics of the coupled social-ecological system. Population dynamics can include not only increasing human population pressures, but also reduced herder populations due to patterns of rural to urban migration. The economic opportunities and the social and other services that cities provide are attracting the younger generation of pastoralists who are leaving their traditional homes and livelihoods, with significant consequences for the resilience and running of the pastoral system.

On the other hand, the herder's decision and action in response to an environmental change is highly determined by the institutions and policies such as policy changes, public services and rules. For example, mobility is the main strategy of the pastoral society in response to climate shocks, such as droughts, as it offers access to key resources such as water and forage resources for livestock during the drought season. The movements of grazing animals across the landscape also provide an opportunity for the grazed landscape to rest and recover. However, local and national government encourages pastoralists to settle because they can control less mobile pastoral populations, tax them and provide social services to them. Settlement encourages privatisation and fragmentation of rangelands which makes the social-ecological system more susceptible to climate-related shock. In contrast to this, government working towards in support of traditional practices of the pastoral community, such as mobility and common property regimes, co-management and capacity-building can reduce the vulnerability of a pastoral community. This can also improve coordination between the community and the government. Institutions and policy have a significant impact on access to assets, namely: They (i) generate assets, for example, if government works towards improving infrastructures, promoting human capital or the presence of local organisations that reinforces social capital; (ii) govern access, for example, tenure rights; (iii) impact rates of asset growth, for example, policies that impact earnings from various livelihood activities and taxation. Government commitments regarding early warning information (EWI), preparedness and supporting the community to respond and recover from climate-induced shock impacts can enhance the resilience of pastoralists. All these factors shape the way various assets (land, labour) are used in production strategies.

The resilience conceptual framework also depicts the coping/adaptation strategies of pastoralists, which may either lead to climate resilient households or climate vulnerable households, depending on the relationship and interactions among other components of the resilience framework. The coping/adaptation mechanisms include livestock mobility, livestock diversification and splitting, and traditional social security systems. Using this conceptual framework, this study identified which elements of the framework made the household resilient to climate change and variability, and which drivers increased the vulnerability of the households in the Afar region. It also contributed to scientific understanding of the specific response adaptation and coping strategies that pastoralists were using to cope with climate-induced disturbances for more effective targeting of policies and resilience programmes.

2.6 Vulnerability, Conceptual Context and Analytical Tools

Vulnerability is multidimensional and its conceptualisation has developed over time (Cutter *et al.*, 2003). According to Finan *et al.* (2002), vulnerability is conceptualised by different disciplines in various approaches depending on their subject matter, purposes to be accomplished and the approaches developed. Due to these variations, there is no universally recognised definition for measuring vulnerability.

This study used one of the most widely recognised definitions of vulnerability by the IPCC, where vulnerability refers to how much the system is susceptible or incapable to adapt to adverse impacts of climate-induced shocks and stresses (McCarthy *et al.*, 2001). Therefore, vulnerability is a function of the adaptive capacity, exposure and sensitivity of the system. According to Deressa *et al.* (2008), the socio-economic, biophysical and integrated assessments are the three techniques identified in measuring vulnerability. The socio-economic vulnerability assessment approach identifies the political and socio-economic aspects of a household or a community that may decrease or increase their vulnerability to a disaster risk (Adger *et al.*, 2004). Vulnerability, thus, is taken as the combined impacts of risk and social vulnerability that leads to some consequences, such as loss of life and properties (Brooks & Adger, 2003). Adger *et al.* (2003) also considered a socio-economic vulnerability as the quality of a system that causes the potential for damage. For example, households in a specific area usually vary with respect to income, skills and knowledge, gender, credit access, type of building, well-being and assets. These socio-economic factors are the driving forces for the variations observed among household vulnerability levels.

Furthermore, biophysical vulnerability focuses on the eventual influences of a disaster. According to Adger *et al.* (2004), biophysical vulnerability refers to the extent of harm occurred in the system due to disasters. Thus, the biophysical approach measures the degree of harm due to climate perturbations and stresses on the systems (Jones *et al.*, 2005). The biophysical, or impact assessment approach is mostly focused on the physical influence of change in climate on various features, such as harvest and earnings (Füssel, 2007). Though very useful, the impact assessment approach has its own weaknesses. Its main weakness is that its emphasis is mostly on physical damages, such as productivity and revenue. For instance, research on the influence of change in the climate on crop production can reveal the decline in productivity as a result of a rise in temperature or rainfall reduction. Thus, from these simulations, one can understand the amount of yield that declined due to increased temperature or a decline in rainfall. However, it will be difficult to understand what that specific decrease means for various households.

Both socio-economic and biophysical approaches are combined to measure vulnerability. The definition of vulnerability given by the IPCC also explains this integrated vulnerability assessment approach. However, this approach has no standard method for merging the social, economic and environmental indicators. This approach also does not consider vulnerability changes over time or the dynamics of vulnerability. Persistent changes of community strategies to use the benefits of opportunities are the main features of adaptation and coping (Eriksen *et al*., 2007). Therefore, dynamics of the vulnerability are not considered under the integrated assessment approach. Despite its limitations, the integrated assessment approach provides significant contributions for policymakers.

Various methods are available in the literature to measure vulnerability, though some problems have been observed in its quantification. The econometric approach is one of the methods employed to assess the degree of vulnerability among individuals or communities or regions, by employing individual level, community or regional level data (Hoddinott & Quisumbing, 2008). The other approach to assess vulnerability is the indicator approach. The indicator approach targets to assess vulnerability to climate-induced impacts by integrating the indicators of socio-economic features (adaptation capacity and sensitivity) and biophysical impacts (exposure) (Gbetibouo *et al*., 2010). The present study used an integrated assessment approach based on biophysical and socio-economic indicators to assess vulnerability.

It is significant to consider the various aspects of vulnerability for better planning and application of policies that advance equitable and sustainable development. Nevertheless, it is difficult to quantify vulnerability, since it is a latent variable. According to Hebb and Mortsch (2007), identifying and quantifying the indicators of socio-economic and biophysical characteristics are the best approach in measuring vulnerability to climate-induced stresses and shocks. Birkmann (2010) also explained the indicators of vulnerability as variables which are operational representations of a characteristic or quality of a system able to offer information regarding the sensitivity, coping ability and resilience of the system's components at risk to the impacts of a hazard. Vulnerability indicators are vital to identify the most vulnerable social groups or natural resources which are crucial for policymakers to give priority for vulnerable communities in their development intervention (Clerici *et al*., 2004). The indicator approach can be useful at global, national, regional and local level (Brooks *et al*., 2005). However, the indicator approach has its own restrictions. The selection of indicator variables and assigning weights to them is very subjective (Luers *et al*., 2003).

2.7 Summary

In this chapter, the theoretical framework provided a general understanding of the adaptive cycle theory. The theory explained that all systems undergo disturbances and follow four phases of adaptive cycles: (i) growth phase – a system that grows slowly; (ii) conservation phase –- a system that accumulates wealth for a continued period of time; (iii) release phase – a system that collapses upon a disturbance; and (iv) reorganisation phase – allows the system to grow either in the same or a different state. This broad scope explanation of the adaptive cycle theory guided this study to formulate the present research work and develop the following research questions: (i) What are the adaptive capacities of pastoralists in the Afar region that enables them to cope with and recover from climate-related shock such as droughts and floods, and climate stress such as climate change and variability? (ii) What are the resilience and vulnerability status of the Afar pastoralists? (iii) What are the drivers that make the pastoralists susceptible or resilient for climate-related shock and stress, (iv) What are the driving forces of rangeland ecosystem changes in the Southern Afar region?

Recently, conceptual frameworks to assess the resilience and vulnerability of a system to natural disasters have been developed by different researchers. However, each conceptual framework has its own limitations and benefits to resilience and vulnerability assessment of a system. For instance, the pressure and release model is mainly useful for understanding the various faces of interaction between factors of vulnerability and hazards. It identifies the root causes of vulnerability such as limited access to resources, structures, power, and ideologies, and determines the dynamic pressures such as rapid population growth, epidemic disease, rapid urbanisation and deforestation that translate the root causes into vulnerability due to unsafe conditions. The release model is incorporated to reverse the mechanism that translates the root causes of vulnerability into an unsafe condition. However, the central weakness of the pressure and release model is that the development of vulnerability is not combined with the mechanisms in which natural hazards affect people. The other conceptual framework that was discussed in this chapter was the sustainable livelihood framework. It seeks to understand how persons or groups derive their livelihood by drawing on or combining five types of capital (human, social, financial, physical and natural). However, this framework is crucial to understand the livelihood bases of communities and vulnerability to shocks or stresses which affect a community's well-being, it does not place emphasis on informal institutions but rather places more emphasis on formal institutions.

The resilience conceptual framework developed by Frankenberger *et al.* (2012) was the third conceptual framework discussed in this chapter. It was designed to give a comprehensive understanding of the drivers and processes that affect resilience and vulnerability of individuals or communities. This resilience framework combines a framework of livelihood, framework of disaster reduction, and components of a climate change approach to understand the basic causes of vulnerability of individuals or communities to shocks and stresses. Therefore, an attempt has been made to employ the conceptual framework developed by Frankenberger *et al.* (2012), with some modifications, to understand the resilience and vulnerability status of Afar pastoralists. In the next chapter a comprehensive literature review will be discussed with respect to an overall review of climate change and variability and its impacts on the livelihood of people and the challenges facing pastoral communities and their traditional adaptations/coping mechanisms.

Chapter 3
LITERATURE REVIEW

3.1 Introduction

Change in climate and climate variability is happening all over the globe (IPCC, 2013, 2014a). A few realities about this change involve the following: rising of surface temperature on the globe (temperature has risen by 0.74 °C in the twentieth century); ice melting in the Polar Regions (an annual average rise in sea level by 3.1 mm) (Lemma *et al*., 2013). Change in climate has several components that impact human and biological systems in various ways. Change in climate and climate variability are frequently perceived as main threatening variables to food security in regions of the globe that are, to a great extent, subject to rain-fed farming systems (Parry *et al*., 2004). The poorest and marginalised people are particularly the most susceptible groups in these countries because of their restricted capacity to grasp the opportunity to make adaptive decisions (Thomas & Twyman, 2005). People in the Horn of Africa (a peninsula in Northeast Africa) are frequently thought to be among the most vulnerable, but on the other hand, are thought to be the least prepared for the negative influence of climate-induced shocks and stresses (Amsalu & Adem, 2009). Ethiopia has been commonly considered as a home of starvation, particularly starting from the last thirty years of the twentieth century, mainly due to increasing vulnerability to climate-induced shocks and stresses. Recently, the pastoral communities occupying the arid and semi-arid areas of the country have especially turned out to be progressively vulnerable to persistent destitution, somewhat because of their intermittent exposure to the negative impacts of climate-induced shocks and stresses. In this review, the possible influence of change in climate and climate variability on food and biological systems, health and nutrition will be discussed. Furthermore, the current and future trends of the climate in East Africa, adaptation to climate, overview of climate change and variability in Ethiopia will also be discussed. This chapter will also provide an overview of pastoralism focussing on the main challenges facing pastoral communities in East Africa, Ethiopia and the Afar region.

3.2 Climate Change and Variability

The human and natural systems can be impacted by change in climate and climate variability in various directions (IPCC, 2012). The impacts of climate change have been broadly studied at different spatial scales. The increases in average global temperatures are characterised by substantial variances in temperature increase between dry land and water bodies and between high- and lowland areas. On the other hand, it is more likely that rainfall increases in highland areas, while it declines in most of the tropics and subtropical land regions. The impact of climate change on the natural and human systems is linked to the duration and extent of droughts, floods and other climate-induced shocks and stresses (IPCC, 2007a). It is projected that the incidences of heat stress, droughts and floods will increase in the future and will have more serious impacts than due to alterations in mean variables only (IPCC, 2012).

Change in climate is happening, which impacts natural resources and food security (Bates *et al.*, 2008; Brown & Funk, 2008; IPCC, 2013). Since the late nineteenth century, global temperature has been increasing, resulting in an increasing temperature for the previous thirty years, and the warmest decades had been observed during the twenty-first century (IPCC, 2013). The world's average temperature has risen by 0.72 °C since 1950 and caused a high incidence of warmer days and nights, and increased heat waves, and a decline in the incidence of cold days and nights (IPCC, 2013). The global temperature will continue to increase if no mitigation strategy is implemented to reduce the emissions of greenhouse gas (Collins *et al.*, 2013). Temperature will rise in the range 0.3–4.8 °C close to the end/middle of the twenty-first century, based on greenhouse gas emission situations (Collins *et al.*, 2013; Kirtman *et al.*, 2013). In vast areas of the world, water cycle changes can also be observed due to global warming, such as changes in patterns and intensity of rainfall, an increase in atmospheric water vapour and a declined snow cover (Bates *et al.*, 2008; IPCC, 2013).

According to Ravallion (2012), around 48% of the inhabitants in Africa are under poverty. People in Africa are the most susceptible to climate-related shocks and stresses due to deepening of poverty and, hence, unable to deal with climate-induced shocks (Eriksen *et al.,* 2007; Wheeler & Von Braun, 2013). In Africa, climate extremes such as floods and droughts are frequently observed climate-induced hazards, representing 80% of the loss of life and 70% of property damages (Bhavnani *et al.,* 2008). As a result of changes in climate and variability, the severity of climate extremes will increase in Africa (IPCC, 2007b). The people in Africa are largely dependent on rain-fed agriculture, which is characterised by low input and output, and thus, they are highly susceptible to changes in climate as their economy is climate sensitive (Chauvin *et al*., 2012).

3.2.1 Impacts of climate change and variability

3.2.1.1 Impacts on biological systems

The suitable temperature for livestock is in the range of 10–30 °C (Thornton *et al.,* 2014). Maintenance requirement for feed may rise to 50% if the temperature is below this range, while feed intake may decrease up to 3–5% if the temperature is above this range. Changes and variability of climate can impact the quantity and quality of livestock feed. Recurrent and prolonged droughts can cause severe feed shortages which can affect livestock numbers, reproduction and productivity, especially in dry land areas (Thornton & Gerber, 2010; Thornton *et al*., 2014). In pastoral lands of East Africa, when drought occurred once in five years, there was a possibility to maintain a constant number of cattle (Thornton, 2010). However, when the incidence of drought increased from once every five years to once every three years, it would decrease livestock assets, making it difficult to recover (Thornton, 2010). For example, in Kenya, a loss of 1.8 million additional cattle is expected by 2030 due to the recurrent droughts (Ericksen *et al.,* 2013).

According to Craine *et al.* (2012), the seasonal variability of climate is as significant as its amount in determining the grassland productivity since the main functions of the rangeland ecosystems are sensitive to seasonal variability in climate, and hence, it is essential to recognise the timing of variability of climate variables to increase the understanding of plant productivity. Since livestock are plant species selective during grazing, the heterogeneity of plant species in a given rangeland is a main factor in shaping the productivity of livestock. The species composition will be changed in grasslands as the patterns and trends of temperature and rainfall and CO_2 levels change (Craine *et al*., 2012). The species composition of grasslands and its dynamics may be impacted due to changes in climate and climate variability and these may have an impact on livestock production (IPCC, 2007a). Nevertheless, the overall influences of variability and change in climate on species composition and quality of grassland are not yet understood and remain to be clarified (IPCC, 2007a). Herrero *et al.* (2010) indicated that future variability and change in the climate may change the relationship that exists in many places between livestock production and crop farming. Livestock production may become an optional livelihood in places where crop production becomes a challenge. The increase in the likelihood of periodical rainfall failure in the arid livestock–crop production systems of Africa may see such transitions becoming common in up to 3% of the total area of the continent.

Furthermore, climate change and variability also considerably impacted the occurrence and spread of livestock diseases such as Rift Valley fever in East Africa and northern Europe, and African horse sickness in South Africa (Baylis & Githeko, 2006). According to Martin *et al.* (2008), it is projected that the prevalence and distribution of Rift Valley fever in the northern part of Europe may increase due to future increases in the frequency of extreme weather events in the region. However, the impacts of future variability and change in climate on outbreaks of disease and pests are not well-known (Gornall *et al.,* 2010).

Although excessively cool or hot weather will negatively impact plant productivity, moderate rise in temperature will generally accelerate plant growth and development. It has been observed that higher temperatures caused earlier flowering and maturity of several crops (Craufurd & Wheeler, 2009). However, a reproductive failure and decline in yield of many crops have been observed linked to a rising in maximum temperature. For example, Lobell *et al.* (2011) indicated that a reduction of 1.7% of maize yield was observed for each spent above 30 °C per day during drought seasons. Mohammed and Tarpley (2009) also reported that a 90% decline in rice yields was observed at night temperatures of 32 °C compared with 27 °C. In addition, climate variability also impacts yield quality. The findings reported by Porter and Semenov (2005) indicated that as the mean and variability of climate variables (rainfall and temperature) change, the protein content of wheat grain also changes; especially, a rising temperature during grain filling can impact the protein content of wheat grain (Hurkman *et al.,* 2009).

Furthermore, rainfall variability also drives inter-annual crop yield variability. Hlavinka *et al.* (2009) revealed that a significant correlation was observed between a monthly drought index and the yields of crops sown during spring and winter seasons for several years in the Czech Republic, indicating different sensitivities for drought. Furthermore, a research conducted by Rowhani *et al.* (2011) in Tanzania revealed that cereal yields were impacted by seasonal variability of rainfall and temperature. It is expected that rainfall and temperature variability will have an important influence in the future of ecosystem services provided by rangelands and forestry systems. Climate change and variability needs to be well-understood, even though there is uncertainty to know the exact changes in the environment. Rowhani *et al.* (2011) reported that the influence of climate variability on crop yields may be undervalued in East Africa in the range of 4–27%, depending on the type of crops and taking the long-term mean variations in climate in consideration.

It is expected that the onset and extent of the growing period will be altered due to variations in the amount and patterns of precipitation. Thornton *et al.* (2010) indicated the anticipated variations in the length of the growing season for Africa to the 2090s. The authors anticipated that a large percentage of the cropland and rangeland of Africa will decline in the length of the growing season and a minimum of 20% loss in most of Africa in the southern latitudes. Similarly, season failure is more likely expected all over sub-Saharan Africa, excluding central Africa. In southern Africa, less than latitude 15°S, it is projected that there will be a failure of nearly all rain-fed agriculture in every two-year period (Thornton *et al.*, 2010). Thornton and Gerber *(*2010) further reported that the robustness of these projections regarding intra-model variability is low in southwestern Africa and the Sahel region. Crespo *et al.* (2011) also reported regarding the onset of the growing season and forwarded their argument that parts of southern Africa may adapt to projected climate changes by the 2050s for maize production by changing planting dates. During the larger climate change and variability, especially when critical thresholds in rainfall and temperature are reached, more fundamental variations in the length of the growing period may occur and this phenomenon may force farmers to grow drought resistant crops (Gornall *et al*., 2010). There is still relatively few information to confirm vegetation changes due to an increase of changes in climate and incidences of extreme climatic phenomena. However, there are reducing processes that can minimise and offset the impacts of climate-related shock, strengthening resilience of the society (Lloret *et al.,* 2012).

3.2.1.2 Impacts on food systems, health and nutrition

There is little information about the impacts of climate change and variability in the food system as compared to food production. A study conducted by Codjoe and Owusu (2011) in Ghana indicated how droughts and floods disturb food grain production in rural areas, transportation, processing and storage. According to Codjoe and Owusu (2011), enhancing food security in this region could be achieved through improving farm-based storage facilities; advancing the transportation system, particularly linking market centres with food production areas; promoting farmers' access to affordable credits and early warning systems; and supporting irrigation farming.

Change in climate and variability has direct as well as indirect impacts on human health. The elders are more susceptible to climate shocks such as heat stress (McMichael & Kovats, 2000). Temperature and rainfall interacts with vector-borne and infectious diseases which directly affect the well-being of human beings. Costello *et al.* (2009) reported that the seasonal variability of rainfall and climate extremes such as floods and droughts affect the prevalence of cholera, malaria and dengue fever. McMichael and Kovats (2000) indicated that if variability of rainfall and temperature patterns causes changes in temporal and spatial variation in water distribution and vegetation, we would see more disease outbreaks as the vector moves to new areas. McMichael and Kovats (2000) further indicated that El Niño and La Niña cycles can be linked to the occurrence of malaria and dengue fever. An increase in climate variability could cause massive human displacement, especially due to climate shocks such as droughts and floods. Poor sanitation, scarcity of clean water, displacement and damages of infrastructure and lack of proper health care services, which are common in developing countries, could aggravate the influences of climate shocks and stresses on human health (Few, 2007; Haines *et al.,* 2006).

Healthy living is a product of good nutrition. Sufficient amounts of calories, together with adequate nutritional diversity and proteins, are very vital to human health. As delineated above, overall availability of food shows some correlation with variability and change in climate. Nelson (2009) indicated that climate shocks and stresses will impact food production and have a continuous influence on the incidence of under nutrition, thereby increasing severe stunting by 55% in East and southern Africa and 62% in South Asia by the 2050s. Nutrition is not just the unavailability of food, but also the access to nutritious food as well as proper child care practices (Tirado *et al.,* 2010).

3.2.2 Climate change, trends and projections in East Africa

Studies indicated that in East Africa temperature trends have been increasing. Average temperatures throughout East Africa have generally increased from 1–3 °C over the past five decades (Christy *et al*., 2009). These authors further reported a warming trend at a rate that was consistent with broader global and African trends. Furthermore, changes in extreme temperature events have been observed in East Africa and the evidence indicated that the duration of warm spells, and extreme maximum and minimum temperatures have been increasing (Mekasha *et al*., 2014; Omondi *et al.,* 2014).

Climate research at the national level supported the regional temperature trends. There was a significant increase in seasonal and annual trends of night time temperatures in the Ethiopian Blue Nile Basin, while opposing trends of daytime temperatures were observed in the same study area (Mengistu *et al.,* 2014). According to Meikle (2010), climate data for Ethiopia from 1951–2006 indicated a general warming trend estimated at 0.37 °C per decade in Ethiopia. A more noticeable temperature was observed in the semi-arid lowland regions of Ethiopia which was higher than the national average and the highland regions. For instance, Amsalu and Adem (2009) reported that the Borena, Guji and South Omo regions of the southern lowland have experienced a rising trend in temperature by 0.40 °C every 10 years over the period 1950–2000.

McSweeny *et al.* (2009) also indicated rising trends of the annual mean temperatures by 1.0 °C since 1960 at a mean rate of 0.21 °C every ten years in Kenya. The prominent indicator of the increasing temperature trend has been the decrease of the Lewis Glacier on Mount Kenya, which has experienced a loss of approximately 40% of its mass since 1963 (MENR, 2002). Christy *et al.* (2009) analysed the climate of East Africa investigating the air temperature of 60 weather stations all over Kenya. The study reported significant increasing trends in lowest temperatures in the highlands region of Kenya, using the spatially interpolating station-based data. Omumbo *et al.* (2011) also indicated that there were rising trends of mean, maximum and minimum temperatures from 1979–2009 in Kericho, Kenya.

Temperature trends were observed over the past five decades, though rainfall trends were imprecise, and there existed great differences in the direction and rate of changes throughout East African regions. Increases in rainfall were observed in some areas, while there was a reduction in rainfall in other areas but, overall, trends were generally weak and sometimes difficult to detect (Daron, 2014). Over the last 50 years, there has been considerable variability in rainfall almost every decade. During the previous period of fifty years, there had been considerable inconstancy in precipitation for multiple decades. A few areas, for example the central parts of Ethiopia, were curiously wet in the 1970s and strangely dry in the 1990s. Different locales reveal the inverse trend (Omondi *et al*., 2014). Prominent precipitation change seems to have happened in the March to May season over vast parts of the East African regions, particularly in Tanzania, Kenya and in southeast Ethiopia, all experiencing declining rainfall below 100 mm (Christy *et al.,* 2009).

Certain highland regions of Ethiopia experienced dryness in the June, July and August seasons, while some parts of South Sudan experienced an upward trend in rainfall during the same season (Christy *et al.,* 2009). These examples of progress are not steady over the areas and, hence, signals showing the systematic changes are not strong. Certain researchers in Ethiopia have indicated descending trends of precipitation in certain areas of the nation, basically in the southern, south-eastern and eastern areas (Seleshi & Camberlin, 2006; Seleshi & Sanke, 2004). According to Conway and Schipper (2011), decreasing trends of the Belg rainfall were observed in most parts of eastern Ethiopia. However, other climate-related studies in the central and northern regions of Ethiopia could not indicate any significant rainfall trends (Bewket & Conway, 2007; Mekasha *et al.,* 2014; Mengistu *et al.,* 2014).

On the other hand, more prominent precipitations were experienced in Kenya during periods of 'short rains' in the October to December months, especially in the northern region of Kenya, where the precipitation have started to reach into the warm and dry months of January and February (GoK, 2010; Butterfield, 2011). Contrarily, it was observed locally that the 'long rains' of March and April have become increasingly erratic in the Eastern Province of Kenya (Awuor, 2009). Rainfall has experienced a change in intensity, with more intense rains along the coast of Kenya (MENR, 2002). Empirical evidence in Ethiopia has indicated that there is no systematic evidence to show constant alterations in the extent, incidence or strength of the extreme climate (Bewket & Conwy, 2007; Mekasha *et al.,* 2014). There were significant downward trends in total rainfall in rainy days of more than 1 mm in East African regions (Omondi *et al.,* 2014). However, this study revealed the occurrences of high intra-seasonal and inter-annual precipitation variability, followed by risks of drought and floods.

Significant increases of temperatures are predicted across the East African region. Daron (2014) reported that the central and northern regions of East Africa are anticipated to experience the largest increases in temperature. Even though it is difficult to predict temperatures with full certainty, the predicted increases in annual mean temperatures will be in the range of zero change to 4 °C by 2050. For East African countries, IPCC (2014a) predictions indicated a rising temperature in the range of 0.2 °C to more than 0.5 °C, an increase rainfall in the range of 5 to 20% during the months of December and February, a decrease rainfall in the range of 5 to 10% during the months of June and August. An increasing mean temperature of 1 °C in the 2020s and 3.9 °C in 2080s is predicted for Ethiopia (Department of International Development, UK [DFID], 2009). Weldegebriel and Prowse (2013) reported a significant rising of annual mean temperature as compared to 1961–1990 temperature trends and predicted temperature rises of 1.1 °C in 2030, 2.1 °C in 2050 and 3.4 °C in 2080. Funk *et al.* (2010) also predicted that plateaus and mountain ranges of Kenya might experience much cooler than the lowlands. By 2025, the western region of Kenya is predicted to experience increasing temperatures in the range of 0.9 to 1.1 °C, while the southern coastal area could experience a rise in temperatures at a mean rate of 0.5 °C, and in the north-eastern region of Kenya, temperatures could increase by 1.1 °C.

3.2.3 Adaptation to climate change

The two alternatives to decrease the negative influences of climate-related stress and shocks are adaptation and mitigation (IPCC, 2007a). Mitigation denotes the reduction of greenhouse gas emissions to decrease the damages of climate change and variability and climate extremes, while adaptation refers to adjustment in human or natural systems in reaction to real or predicted climate-induced stress and shocks to reduce climate-related hazards or uses beneficial opportunities as a result of climate change (IPCC, 2007a). According to Smit *et al.* (2000), adaptation is defined as any adjustment to moderate the expected negative impacts linked with changes in climate. Although mitigation aims to alleviate the root causes of change in climate and provides long-run solutions, adaptation is necessary given the current situation of the globe. Füssel (2007) argued that much attention should be given to adaptation, mostly due to the fact that the climate system is affected by anthropogenic activities; climate change is expected to persist, given past trends; mitigation strategy takes several decades to see its impact; and adaptation can be implemented at the district or regional level.

Adaptation can be implemented at individual level or at society level. At the individual level, adaptation activities are likely to be autonomous while government agencies tend to implement proactive and planned adaptation (Maddison, 2007; Smit & Pilifosova, 2003). The concept ‘autonomous /spontaneous adaptation’ is widely used to describe an adaptation that does not involve an aware reaction to climate change and climate extremes, but is initiated by ecological changes and by the market or changes in well-being (IPCC, 2001, 2007a). There is no involvement of government or non-government organisation (NGO) interventions in autonomous adaptation (Agrawal, 2010). Planned adaptation is the result of a thoughtful policy decision, based on the consciousness that situations have altered or are about to alter and a response to the altered condition is required to achieve a desired state (Adger *et al.,* 2003; IPCC, 2007a; UNDP, 2012). It includes government appraising various social and economic interests, and taking decisions to manage the influence of change in climate (Filho & Mannke, 2014).

Coping denotes human reactions to perturbations, described as an arrangement of short-term activities against a given hazard (Davies *et al.,* 2009). Adger *et al.* (2003) and Eriksen *et al.* (2005) showed that coping activities occur within existing structures, while adaptation underpins altering the structure within which coping occurs through, for example, learning from the previous (Yamin *et al.,* 2005). According to Schindler (2010), sociologists criticised the usage of the terms 'strategy' and 'coping' interchangeably since the previous entails the existence of aware and countrywide decisions including a long-term perspective. In contrast to strategy, coping denotes mostly short-term activities and the associated responses lack planning. On the other hand, Adams (2006) reported that coping includes deliberate response to minimise the severity or extent of the crisis. Furthermore, short-term coping activities, through time, may lead to long-term adaptive strategies and, hence, coping should be taken as a first step to adaptation (Berkes & Jolly, 2002; Cooper *et al.,* 2008). Yamin *et al.* (2005) also related coping as short-term responses intended to sustain or return to the *status quo*. Arguing in the context of the Sahel region, Adams (2006) showed that the focal target of coping is to sustain the different aims of the household and safeguarding individual and/or collective well-being.

People in rural areas whose livelihood is dependent on agriculture are already adapting to climate shocks and stresses since they have lived with climate variability and climate extremes over hundreds of years (IPCC, 2007a). According to Adger *et al.* (2003) and Burton *et al.,* (2002), people have always lived with climate change and have revealed resilience to climate shocks and stresses. Cooper *et al.* (2008) and IPCC (2007a) indicated that adapting to the present climate shocks and stresses can enhance resilience to long-term climate-related hazards. Nevertheless, although some adaptations to the present climate shocks and stresses are happening, farming communities may not essentially show similar levels of resilience in the future, especially, upcoming changes in climate are expected to happen at a rate faster than has been formerly experienced in history (Burton *et al.,* 2002). Challinor *et al.* (2007) also stated that farming communities have established advanced reactions to climatic variability and change to build more viable production systems. However, climate extremes, such as droughts and floods that have happened in Africa, particularly in sub-Saharan Africa over the past 40 years, have revealed that adaptation at household or community level may not sufficiently deal with these extremes (Challinor *et al.,* 2007).

3.2.4 Climate variability and change in Ethiopia

According to the NMSA (2001) reports, the seasonal migration of the Inter-tropical Convergence Zone mainly controls the Ethiopian climate, which is linked to the position of the sun in relation to the globe, and the large-scale movement of the air together with the complex geography of the country. Ethiopia is characterised by landscape heterogeneity as well as recurrent droughts and floods and rising and declining trends of temperature and rainfall (NMSA, 2001). The history of climate extremes, particularly drought, is not uncommon in Ethiopia and the documented history indicated that drought in Ethiopia started before 250 BC (Webb & Braun, 1994). Though droughts are common natural hazards in Ethiopia, its frequency and extent of severity have increased over the past few decades, mainly in lowland areas of the country (Lautze *et al.*, 2003; NMSA, 2001).

In Ethiopia, the livelihood of the people has been seriously affected by variability and change in climate. According to Conway and Schipper (2011), Ethiopia's economy is dependent on climate-driven agriculture, which accounts for more than the gross domestic product (GDP) of 40%, and 90% of national profits from exporting. Hence, agriculture is highly vulnerable to climate-induced shock which may lead to severe food insecurity in the country. The NMSA (2001) revealed a declining trend in annual rainfall over the northern parts of the country and rising trends in the central parts of the country. Projections by means of General Circulation Models for the year 2030 indicated a rise in temperature by 1 °C and a decline of precipitation by 2%. The projections indicated that change in climate leads to severe climate-related shocks, making the food production sector more susceptible. This will definitely result in poor harvests and/or complete crop failure, leading to shortages of food and pastures (United Nations Framework Convention on Climate Change [UNFCCC], 2007).

According to Tadege (2008), Ethiopia has encountered both drought and rainy seasons for the past 40 years. However, rainfall has indicated a general decreasing trend since the 1990s. The food production, domestic water consumption and irrigation schemes have been seriously affected associated with the declining trend of rainfall, particularly in the north, north-eastern, and eastern lowlands of the country. Droughts, heat waves and floods have increased in Ethiopia over the last few decades. Excessive floods due to the high intensity of rainfall in the Ethiopian highlands caused loss of life and damaged properties of the people who inhabited the arid and semi-arid areas (Tadege, 2008). For the past 40 years, the mean annual temperature in Ethiopia has been rising by 0.37 °C dec^{-1}, which is somewhat smaller than the mean global temperature rising (NMSA, 2007).

Conway and Schipper (2011) further reported that in Ethiopia, climate variability and incidences of floods and droughts have increased over time. For instance, flooding has become a common problem and occurs in lowlands where rivers flow over the gentle slopes with higher volume of water from the highlands. The Awash River in the Afar region, the Baro River in the Gambela region, the Wabeshebele, Genale and Dawa Rivers in the Somali region, the Omo, Weyto and Segen Rivers in the South Omo region commonly flood large areas of grazing lands and cause heavy loss of life and damage to resources. Flooding caused by heavy rainfall and river overflowing, has regularly damaged people's lives and their properties, especially those in the lowland areas of Somali, Afar, Gamella, Oromiya, Amhara and the southern regional states. The devastating flood incidences in the Dire Dawa city, Gode in the Somali Regional State and South Omo in the Southern Nations, Nationalities, and Peoples' Regional state (SNNPR) in 2006 are recent examples. Flash floods affect all regions depending on the intensity of rainfall. Floods which occurred during 1996 and 2006 in the region of Gambella and Dire Dawa, respectively, caused loss of lives of hundreds of people, displaced thousands of people and damaged people's properties. According to Osman and Sauerborn (2002), a series of flooding had inflicted environmental as well as socio-economic damage to the central highlands of Ethiopia. On the other hand, Conway and Schipper (2011) indicated that there was a rise in the incidence of drought from one in 100 years in the first century to one in six years in the twentieth century, and also once in three years towards the end of the twentieth century and the beginning of the twenty-first century. In general, the intensity, occurrence and the impacts of droughts have increased since the mid-1970s in Ethiopia. Besides climate variability, the dramatic increase in the frequency of drought in the past three decades is attributed to global climate change.

3.3 Overview of Pastoralism

Pastoralism is a social and economic system well-adapted to arid and semi-arid areas that seeks to maintain a viable balance among livestock, pastures and people (Rota, 2010). Pastoralists are individuals who obtain more than 50% of their income from livestock production. On the other hand, agro-pastoralists are individuals who obtain less than 50% of their income from livestock production, and the greater part of their income from crop farming (Swift, 1988). Pastoralists keep different types of livestock depending on environment, climate, pasture, water and other natural resources and topographical range, and involve cattle, camels, sheep, goats, horses, reindeer, yaks and llamas (Rota, 2010). Mobility is the main element qualifying pastoralism. The term 'transhumance' is used when mobility is seasonal between relatively fixed grazing areas; nomadic when mobility is continuously throughout the year to search feed and water and in unpredictable patterns; and sedentary for the rest (Rota, 2010).

3.3.1 The physical and biological context

Rangelands which cover 40% of the world's land surface and occupied by close to 40% of the world's population are water-limited ecosystems, including arid, semi-arid and dry sub-humid areas (Reynolds *et al.,* 2007). The main land use in rangelands with the greatest areal extent on earth is grazing (Asner *et al.,* 2004). The other ecosystem services of rangelands include food, medicine, clothing, fuel, shelter, freshwater resources, minerals, habitat for wildlife, recreation and tourism. Furthermore, rangeland systems also regulate climate, soil development and conservation, the quantity and quality of freshwater resources, and nutrient cycling and retention. Rangeland systems are highly valued for pastoralist's cultural services, recreation and aesthetics (Havstad *et al.,* 2007; MEA, 2005). According to Easterling *et al.* (2007), rangelands occur on every continent, and include hot and cold deserts, tundra, scrub, chaparral, and savannah and grassland systems. Rangeland's vegetative productivity, composition and diversity over a range of spatial and temporal scales are determined by the amount, timing and variability in precipitation (Boone, 2007; Heisler-White *et al.,* 2009).

The effect of precipitation is further modified by temperature (Oechel *et al*., 1998), grazing management (Collins *et al*., 1998; Fernandez-Gimenez & Allen-Diaz, 1999; Schlesinger *et al.,* 1990), fire (Collins *et al.,* 1998) and other properties such as soil texture and competition (Berlow *et al.,* 2003; Callaway *et al.,* 2002). Furthermore, the interactions among the primary system drivers also determine system structure and function (Klein *et al*., 2007; Shaw *et al.*, 2002). Due to the inconstant nature of climate, the influence of patchy grazing of mobile animals and the heterogeneous nature of processes such as fire, resource availability in rangeland systems tends to be highly variable across both space and time (Augustine & McNaughton, 2006; Schlesinger *et al.,* 1990).

3.3.2 Pastoral strategies and the social and institutional context

According to the Food and Agriculture Organization of the United Nations (FAO) (2001), pastoralism is a livelihood strategy for 20 million households and approximately 240 million people, being practiced in 25% of the world and offering 10% of the global meat production. Bonte *et al.* (1996) reported that livestock are not only a means of production and consumption for pastoral societies, but they also maintain important socio-cultural value. One of the strategies of pastoralists to recover from drought and epidemic diseases and to meet subsistence needs is to keep large numbers of livestock. According to Burnsilver (2008), pastoralism differs from commercial ranching since its objective is to meet subsistence needs and then produces for trade and market, and it relies more on human labour, local knowledge, common tenure, and some type of mobility. In contrast, ranching tends to be a more intensive commodity-oriented production system where animal raising occurs primarily for monetary exchange, rather than for direct consumption and where primary pasture lands are individually owned and fenced.

According to Fernandez-Gimenez and Le Febre (2006), pastoralists inhabit areas with variable and extreme climates, non-uniform distribution of resources, and often insecure political and economic environments, situations that expose pastoralists to the risk of losing part or even most of their livestock. Even during normal seasons of the year, overall production is low and a high spatial and temporal variability of rangeland resources is common. Pastoralists traditionally coped with these circumstances by using a wide range of strategies that allowed maximum flexibility and manoeuvrability in dealing with these changing and uncertain conditions. Fernandez-Gimenez and Le Febre (2006) further indicated that the main coping and adaptive strategies of pastoralists include diversity, reciprocity and cooperation, reserves, flexibility, mobility, and shared access to resources.

A diversity which is explained in terms of diversity through their livestock, products, livelihoods and institutions, is one of the strategies deployed by pastoralists to cope with climate-induced hazards. Livestock diversity includes multi-species grazing (for example, browsers, grazers and generalists) and herd diversification (for example, age and reproductive structure), providing for maximum use of heterogeneous resources Livelihood diversity refers to livelihood activities outside pastoralism such as crop farming, wage labour, and petty trading (Fernandez-Gimenez & Le Febre, 2006).. Institutional diversity includes owner groups and *ad hoc* organisations. Neumann (1998) also reported that another pastoral coping strategy involves reciprocity or moral economy, which refers to the practices and norms, such as social ties of mutual obligation, that serve to help the poorer members during bad times. Pastoralists also manage risk through the use of ecological and social reserves, such as setting aside land so it can be grazed in times of drought and maintaining a network of different groups of people in different areas for potential cooperation and reciprocity (Neuman, 1998).

Fernández-Giménez and Swift (2003) noted that flexibility of management decisions, movements, livelihoods and institutions is another key strategy for the persistence of pastoral systems globally. Mobility and common property regimes are two important features to pastoral household survivals that are today under great pressure. Mobility is one of the most important and characteristic trademarks of pastoralism worldwide. Since resource availability among and within pastoral regions are highly heterogeneous, the number, distance and duration of movements similarly vary. Pastoralists living in the most extreme environments can be highly mobile and nomadic, moving opportunistically and without a regular pattern in response to stochastic weather events. Fernández-Giménez and Swift (2003) further stated that transhumance occurs in areas where resources are highly seasonal and herders move either vertically or horizontally between relatively fixed points to exploit the seasonal availability of resources. Seasonal aggregation and dispersal occurs when animals cluster during one season, such as the dry season when water is scarce, and then disperse in another season when resource availability changes, such as the wet season when resources are more abundant.

Fernandez-Gimenez and Le Febre (2006) noted that mobility gives multiple advantages to pastoralists, their livestock and rangeland ecosystems. Through mobility, pastoralists take advantage of changing climatic conditions and corresponding spatio-temporal resource patchiness so their animals have access to the most nutritious forage available. Mobility can provide access to key resources, such as water and salt, and also reduce competition for resources. Livestock survival is enhanced when pastoralists can move out of areas affected by insects and disease or those that have been exposed to extreme weather events, such as droughts or severe storms (Davies, 2008; Fernandez-Gimenez & Le Febre, 2006). Mobility can also give social, political and economic advantages. For example, pastoral communities can market livestock and their products, engage in trade, avoid conflict and access other social services, and pursue diverse income opportunities during the mobility period. Mobility also provides opportunities to enhance social relationships that underlie reciprocity, an important aspect of pastoral persistence. The movement of livestock across a landscape also provides an opportunity for the grazed rangeland to rest and recover (Fernandez-Gimenez & Le Febre, 2006).

Communal use of resources is another adaptive characteristic of most pastoral communities. Rangelands are one of the shared resources, also known as common pool resources (Walker & Salt, 2012). However, there is a risk of overgrazing and impoverishment of rangeland resources if the rangeland is open access with no rules that restrict who may graze, the time of grazing and the number of livestock kept for grazing. However, rangelands are usually not free access in pastoral communities and the customary institutes had some form of property regime that define tenure of households or social groups regarding the management of the rangeland resources in pastoral communities (Fernandez-Gimenez & Le Febre, 2006). Communal use of resources, a feature of most pastoral communities, happens where the pastoral society communally has the rights to use, and manage the rangeland, involving the right to reject non-members for use. In pastoral communities, the absence of property rights and rules for pasture use can lead to an undesirable open access situation where there is no incentive for individual herders to conserve forage, and overuse and degradation ensue, although this rarely occurs in traditional pastoral systems (McCabe, 1990). On the other hand, privatisation and allocation of pasture to individual households in extensive semi-arid grazing systems can also have negative social and ecological consequences (Williams & Funk, 2011).

3.3.3 Changes in pastoral systems

A suite of climate, biological and socio-economic and political drivers are changing the fundamental nature of pastoral systems. Climate change, intensification of pastoral production, privatisation, sedentarisation, land use change, livelihood diversification, resettlement, economic change and degradation are exerting tremendous pressure on rangeland ecosystems and pastoral communities (Galvin, 2009).

3.3.3.1 Climate change

Climate change is affecting social and ecological systems globally. Over the past century, global mean temperatures had increased by 0.74 °C and mountain glaciers and snow covers have declined globally. Changes in precipitation have also occurred, with overall increases in wetter regions and overall decreases in arid regions, including dry lands (IPCC, 2007a). Rainfall is the most important climate variable that controls the geographic distributions of rangeland vegetation and production (Sala *et al.*, 1988; Stephenson, 1990; Webb *et al.,* 1983). A strong linear relationship has been observed between annual rainfall and above-ground biomass and net productivity in rangeland ecosystems, and the annual rainfall explained 90% of the variance in primary production (Le Houerou, 1984; Sala *et al.,* 1988; Scholes, 1993; Webb *et al*., 1983), while temperature does not appear to be a significant factor in controlling above-ground biomass and net primary productivity in a particular region (Sala *et al.,* 1988). However, it was observed that the process of decomposition in rangeland ecosystems has been significantly controlled by temperature (Burke *et al.,* 1989). In the availability of sufficient moisture, as temperature increases, the rate of decomposition also increases (Burke *et al.,* 1995; Ojima *et al.,* 1993; Parton *et al.,* 1993). African rangelands are characterised by frequent shifts from relatively wet periods to dry periods. Based on long-term precipitation records and other indicators, Hulme (1990) indicated that unpredictable climate dynamics have been observed in African rangelands for at least the past 10 000 years. The highly variable rangeland ecosystems seriously impacted livestock production in Africa (Ellis & Galvin, 1994; Lambin *et al.,* 1995).

As indicated by the IPCC (2014a), the non-climatic factors will act together with climate change and variability to increase vulnerability of livelihoods in arid and semi-arid areas of Africa. As a result of high and persistent destitution, deteriorating livelihoods have been distinguished as a risk in arid and semi-arid regions of Africa. According to the IPCC (2014a), with rising of 4 °C temperature, irrespective of adaptation, there will be a high level of risk of getting tipping points for livestock and crop production in crop–livestock farming communities and/or pastoral communities by 2080−2100. However, it was recently estimated by the IPCC (2014a) as a medium risk of getting tipping points. The report further indicated that high levels of risk can be decreased to medium by employing adaptation strategies. However, adaptation options can be limited by the existing land degradation, persistent destitution and inadequate supports by the government.

Easterling *et al.* (2007) reported that rangeland quality and quantity will be affected by changes in CO_2 and climate through changes in production, species composition and plant tissue chemistry. Enhanced CO_2, in combination with up to 200 °C warming, is predicted to have positive effects on production in humid temperate rangelands and negative effects in arid and semi-arid rangelands. Climate change may decrease the rangeland quality through CO_2-induced decreases in plant protein content or through climate-induced increases in shrub production, but may enhance rangeland quality through CO_2-induced increases in N-fixers or C_3 relative to C_4 plants. Warmer and drier conditions increase animal thermal stress with resultant declines in meat output, dairy production and measures of animal success, such as conception rates (Easterling *et al.,* 2007). Rangelands and livestock are likely to be susceptible to extreme weather events, such as floods and droughts. Warming reduces forage quality through plant tissue chemistry changes and through the replacement of more digestible graminoids with less digestible shrubs (Klein *et al.,* 2007).

3.3.3.2 Intensification

According to Klein *et al.* (2007), intensification of pastoral production systems is a global phenomenon whose goal is to modernise traditional livestock operations, which have been perceived by outsiders as economically irrational and inefficient. Intensification refers to an increase in the unit of livestock production (meat, wool, dairy) relative to a given amount of inputs (labour, land area, water, feed, medicine). The intensification process typically involves increasing livestock off-take rates and acquiring additional inputs (for example, improved livestock breeds, veterinary medicines) to both bolster outputs and to increase the efficiency of production (Klein *et al.,* 2007; Shaw *et al*., 2002). Access to credit is generally required to purchase inputs. Intensification also involves activities such as water development projects and market development. Formalising rights and privatising land are often part of the intensification process, as it is thought that ownership will enhance investments and lead to greater outputs. This is often also accompanied by sedentarisation as described in the next section. The motivation for intensification is economic, but it is also intended to address degradation and is inspired by political and other reasons. It is not always planned, and does not necessarily lead to positive outcomes. While the pressure from policymakers is toward intensification, economic factors, such as limited access to credit, can hinder this process. Moreover, climatic and ecological factors, which favour mobility, are also in conflict with the top-down approach (Klein *et al.,* 2007; Shaw *et al*., 2002).

3.3.3.3 Sedentarisation

In pastoral systems, globally, there is a dramatic transformation in land use toward reduced mobility and sedentarisation. The process of sedentarisation is inextricably linked to the privatisation and overall intensification process. Factors contributing to this trend include the conversion of rangelands to other uses, such as agriculture or parks and protected areas; establishment and enforcement of political and administrative boundaries; disruption of local institutional control and rangeland practices; increased labour costs associated with the movement; and the development of stationary goods and services such as schools and medical facilities (Fernandez-Gemenez & Le Febre, 2006; Galvin, 2009). Local and national governments encourage pastoralists to settle because they can control less mobile pastoral populations, tax them and provide social services to them. Moreover, decreased mobility can result from pastoral institution adaptations whereby pastoralists are trying to regain local control over their resources by making permanent claims to grazing lands through permanent structures or establishing year-long residences on grazing lands by all or part of the households (Fernandez-Gemenez & Le Febre, 2006; Galvin, 2009). Both privatisation and sedentarisation have been shown to increase rangeland degradation (Williams & Funk, 2011) and may decrease pastoral identity and control over or access to critical resources. Vulnerability to livestock losses under drought or storms increases with sedentarisation

(Galvin, 2009; Klein *et al.*, 2011). Moreover, the loss of movement must be compensated by economic inputs or livelihood diversification (Galvin, 2009).

3.3.3.4 Land use change

Changes in land tenure, agricultural expansion, sedentarisation and institutions have led to rangeland fragmentation, the dissection of previously intact, extensive grazing lands into spatially isolated parts. This phenomenon was common in the United States of America and Australian rangelands in the twentieth century and in Africa and Asia in twenty-first century (Galvin, 2009; Hobbs *et al.*, 2008). . According to Reid *et al.* (2008), as land tenure changes and use of rangelands intensifies, pastoralists often settle and convert rangelands into other uses or fragment them, often with fences. Globally, 35–50% of semi-arid and sub-humid rangelands, and 10% of arid rangelands are now used for urbanisation, crop farming or conservation areas (MEA, 2005). Fragmented rangelands can support fewer livestock per hectare because herders and their livestock can no longer move freely and thus do not have easy access to different types of vegetation that are important for grazing in different seasons and during drought (Boone, 2007; Hobbs *et al.*, 2008). While it appears that herders in the driest lands are largely immune to the impacts of this conversion, this is often an illusion; incoming farmers plough the small pockets of wetlands, river edges or bottom lands that are critical to livestock during drought (Campbell *et al.*, 2000). Galvin (2009) also noted that fragmentation not only affects livestock and rangeland resources, but also affects pastoral social networks and the use of reciprocal rights and obligations, factors that are important in fostering resilience of pastoralists.

Rangeland fragmentation refers to disconnection of rangelands or rangeland-cover types into spatially isolated units (Behnke, 2008; Stafford *et al.,* 2009). Dissection is one of the causes of rangeland fragmentation. Rangelands can be disconnected into several separate units by barriers that restrict movement. The barriers can be social, or physical such as fences or hedge rows. Privatisation of communal lands increases the extent of fencing within an area (Kristjanson *et al.*, 2002). The other cause of rangeland fragmentation is the transformation of one land-cover type to another which separates a previously intact rangeland (Hobbs *et al.*, 2008; MEA, 2005). It occurs mostly due to the expansion of crop farming into a rangeland ecosystem. The dissection of rangelands into spatially isolated units can also be caused by housing and urban development, bush encroachment and degradation that cause rangelands to be unproductive (MEA, 2005). Government land policy, administration such as development of protection areas and tenure can also be other drivers of rangeland-use/land-cover changes in some areas and the fragments come to be inaccessible for humans or livestock (Boone *et al*., 2006; McPeak & Little, 2005). Rangeland use or rangeland-cover types changes can also occur due to sedenterasion of pastoralists caused by government policies and interventions, pastoral households options for lifestyle close to settlements, lack of boreholes, labour and transportation (FAO, 2001; Fratkin, 2001; Galvin, 2009). Recently most government strategies are transforming the mobile lifestyle of pastoralists who depend on livestock production by extensive use of rangelands into sedentary agriculture (Fratkin & Roth, 2005).

Rangeland fragmentation is one of the reasons for loss of heterogeneity of resources on the landscapes. Heterogeneity improves the capability of livestock, pastoralists and wildlife to access the spatial and temporal variable resources in arid and semi-arid rangeland ecosystems, especially during dry periods (Illius & O'Connor, 2000; Owen-Smith, 2004). The spatial and temporal variability of rainfall are the characteristics of arid and semi-arid rangeland ecosystems, which, in turn, affects the quality and quantity of pastures available to livestock (Adger *et al.,* 2005; Ellis & Swift, 1988; Osbahr *et al.,* 2008). Furthermore, heterogeneity also aids livestock to find resources that are not interchangeable for one another. Resources such as nutrients, water and energy which are essential for the maintenance and production requirements of the animals are usually obtainable at different places on the rangeland. Mineral concentrations may be available far from water points, and water may not be available in places with most palatable and nutritious pastures (Coughenour, 1991, 2008). The above non-substitutable resources can be accessible through livestock mobility by choosing feeds from different places on the rangeland. However, if the rangeland is fragmented, all the above resources will not be accessible for livestock, resulting in the reduction of livestock assets and increasing food insecurity in pastoral communities.

3.3.3.5 Livelihood diversification

Diversification beyond livestock production is occurring in many pastoral communities. Galvin (2009) indicated that factors encouraging pastoralists to diversify out of the pastoral sector include population growth, loss of land, drought, livestock raiding, agriculture, wage labour and other economic opportunities. Galvin (2009) stated that while some would argue that the movement away from the pastoral sector demonstrates crossing a threshold in terms of being a pastoralist; others contend that diversifying income sources are an adaptive feature of a resilient pastoral system. Encroachment of commercial farming, protected areas and other non-pastoral land use, as well as recurrent drought and population increase have put increasing pressure on traditional pastoralism (Abdulahi, 2003). Niamir-Fuller & Turner (1999) stated that traditional pastoralism requires large areas to effectively exploit the spatially and temporally variable resources such as pasture and water(and that pastoralists are increasingly engaged in other economic activities since relying on only livestock production would not meet their subsistence needs. According to McCabe *et al.* (2010) it is widely recognised that pastoralists across Africa, or even the rest of the world, are rapidly diversifying their livelihoods. Because the social and ecological environments of pastoralists are heterogeneous, livelihood diversification in pastoral communities is complex and multifaceted. Thus, some livelihood diversification strategies can increase pastoralist's resilience (McCabe *et al.,* 2010), while others can increase their vulnerability to climate change and variability (Pedersen & Benjaminsen, 2008).

3.3.4 Challenges faced by pastoralists in East Africa

According to Hesse and MacGregor (2006), 20 million people are estimated to pursue pastoralism as a livelihood strategy in the Horn of Africa and the East Africa region. Twenty to twenty-five percent of the agricultural GDP across Africa is represented by the livestock sector (Mortimore *et al*., 2008). African pastoral communities represent large percentages of livestock, for example, 70% in Kenya (GoK, 2007). It implies that large portions of milk, red meat and other livestock products are contributed from pastoral communities in Africa, and millions of people are employed by the livestock sector (Kirkbride & Grahn, 2008).

Many adaptive mechanisms have been evolved by pastoralists to manage the risks for long periods of time (World Initiative for Sustainable Pastoralism [WISP], 2008). However, in the past few decades, the adaptation and coping strategies of pastoralists to stressors and shocks have been highly constrained due to multi-dimensional factors. Studies indicated that pastoralists in East Africa are highly vulnerable, not only due to environmental changes but also their social, economic and political marginalisation by the government (Kirkbride & Grahn, 2008; Morton, 2008; World Initiative for Sustainable Pastoralism [WISP], 2008). A series of challenges, including climate shocks and stresses, economic and political marginalisation, unsuitable intervention strategies and increasing competition for scarce resources have hampered pastoralism and overwhelm abilities of pastoral communities to adapt to alterations in their external environment.

3.3.4.1 Climate change

Kirkbride and Grahn (2008) noted that East African pastoral communities have been able to adapt to climate change and variability for millennia using their indigenous knowledge, and they are still struggling to cope with the increasing challenge. However, currently, due to climate shocks and stresses becoming increasingly exacerbated by other socio-economic factors such as deepening of poverty, population growth, resource competition, political and economic marginalisation of pastoralists by the national decision makers, pastoralists are becoming less resilient to climate change and variability. The widely-accepted threshold at which climate change becomes much more likely risky, devastating and unpredictable is a rise of 2 °C above pre-industrial levels (Kirkbride & Grahn, 2008). The climate of the dry lands is characterised by limited and unreliable rainfall and occurs for short periods of time, which is not enough for agricultural practices as well as human use.

Anderson *et al.* (2010) reported that high temperatures during rainy seasons cause much of the rainfall to be lost in the form of evaporation, and heavy rainfalls lead to loss of water in the form of run-offs. Even though the dry lands are characterised by spatial and temporal variability of rainfall, the man-made climate variability and change is starting to pose more harm in dry land areas (Kirkbride & Grahn, 2008). When there is consecutive failure of rainy seasons, grazing land will not have enough time to recover to its original state, which leads to impoverishment of the pasture land, resulting in weakening of pastoralists' resilience to the next climate-related shocks and stresses.

Similarly, intervals of droughts are decreasing in East Africa (Kirkbride & Grahn, 2008). Due to the recurrent and prolonged droughts in the past few decades, pastoralists had no time to recover from the previous droughts leading them to chronic food insecurity and mounting poverty. The authors further indicated that in previous decades, it was common to see droughts every ten years; however, recently the occurrence of droughts has been every five years or less. Unpredictable and sometimes heavy rainfall events are the other challenges faced by pastoralists in East Africa. Possibly, one of the most widespread and potentially overwhelming impacts of climate change in East Africa will be changes in the intensity, frequency, and predictability of rainfall. Case (2006) also noted that changes in regional rainfall will finally impact the availability of surface and underground water and may cause decreased agricultural production and potentially widespread food shortages. Similarly, Songok *et al.* (2011) noted that the recurrent droughts hamper the ability of pastoralists and agro-pastoralists to rear livestock and grow food crops because of their dependency on rain-fed agriculture. Hence, there is a need to develop adaptive strategies to these changes in order to sustain their livelihood strategy. It is anticipated that climate change and variability in East Africa will continue to cause increases in the frequency of climate extremes (IPCC, 2014b; Tschakert *et al.*, 2008), changes in the prevalence and distribution of some vector-borne diseases (Chen *et al.*, 2006; Hay *et al.*, 2002) and expansion of desertification (Reich *et al.,* 2001). It is expected that all these changes may result in marginalisation of farmlands, reduction of productivity and disrupted growing seasons in East Africa (IPCC, 2014b; Müller *et al.,* 2011; Sarr, 2012). Moreover, climate shocks and stresses can have a significant negative influence on food security in Africa due to its negative effects on livestock and crop production (Challinor *et al.*, 2007; IPCC, 2014b; Thornton & Cramer, 2012).

Overall, in addition to increasing trends of temperature, the rainfall in East Africa is becoming more unpredictable, erratic and highly variable and drought cycles are becoming shorter and occur frequently. Therefore, climate change and variability is exacerbating the existing biophysical, political and socio-economic stresses, resulting in weakening of the resilience of pastoralists in East Africa.

3.3.4.2 Political and economic marginalisation

The long-standing political marginalisation of pastoralists in East Africa is widely recognised to be the main driver for their chronic vulnerability. Pastoral communities are the most politically marginalised groups in the Horn of Africa and East Africa (Kirkbride & Grahn, 2008). According to McGahey *et al.* (2008), there is a consensus that good policy and governance play a significant role to lessen conflicts and insecurity problems, increase access to resources and markets, access to services and infrastructure in the pastoral community. However, pastoralists have been politically marginalised in East Africa due to failure of long-standing governance, lack of responsibility and accountability of institutions and lack of willingness of decision makers to involve the needs of pastoralists in national development policies. Moreover, pastoralists often are unable to participate and organise themselves and exercise their collective action to politically influence decision makers (McGahey, *et al.*, 2008).

According to Morton (2008), geographical remoteness is one of the reasons for the political marginalisation of pastoralists in East Africa. The availability of rangeland resources varies with space and time in arid areas which are linked with spatial and temporal variability of rainfall. Mobility is the main strategy of pastoralists to utilise the spatial and temporal variable rangeland resources. As a result, pastoralists live in remote areas which are far from urban areas where economic activities are concentrated (Morton, 2008). Kirkbride and Grahn (2008) also reported that national governments assumed the rangelands of pastoralists as marginal with minor economic potential. Since pastoral communities often characterise a small percentage of the country's population and are distributed over various regions of the country it means that decision makers usually undermine pastoral communities and consider them as a 'minority vote' and, hence, pastoralists cannot be included in their electoral campaigns (Hesse & Odhiambo, 2006). Furthermore, Grahn (2008) noted that it is difficult to build social capacity and make collective action in pastoral communities in remote areas and scattered across wide areas of the region characterised by poor infrastructure. As a result, pastoral communities cannot formulate a coherent and collective demand and will be unable to convey their interests in a persuasive way to politicians. Eventually, the feeble citizen's ability of the pastoral societies to participate in political decision-making processes in East Africa means that pastoral communities lack the means to hold the powerful to account, and too often their rights are not tackled compared to the rest of the population (Kirkbride & Grahn, 2008).

In addition, misunderstanding of national governments about pastoralism is also another reason for the marginalisation of pastoral people in the East African countries. Pastoralism is often seen as an out-dated livelihood strategy, which is unfeasible and even unreasonable (Kirkbride & Grahn, 2008). Recently, the perceptions of NGOs, academia and international policy circles about pastoralists have been changed and there is a large agreement that pastoralism is a worthwhile and sustainable way of life, even though it was previously perceived as an outdated livelihood system. WISP (2007) also reported that many researchers in their studies, non-governmental organisations and advocacy activities focus on supporting pastoral communities towards increasing their resilience. However, this transformation in speculation presently cannot seem to completely pass through to national governments, and the negative picture of pastoralism still seems not to be completely dissipated among national strategy producers (Morton, 2008; WISP, 2007). Hitherto, the development policy and strategies towards increasing livelihood security and resilience of pastoral communities are still undermined by national decision makers.

Consequently, marginalisation of pastoralists by national decision makers impacts their access to productive assets. Markakis (2004) indicated that mobility and access to rangeland resources are crucial for pastoralists' mode of production. Pastoralists depend on spatial and temporal variable heterogeneous resources of rangelands to keep their different compositions of livestock. Land reform, involving access, property rights, and use, is a major factor of pastoralists' resilience, and in many studies they are broadly debated from the point of view of political marginalisation of pastoralists (Helland, 2006; Markakis, 2004; Morton, 2008). Decision makers still have not recognised the rights of pastoralists to land since the colonial era. For instance, in Kenya the common tenure arrangement is based on English property law, which does not recognise the informal resource management systems in a pastoral society (Markakis, 2004). On the other hand, access to land and tenure security in Ethiopia has been progressively dependent on the supreme country's legislation of land which gives high priority to crop farming in the highlands. Pastoral communities are either disregarded or very lightly treated (Helland, 2006). Allocation of rangelands for commercial farming and conservation areas is common in pastoral communities without consulting or communicating with them, and these inappropriate interventions cause impoverishment of pastoralist's key productive assets which leads to weakening of the informal institutions and resilience of the pastoral communities. Furthermore, many pastoral communities cannot exert political influence to keep their land rights and, hence, many have been forced to migrate or adopt alternative livelihood options for survival, such as wage labour, charcoal making and other temporal employment (Helland, 2006).

On the other hand, Trench *et al.* (2007) reported that pastoral communities have no access to basic services such as education, health and veterinary clinic. In East Africa, access to education is very low in pastoralist communities as compared to the national average.

The Regional Learning and Advocacy Programme for Vulnerable Dryland Communities [REGLAP], (2012) reported that in Kenya, access to education at primary level in the central province was 93%, while in the north-eastern province, where the majority of pastoral households live, only 36.3% of the pastoral households had access to education for the same level. (In Ethiopia, 90% had access to primary level in national education, but in the Afar region only 39% of the pastoral households had access to education. Kirkbride and Grahn (2008) reported that poor access to schooling among pastoral households is the main driver that decreases their capability to participate in non-climate sensitive livelihoods.

Similarly, there is a growing awareness that the resilience of pastoral communities has been progressively declining and pastoralists are increasingly unable to cope with environmental shocks and, hence, their dependency on food aid is increasing, which makes them to be neglected and misunderstood by central governments (Kirkbride & Grahn, 2008). Over the last few decades, droughts in East Africa became more frequent and severe. For instance, the drought cycles in Kenya are becoming short and severe, causing pastoralists not to have enough time to recover and rebuild their stock (Longley & Wekesa, 2008). Their reliance on humanitarian aid, however, can likewise be viewed as related to marginalisation by governments (Grahn, 2008).

3.3.4.3 Inappropriate development policies

In the twentieth century, rangeland management in Africa was based on the equilibrium paradigm model adopted from North America, where stable weather conditions prevail (Scoones, 2007). This promoted sedentarisation, privatisation, more population around water points and no mobility. However, in African rangelands, where the spatial and temporal climate variability causes great variations in availability of the rangeland resources over space and time, the adopted equilibrium model leads to rangeland degradation. Managing the spatial distribution of livestock is more crucial than trying to adjust the carrying capacity of the rangeland, in order to reduce rangeland degradation, which indicates the importance of mobility in arid and semi-arid rangeland management (Scoones, 2007). Kirkbride and Grahn (2008) further reported that in Kenya, the majority of the government development funds have been allocated for the agriculture sector in highland areas of the country. The crop producing highland districts have received up to ten times the amounts allocated to the pastoral areas. The same holds true for Tanzania and Ethiopia.

Furthermore, pastoralism is also considered as an economically non-viable and environmentally destructive livelihood activity.

3.3.4.4 Resource competition

In pastoral communities, the population have increased and key grazing areas have been allocated for private and state commercial farming and conservation areas and, hence, degradation and shrinkage of rangelands have increased over the past decades (Kirkbride & Grahn, 2008; Pavanello, 2009). In East Africa, recently about 60–70% of previous forest, 33% of all bushlands and woodlands, 23% of grasslands, and 13% of deserts and semi-deserts are allocated for crop farming (Kirkbride & Grahn, 2008). For instance, most dry season grazing areas in pastoral areas have been allocated for irrigated and opportunistic rain-fed crop farming. Once pastoralists lose their dry season grazing areas, they cannot cope with the recurrent and prolonged droughts (Kirkbride & Grahn, 2008; Pavanello, 2009; Reid *et al.,* 2008). Although large-scale agriculture can be a threat, small-scale farming can enhance resilience of pastoralists (Kirkbride & Grahn, 2008).

Risk of conflicts among, or within, pastoral communities can be raised as a result of competition for scarce rangeland resources such as forage and water, and the risk can be aggravated by climate-induced shocks such as droughts or floods (Kirkbride & Grahn, 2008; Pavanello, 2009). For instance, in the 2005/2006 dry season, an episode in Turkana supposedly left 40 individuals dead in a conflict amongst Turkana and neighbouring Ethiopian pastoralists (Kirkbride & Grahn, 2008; Pavanello, 2009). There were likewise reports of battling between groups trying to get to grassland and water in the Kenyan pastoralists areas amongst the Isiolo and Wajir County. Conflicts among pastoral communities are more likely exacerbated by climate shocks and stresses (Reid *et al.,* 2009).

3.3.5 Pastoralism in Ethiopia

Twelve million pastoralists in Ethiopia occupy over 60% of the country's land which is arid and semi-arid areas and dominated by the livestock economy (United Nations Office for the Coordination of Humanitarian Affairs [UN OCHA], 2008). The main pastoral communities are the Somali (37%), Afar (29%) and Borana (10%) living in the south-east, north-east and southern parts of Ethiopia respectively (Afar National Regional State [ANRS], 2010).

Ethiopian pastoralists raise a large portion of the national herd, estimated at 42% of the cattle, 7% of the goats, 25% of the sheep, 20% of the equines and all of the camels (PFE, IIRR & DF, 2010).

According to Nyong *et al.* (2007), rangelands in pastoralist's communities have experienced drastic events such as environmental degradation and climate variability leading to livestock mortality and food insecurity. In arid and semi-arid pastoral areas of Ethiopia, rainfall is scarce, unreliable, occurs within short rainy seasons and usually its availability is limited for human and livestock consumption (Vetter, 2005). On the other hand, high temperatures in these areas can cause loss of rainfall in the form of evaporation. Climate change and variability are said to be serious environmental issues for the sustainability of pastoral communities over the next 30 years (Vetter, 2005). Hundle (2008) stated that pastoralists are faced with a number of challenges such as ecological changes, recurrent droughts and political marginalisation, and they are currently the poorest of the poor in terms of access to social services, well-being and disposable income. Mounting of poverty and worse human development indicators have been observed among pastoralists compared to non-pastoralists in Ethiopia. Anderson *et al.* (2010) and Nassef *et al.* (2009) reported that access to health is very low, with only 10% of the population having vaccination and more than 90% living in malaria-infested areas. Therefore, it is expected that the low level of human development will exacerbate the adverse influences of climate shocks and stresses in pastoral regions. (Pantuliano and Wekesa (2008) as well as Tache and Oba (2008) mentioned that although the pastoral communities have until recently been capable to adapt to frequent dry seasons using their own indigenous strategies, the recurrent and prolonged droughts are becoming beyond their capacity and noticeable marks of predicament are observable. The livelihoods of pastoral communities are overstressed, mostly due to the twin effects of climatic and non-climatic factors. Recently, the quantity of individuals dropping out of the pastoral system has expanded extensively.

Although pastoralists have contributed significantly to the economy of the country, the decision makers are still not willing to address the challenges facing pastoral communities. Policymakers focused on crop farming in the highlands of the country (Mohammed, 2003). For example, Agricultural Development Led Industrialization strategy, which is the general development policy in the country, is unfair regarding pastoralism and does not sufficiently address the constraints and potentials of the pastoral communities (Mohammed, 2003). Likewise, Hundle (2008) reported that little consideration is given to pastoralists regarding their access to public services such as access to health services and schools.

Frequent drought is a main challenge in pastoral areas which causes livestock loss, leading to mounting poverty and food insecurity. According to Sanford and Habtu (2000), a 5–15% drop in livestock assets happened in Afar due to the drought of 1999/2000. Under the worst scenario, the livestock loss was estimated to range between 15% and 45% (Famine Early Warning System Network [FEWS NET], 2002; United Nations Emergencies Unit for Ethiopia [UN-EUE], 2002). Disaster valuation reports of different development organisations and relief agencies show that the extended drought of 2002/2003 was even more severe for Afar pastoralists. For instance, a team of experts from the UN-EUE and FAO observed thousands of emaciated animals and several carcasses in different parts of the Afar region between June and July 2002 (UN-EUE, 2002). This condition suggests that the decrease in livestock assets can cause food insecurity and poverty in pastoral communities, unless livelihood diversification strategies are introduced. Although opportunistic small-scale cereal production has been practiced by pastoral households for the past years, their main livelihood has depended mainly on livestock and livestock products. However, crop farming has recently increased in pastoral areas which are encouraged by the government extension agents, and most dry season grazing areas have been allocated for crop farming, leading to shrinkage of rangelands in pastoral communities.

3.3.5.1 Government policies on pastoralism in Ethiopia

In general, the history of development policies and programmes in Ethiopia shows that pastoralism has been undermined regardless of its contribution to the national economy. Decision makers have not developed policies and strategies that address the interests of pastoralists in the country. Previous policies did not even guarantee the land use rights of pastoralists (Getachew, 2001). The national and local governments perceived the land in the pastoral areas as being free and unutilised land in the country. Therefore, the national government designed an intervention policy to allocate the pastoral lands to foreign and local investors or settling people from other densely populated areas and advocates villagisation to settle pastoralists themselves. For example, at different times, the Ethiopian governments have introduced various large-scale development schemes in the river basins where pastoral groups are living (Getachew, 2001). In the past four to five decades the process of external encroachment into pastoral areas has taken place. This included the establishment and expansion of commercial irrigation farms and plantations, and designation of national parks, game reserves and conservation areas. At the time, the pastoral land was seen by the state and policymakers as a *vast fertile, vacant and unoccupied* area to be harnessed for national development without considering the pastoral traditional land use (Getachew, 2001). Moreover, settled life and agriculture received more priority than the pastoralism and pastoral economy.

Pastoral mobility, a key to risk management, was perceived by the state and its planners as *backward* and *inferior* to settled agriculture. Consequently, as researchers such as Getachew (2001) and Mohammed (2003) stated, pastoral groups were regarded as *inefficient land users*, *lawless*, and *Zelan* (literally meaning wanderer), which has derogatory implications. Mobility of pastoralists was also perceived as a threat to settled life and state security. These misperceptions were the beginning of the economic and political marginalisation of pastoral groups. As a result, ill-conceived policies or programmes that disrupted pastoralists' way of life, were established. These included the forced settlement of pastoralists, alienation of customary users, inappropriate interventions resulting in overgrazing, and land degradation. The detrimental effects of these interventions on different pastoral groups were well-documented by many authors (Ayalew, 2004; Getachew, 2001; Markakis, 2004; Tolera, 2000). Some of the consequences identified by many authors included loss of grazing land; restriction on mobility; displacement; disruption of communal tenure and traditional resource management systems; erosion of traditional local authority; intensification of inter- and intra-ethnic conflicts over grazing lands and water points; health impacts; the aggravation of the effects of drought; and economic differentiation among pastoral households (Ayalew, 2004; Markakis, 2004). The advent and expansion of large schemes in the Awash Valley could serve as illustration of the consequences of external encroachments. The same authors noted that since the 1950s and 1960s, there was a persistent assumption that vast, excess and unutilised land existed in pastoral areas and could be allocated for other uses. This attracted the central government to establish large-scale irrigated commercial farms and national parks. This has been mainly undertaken in the Awash Valley where the Afar pastoralists are living. Large-scale development schemes in the Awash Valley or elsewhere were established for commercial and political interests of the central state, with little or no concern for the subsistence of the local people (Ayalew, 2004; Markakis, 2004). The expansion of commercial farms and delineation of the parkshave resulted in loss of rangeland, restriction of livestock mobility and eviction of pastoral groups. Particularly, mobility disruption has put pastoral livelihoods in an unstable situation. One can imagine how risky pastoralism is in a situation where territorial rights alienated, and freedom of movement is restricted.

3.3.5.2 Provisions of the Ethiopian constitution

Enormous political changes occurred in Ethiopia since the early 1990s. Since 1991, new political arrangements and administrative structures have been applied in the country. Accordingly, there have been some changes in the state's approach towards pastoral communities. The Charter of the Transitional Government was adopted in 1991 and paved the way for the establishment of a federal system of government. The change in state structure resulted in the decentralisation of power and administration. Consequently, regional and local self-administrations were established for pastoral groups, mainly on an ethnic basis. Accordingly, the two largest pastoral societies (Afar and Somali) have their own regional governments. The other major pastoral groups (for instance, Borana) have their own zonal and district administrations under the Oromiya Regional State to which they ethnically belong. This new political and administrative arrangement can be viewed as a positive step compared to the previous political space accorded to pastoral or marginal groups by the previous governments. In the past, pastoral societies were divided into different provinces with no self-administration. In addition to self-administration, some constitutional provisions and institutional measures have been made for pastoralist societies in the 1995. The Constitution of the Federal Democratic Republic of Ethiopia (FDRE) recognises the rights of pastoral groups inhabiting the lowland of the country. This provision is stated as follows: *"Ethiopian pastoralist have a privilege to free land for grazing and crop farming and a privilege not to be evacuated from their own lands"* (FDRE, 1995, art. 40(4)). The constitution additionally insists that *"Pastoralists have the privilege to get reasonable prices for their products, that would prompt change in their life status and to empower them to get a fair share of the national wealth comparable to their contribution"* (FDRE, 1995, art. 41(8)).

Taking into consideration their limited access to natural resources and social services and political marginalisation for the past decades, the Ethiopian government has designated four of the country's regions, namely: Afar, Somali, Benishangul-Gumz and Gambella as

Developing Regional States. In this respect, the Ethiopian Constitution stipulates that the government has the obligation to ensure that all Ethiopians get equal chance to advance their economic status and to improve equitable sharing of wealth among them (FDRE, 1995, art 89(2)). More related to pastoralists, the Constitution states that nations, nationalities and peoples least advantaged in economic and social development shall receive special assistance (FDRE, 1995, art 89 (4)).

These and other provisions are general ones, of course showing the government's position and concern towards pastoral communities, though its implementation is not observed in pastoralist areas. In the absence of rule of law, the provision alone is not enough. Therefore, equally important is to what extent the government policies and strategies emanated from the above provisions and have addressed the pastoral issues and concerns in investment decisions and their implementation on the ground. In this case a member of the parliament (from a pastoral area) in Ethiopia stated that *"the wind [wind in this case is an indicator of the coming rain] is blowing in our direction, but it hasn't rained yet"* (as quoted by Markakis, 2004). This is to say that the actual implementation is yet to be seen. Furthermore, Markakis, (2004) reported that in relation to the importance of law interpretation, a herder said this: *"the law does not speak the Samburu language or the Borana, or the Somali or the Turkana, or the Maasai"*. This suggests that enacting law is not sufficient, and equally important is the actual implementation or interpretation of laws. Therefore, it is imperative here to assess to what extent the current policies and strategies in Ethiopia have addressed pastoral issues and concerns at the surface.

Sincerely, both the state and NGOs have begun to give some attention to pastoralists' concerns and priorities in Ethiopia. The government and policymakers also attempt to incorporate some pastoral issues in the national policies, programmes and projects. The following sections discuss some of the relevant policies and strategies and to what extent pastoral issues are incorporated in them.

3.3.5.3 Rural development policies and strategies (RDPS)

A document entitled *"Rural development policies, strategies and instruments"* was published in 2002 focusing on crop farming in highland areas of Ethiopia, even though little attention was given to address pastoral development issues in the lowland areas of the country (FDRE, 2002). The government developed the short-, medium- and long-term policies and strategies towards pastoralism which are discussed as follows:

In the short and medium terms, emphasis is placed on improving of pastoral systems to ensure food security and sustainable development. In this regard the policy document states that development activities have to focus on improving pastoralism, since the main livelihood of the pastoral households is based on pastoralism (FDRE, 2000). The policy document also suggests the opportunity to undertake certain agricultural activities when families settle for several months in one area. Having pointed out the imbalance between stocking rates and the provision of water and pastures during the dry season, the policy puts priority on ensuring a water supply in different selected places. The policy also recommends rangeland management and conservation based on traditional management systems. In general, for short and medium terms, the RDPS focuses on improving livestock husbandry based efforts on a wide range of traditional knowledge. To this end the policy recommends the following: (i) Preparing a package that can strengthen people's knowledge of livestock husbandry; (ii) Training extension workers and provision of extension services focusing on the indigenous knowledge; (iii) Provision of veterinary and livestock development extension services which go well with pastoralists' mobility; (iv) Creating an efficient livestock marketing system that can make pastoral systems market-oriented (FDRE, 2002).

On the other hand, the long-term aspect of RDPS focuses on sedentarisation of pastoralists depending on irrigation crop farming strategies (FDRE, 2002). In the RDPS it is emphasised that, although it takes a long time, sedentarisation of pastoralists is the only option to enhance the living conditions of pastoral communities in a sustainable way (FDRE, 2002). Therefore, RDPS predicts the planning and application of settlement programmes that focus on extensive training on a settled farming system to be given to pastoralists and undertaking the settlement activities step by step.

In the RDPS, there seems to be contradictory ideas between prescriptions given in short and medium terms, and those in the long term. In short and medium terms, the RDPS recognises pastoralists' livelihoods and their wide range of traditional knowledge, and thus envisages the need to improve the pastoral way of life. In the latter case of RDPS, total sedentarisation of pastoralists and total transformation of way of life is envisaged. This implies that pastoralism (mobility) is neither desired nor needed in the future. It also implies the preference for settled agriculture or crop cultivation. However, this prescription for settling pastoralists is questionable. Firstly, the policy does not distinguish between different types of the pastoral system ('pure' pastoralism, transhumance and agro-pastoralism) which pastoral groups pursue or combine them depending on the circumstances. Secondly, it is difficult to imagine the total transformation of a pastoral way of life through settlement or sedentarisation, as pastoralism is not simply an economic activity to the pastoral groups. It rather involves social, cultural, psychological and political aspects. Therefore, it is simplistic to think that a pastoral way of life can be transformed through a settlement programme.

3.3.5.4 The pastoral policy in Ethiopia

As a continuation of the various government policies and programmes focusing on pastoralism, a pastoral policy was developed in 2002. The vision of the government's policy concerning pastoral communities in Ethiopia is as follows (Ministry of Federal Affairs, 2003):

i. Settlement of pastoral communities on a voluntary basis following the main rivers to transform mobile, scattered and pastoral households into sedentary, small pastoral villages, towns and agro-pastoral households.
ii. Supplementing settled pastoralists by small- and medium-scale enterprise establishments in the towns and non-farm incomes in the rural areas.
iii. Functioning a mixed crop–livestock production in such a way that crop farming is based on irrigation schemes and opportunistic rain-fed agriculture, and livestock production should be supplemented with static and mobile social services such as education and health services and infrastructures development.
iv. Coordinated and concerted federal support for programme ownership by the local government and people, and increasing their capability to allow them to implement appropriate development.
v. Permitting, empowering and organising the non-government sectors to contribute a positive effect towards the government's policy directions.
vi. Tapping the knowledge and skills of the local people in livestock production and natural resource management.

From the aforementioned strategies and approaches established for pastoral development, it can be understood that some old ideas are reflected in the government policies and strategies, for instance, viewing mobility as a pastoral problem and taking sedentarisation as the best option; high preference to a settled way of life; and over-emphasis on technical inputs, which were dominant views that guided pastoral development policies and programmes in the 1970s and 1980s. Overall, sedentary life or sedentarisation for pastoral areas is considered to be the ultimate goal. In this case it is emphasised that the main strategy of national policymakers to transform pastoralists into a better way of life is villagisation of resettlement programmes (FDRE, 2003). Most of the ideas mentioned in the government's strategies and policies are related to sedentarisation, improving the productivity of the production systems and integrating of the sector in the market, and the provision of technical inputs and construction of infrastructures and services mainly geared to increasing the productivity of the livestock production system. This suggests that historical, socio-political and cultural factors that shape the lives of the pastoral societies have not been adequately analysed during the design of these pastoral development approaches or interventions. Therefore, before designing and envisaging pastoral development programmes, it requires a careful analysis of pastoral ways of life and adequate consultation with concerned pastoral communities for determining (mainstreaming) the kinds of interventions, as pastoral systems and groups are differentiated with varying interests, choices and concerns. Otherwise, policy prescriptions and strategy statements will remain as only shopping lists.

3.3.5.5 National policy on disaster prevention and management

Various disaster risks have been identified in Ethiopia. There have been particular regional emergencies brought on by various types of hazards at various circumstances and in differing degrees and extent. Disaster Preparedness and Prevention Commission (DPPC) (now the Disaster Prevention and Preparedness Agency) claimed that hydro-meteorological hazards, particularly droughts have continued the principal source of hazards and social hardships in Ethiopia in terms of occurrence, extent and the quantity of individuals impacted. Flooding has also adversely impacted individuals and their assets, mainly people inhabiting the lowland areas (DPPC, 2005).

There were times when disease outbreaks also led to severe death, and migrant infestation of pests have been a severe problem in some regions of the country; bush fires happened which exhausted forest and conserved areas; individuals have been displaced because of disputes for scarce resources; and recently, HIV/Aids has come to the level of disaster (DPPC, 2005). In the Ethiopian context, a lot of factors contributed to the vulnerability of individuals or communities to frequent disaster risks such as drought-related famine, epidemics, floods, landslides, civil strife and mass displacement. In particular, millions of people have been affected by drought-related famines for several decades. Very huge amounts of resources have been deployed in the form of relief, which have saved many lives (DPPC, 2005; FDRE, 2002). Depending on lessons learned from past experiences, a policy change on disaster prevention and management was made by the National Policy and approved in 1993. The previous Relief and Rehabilitation Commission, whose duties were mainly to manage effects of drought through relief distribution, and rehabilitation of victims of drought and other disasters, has been replaced by the DPPC with the objectives of (i) preventing disasters by way of removing the basic causes of disasters; (ii) building, in advance, the capacity necessary to ease the extent of damages that could be caused by disasters; (iii) ensuring the timely arrival of necessary assistance to victims of disaster (FDRE, 1995). The National Policy on Disaster Prevention and Management and its mandates have been set up since 1993. The principal targeted areas of the strategy have been:

i. Protecting human lives and their livelihoods.
ii. Securing the life conditions of people in the impacted areas from getting worse due to hazards.
iii. Safeguarding best utilisation of natural assets.
iv. Tackling the underlying drivers of vulnerability to hazard risks by providing a relief in the short term and enhancing viable development in the long term (DPPC, 2005).

The main components of the disaster prevention and management policy are the early warning system developed to assess and provide warning of disasters ahead of time; the Emergency Food Security Reserve; the development of the Relief Plan and National Disaster Prevention and Preparedness Fund. These elements form mainly the preparedness aspect of the policy. In recent years these policy measures have helped largely to avert famine. On the other hand, elements of prevention, especially for addressing the main causes of disasters or livelihood protection are not clearly worked out in the policy implementation process. The national early warning system has been developed in Ethiopia through the DPPC. While the early warning system functions mostly at organising large food aid responses, many shortcomings have been observed and described as follows (Lautze *et al.,* 2003):

i. Its emphasis is on highland areas where crop farming is people's main livelihood, while the focus for pastoral communities is very low where chronic vulnerability and food insecurity is located.
ii. Information flows only in a top-down direction – local level households are not participating in the decision-making process.
iii. It is concerned more or less entirely on calculating food aid requirements and prompting the release of food, and a very small focus on non-food items.
iv. It is oriented mostly with responses of central government to a wide range of food insecurities, not to an early and quick response at local scales to avoid such conditions from developing.

Pastoralism is a way of livelihood which enables pastoral households to utilise the marginal lands and the products are also valuable for the national economy. The current crisis associated with climate shocks and ecological change affected pastoralists first. The formal early warning system in Ethiopia is criticised for not integrating the traditional early warning systems, although the traditional EWI was significant in providing early signals of disaster risks (Lautze *et al.,* 2003). Drought is the most frequent hazard impacting mostly pastoral communities in Ethiopia. Lautze *et al.* (2003) noted that livestock terms of trade for food grains and other goods have collapsed, while livestock feed availability and disputes among pastoral communities and disease outbreaks have increased. Consequently, enormous losses of livestock have been observed in pastoralist communities, causing increased food insecurity and malnutrition. Interventions that have been implemented in pastoral communities usually focused on food aid responses, rather than key livelihood interventions such as improving animal health, market access for on-time destocking with fair prices, promoting forage and water availability.

3.3.6 Pastoral communities in Afar

3.3.6.1 Livelihood of Afar pastoralists

Like many other pastoralists in East Africa and elsewhere, it is also common for Afar pastoral communities to keep multiple species of livestock to cope with droughts and disease outbreaks and meet their subsistence needs (Getachew, 2001). The species composition of livestock kept by pastoralists varies with the vegetation covers of the region (Berhanu *et al.,* 2007; Davis, 2005; Ellis, 2000). In parts of rangelands, where the grazing resources are relatively good, cattle and sheep are the dominant types of livestock. In the drier parts of the region, camels and goats make up the prominent parts of the herd composition with mainly camels in the extremely arid areas. According to Hogg (1997), cited by Müller-Mahn *et al.* (2010), dependence on milk enables many pastoral societies not to depend on the highlanders for grain foods, although many pastoral communities do not have adequate herds to be only pastoralists and have come to be progressively reliant on food grain as a part of their diet. Ellis (2000) noted that in spite of the fact that the interest in grain is generally profoundly occasional, the exchange of livestock to buy food grains has turned into an essential part of the livelihood of pastoralists.

Morton and Meadows (2000) reported that an extensive livestock production system has been the predominant livelihood system which provides subsistence for the Afar pastoral households. It supplies goods for household consumption (milk, meat, butter, hides and skins). Live animals are also used in transactions such as barter, and sources of cash from the market. In addition to the economic value, herds are also a means of establishing networks of social relationships and exchanges which provide mutual aid essential for the continuity of Afar pastoralism. Within the context of kinship and clan affiliation, members practice a good deal of sharing of resources (livestock and labour) and cooperation in economic activities (Getachew, 2001).

Davies and Bennett (2007) noted that adaptation by pastoral communities is not limited to a simple relationship of human–rangeland ecosystems in an isolated setting, but is rather impacted by population dynamics, expansion of crop farming, interventions to involve pastoralists into the national economy, and conflicts among pastoral communities. As a result, pastoralists are forced to pursue non-pastoral activities to meet their needs and cope with recurrent droughts (Little, 2013). Due to the occurrence of droughts in wider areas of the region (Berkele, 2002) and conflicts among ethnic groups (Hagmann, 2005), mobility of livestock among alternative grazing areas has been harshly inhibited, causing poor body conditions of livestock and a substantial increase in death of livestock. The aggregate influence of these drivers has led to the weakening of informal institutions, impoverishment of rangeland resources, and increasing vulnerability of pastoralists to shocks and stresses (Rettberg, 2006).

Overall, inappropriate policies and strategies, fragmentation of rangelands, and prolonged and recurrent droughts have led pastoral communities to pursue other non-pastoral livelihoods such as irrigation crop cultivation; wage labour, charcoal making, and firewood selling (Sanford & Habtu, 2000). Consequently, the hitherto economically undifferentiated pastoral groups have been disintegrated and some pastoral households pursued non-pastoral activities. Some have started practicing crop farming. Still, some are forced to take up wage labour and other non-pastoral activities. And some fortunate ones maintain their herds through a grazing alliance (namely, stock association with the neighbouring farming population or with bond friends) and engaging in animal trading (Mesfin, 1999; Sanford & Habtu, 2000). Therefore, the economic change implies a growing pattern of wealth differentiation. For instance, in the Middle and Lower Awash Valley a few wealthy Afar households were transformed into commercial agro-pastoralists, while the poor Afar households were neither able to sustain themselves in the pastoral sector, nor were they able to cope with the new circumstances that followed the development, including increasing involvement in opportunistic farming on marginal lands, wage labour and the cash economy (Getachew, 2001). As food supply from livestock production declines and the drought interval has decreased, pastoral households were gradually less able to cope with recurrent food shortages and to recover after drought episodes. As a result, poor households and those who lost their stock and assets relied on external food assistance. For instance, during the 2003 drought, 204 115 (that is 18% of the total) of the Afar people were drought affected and chronically food insecure who required not only food assistance, but also basic services such as water, health and nutrition, as well as stock recovery (Beruk, 2003).

3.3.6.2 Customary resource and herd management strategies

In pastoralist areas, herd management strategies are a result of many factors such as limitations set by ecology, physical needs of the stock, the social needs of people who keep the herds and, other socio-cultural factors (Rede, 2012). For example, different species of livestock (i) prefer grazing areas and have different feeding habits, (ii) require distinct herding patterns, (iii) have different breeding rates and tolerance to vagaries of nature, (iv) provide different amount of yields, and (vi) have different social, cultural and religious significance. Sheep and cattle rely largely on the grasses and sometimes on forbs and browse during the dry season. However, goats and camels depend primarily on browses.

Pastoral communities consistently attempt to keep up various species of livestock intended to address their needs and to fit nature. For example, cattle and camels are kept primarily for milk consumption. However, they are also a source of meat and cash deposits of the pastoralists. Sheep and goats are not kept primarily for their milk, but for their meat and cash and capital deposits (Rede, 2012). Therefore, it is in the light of all these considerations that herders or pastoral households pursue various herd management strategies and organising their household labour. Households are production, reproduction and consumption units. The stock management unit in Afar is the household unit/extended family whose basic objective is geared towards the provision of sufficient milk and exchange, and balancing the reproduction and further survival of stock after droughts (Rede, 2012). In general, a successful pastoral production system in an economically risky and politically unstable environment requires an effective livestock management strategy, livestock diversification and mobility, livestock redistribution and transfer, establishing stock alliance and mobilising social networks.

3.3.6.2.1 Traditional herd management

Like other African countries, depending on sex, age, type and productivity, livestock are kept in different groups of herd in the Afar region. Pastoral communities often keep large ruminants separately from small ruminants (Hassan, 2008; Mulubrhan & Tafere, 2013; Rede, 2014). Pastoralists usually split their herds into smaller groups for the following reasons: (i) Livestock species are frequently fitted to various grasses and browse, landscape, and availability of water and herd splitting will guarantee that every species pastures under ideal conditions; (ii) Splitting herds diminishes or spreads the hazard risks of loss of animals. If all of the livestock are kept together, there is a risk that all at the same time are prone to hazards, disease or attacking (McClanahan & Young, 1996). Especially, during a dry spell or dry periods, herds are split depending on their economic importance. Breeding cows/camels delivering milk are kept close to the residence, where most of the pastoralist families, especially kids, women and elders are living. The dry females, males, and other unimportant herds are moved far from the residence, regularly being taken care of by youthful unmarried man. This diminishes pressure of livestock grazing on pastures close to the residence and enhances conditions of grazing for herds delivering milk for the vulnerable individuals of the pastoralist family members (McClanahan and Young, 1996).

3.3.6.2.2 Traditional rangeland management

Mobility of pastoralists and livestock is one of the most common strategies of pastoral communities in arid and semi-arid areas. Although pasture and water availability are the most important factors that determine pastoralist's movement patterns, extreme heat, predator abundance, pests and diseases, availability of labour, regional borders, and relations of the community with their neighbours are also other drivers that determine movement patterns (Rede, 2014).

In the Afar pastoralist situation, movement is controlled by social and political factors as well as practical knowledge about the availability of resources such as pastures and water. It needs extensive use of the rangelands in which most pastoral households obtain by arranging regional rights and agreements with neighbours. Among the Afar strategies, mobility is pursued mainly to minimise livestock losses and to access seasonal varying forages and water and to give rest to the grazed rangelands. Mobility also occurs to escape floods, mosquito infestations and livestock diseases (Getachew, 2001). The most common traditional rangeland management of pastoral communities include grazing reserves and rotation grazing. These strategies are aimed to reserve pastures for dry seasons. For instance, the Afar pastoralists have dry season grazing areas/grazing reserves following the flow of the Awash River. The dry season grazing areas defer using the wet season grazing area in order to preserve good fodder for the dry season (Getachew, 2001). The Afar grazing patterns are based on investigations and assessments of the rangeland by the traditional rangeland scouts. They used environmental and livestock production indicators to assess rangelands. The Afar pastoralists utilised mobility between different grazing landscapes distributed in space and time. The physical features of grazing rangelands are disconnected among the uplands, lowlands, narrow and wide valleys (Oba, 2009). The floodplain with their key grazing resources and the valleys are used as grazing reserves for dry periods. The upland rangelands are also used for grazing during wet seasons (Oba, 2009).

3.3.7 Customary institutions for rangeland management

The Afar social institutions involve indigenous and formal institutions. At community level, there are traditional leaders who made decisions concerning the management of grazing areas, conflicts with neighbours and the government (Oba, 2009; Rede, 2014). As part of the drought coping mechanism, the community leaders reserve the dry season grazing area and the pastoral households will not graze the reserve until the leaders tell them to use it. The preservation is not through physical policing, but consensual agreements until such time when the dry season grazing area is opened for the pastoralists. As the dry season becomes extreme and the grazing for livestock deteriorated, the informal community leaders would meet again to assess the conditions and permit the preserved grazing to be utilised. If the conditions become worse, the elders would allow the herders to lop off branches from trees to feed the livestock as supplementary feed. The next coping strategy is to look

for grazing in the neighbouring territories (Oba, 2009; Rede, 2014). The traditional practice of mutual sharing of grazing and water is practiced with neighbours such as the Karayu Oromo. The negotiations are done through clan leaders. Communication is by word of mouth where every individual is an agent of information transmission (called *Dagu*) that might concern market prices, distribution of rainfall, situation of pastures, livestock and human diseases and armed conflicts. The herders share the information at water points (Oba, 2009; Rede, 2014). The *Dagu* system is a means for coping with risks and allows communication between different clan leader councils. The customary institutions have additional social and political functions. The clan leaders are responsible for the security. They would adjudicate cases of revenge killings. More severe punishments are handed down to individuals who violate customary laws.

3.4 Summary

The literature indicated that globally, climate change is happening. The world's average temperature has risen by 0.72 °C since 1950 and caused a high incidence of warmer days and nights, and increased heat waves, and a decline in the incidence of cold days and nights. The global temperature will continue to increase if no mitigation strategy is implemented to reduce the emissions of greenhouse gases. Average temperatures throughout Africa have generally increased and were consistent with the broader global temperature trends. For the last five decades, the mean temperature over East African countries has risen in the range of 1–3 °C. The literature also indicated that climate data for Ethiopia from 1951–2006 revealed a general warming trend estimated at 0.37 °C per decade in Ethiopia. Likewise, a rising trend of the annual mean temperatures by 1.0 °C since 1960 at a mean rate of 0.21 °C every ten years, were observed in Kenya. However, rainfall trends were imprecise, and there existed great differences in the direction and rate of changes throughout East African regions. Increases in rainfall were observed in some areas while there was a reduction in rainfall in other areas but, overall, trends were generally weak and sometimes difficult to detect. Since people in Africa pursued climate sensitive livelihood strategies such as rain-fed agriculture which is characterised by low input and output, they are the most vulnerable to climate shocks and stresses such as droughts, floods and climate variability. Studies also indicated that in Africa, droughts and floods are frequently observed climate-induced hazards, representing 80% of the loss of life and 70% of property damages.

Studies revealed that climate extremes and variability impacted livestock assets, reproduction and productivity. Since the suitable temperature of livestock is in the range of 10−30 °C, a rising temperature above this range causes heat stress and decreases the feed intake of livestock, leading to a reduction of livestock productivity. Furthermore, the recurrent droughts also caused shortage of livestock feed and aggravated disease outbreaks, resulting in the deterioration of livestock assets. Similarly, seasonal variability of rainfall and temperature and rain failures caused prevalence of crop pests and crop loss in many parts of Africa. For instance, research conducted by Rowhani *et al.* (2011) in Tanzania revealed that cereal yields were impacted by the seasonal variability of rainfall and temperature. Overall, studies indicated that climate extremes and variability impacted the food production sector, human nutrition and health, and its impacts were more severe in African countries because of their low level of adaptation capacity.

It has been observed that most studies regarding research on the trends of climate change and variability and its impacts were done at regional, national and global levels. Climate research at local level was scanty, though its influence and extent differed across multiple levels and scales. Therefore, the present study aimed to understand the trends of climate variables (temperature and rainfall) and its impacts at local level.

Furthermore, studies indicated that pastoralists inhabit areas with variable and extreme climates, non-uniform distribution of resources, and often insecure political and economic environments, situations that expose pastoralists to the risk of losing part or even most of their livestock. Even during normal seasons of the year, overall production is low and a high spatial and temporal variability of rangeland resources are common. Pastoralists traditionally adapted to these circumstances by using a wide range of strategies that enable them to manage the environment in a viable way while also (i) guaranteeing a constant supply of food, (ii) reducing disaster risks to livestock and people, (iii) preventing outbreaks of diseases, and (iv) holding political and social stability. Studies indicated that the main coping and adaptive strategies of pastoralists include livestock species and breed diversification, reciprocity and cooperation, reserves, flexibility, mobility, and shared access to resources.

Pastoralists own different livestock species which are chosen depending on their survival, and are better adapted to the existing environmental conditions. Their rangelands are also represented by diversity of species to enhance various range resources and preserve the rangeland ecosystem services. The other environmentally friendly and economically reasonable strategy of pastoralists is mobility, which allows them to utilise the seasonally available rangeland resources such as pasture and water. Furthermore, it also enables pastoralists to get adequate provisions of food, water and forage, or prevent outbreaks of diseases. Mutually supportive social networks in pastoralist's areas ensure that, in times of need, cash, labour and food are transferred on reciprocal basis.

Even though pastoralists have been sustained over hundreds of years based on the aforementioned strategies, due to the increase of climatic and non-climatic adverse impacts, their sustainability is recently under question. Studies indicated that a sedentarisation policy, market constraints, population growth, limited access to infrastructure, formal EWI and social services are among the factors that constrain pastoralism globally. For example, as discussed in this chapter, total sedentarisation of pastoralists and transformation of way of life is the long-term policy of the Ethiopian government. Moreover, the low prices of livestock and increased prices of food grains, especially during droughts, make it difficult for pastoralists in Ethiopia to cope with droughts. Low access to affordable credit, veterinary and health services, lack of roads that connect the rural areas with nearby towns, training and inputs are also among the factors that make pastoralists more vulnerable to climate shocks and stresses.

However, the above overviews of pastoralism are the reports of different researchers from different parts of the world, including Ethiopia. Therefore, context-specific research is needed to get a better understanding of the social and economic value of pastoralism, to identify the factors that make pastoralists vulnerable for climate shocks and stresses and develop appropriate policies that enhance resilience of pastoral communities.

Chapter 4
STUDY SITES AND METHODOLOGY

4.1 Introduction

This chapter presents a background to the study area, research design, data collection and analysis techniques, with a comprehensive discussion on how to analyse trends of climate change and variability, vulnerability and resilience of households, trends of land-use/land-cover changes, drivers and their impacts on pastoralists of the Southern Afar region. The study incorporated both qualitative and quantitative research based on collecting primary and secondary data.

4.2 Description of Study Area

The Afar National Regional State is situated in the north-eastern part of Ethiopia. It is geographically positioned between 39° 34'and 42° 28' East Longitude, and 8° 49' and 14° 30' North Latitude (ARS, 2004) (Figure 4.1). The total area of the Afar region is around 108 860 km², and the number of inhabitants is approximately 1.4 million people, of which approximately 87% are living in rural areas (Population Census Commission, 2008).

As far as the livelihood system of the region is concerned, pastoralism and agro-pastoralism are the two dominant modes of livelihood systems. Approximately 78% of the people depend on a subsistence pastoral production system, while the remaining 22% pursue agro-pastoralism. The districts where agro-pastoralism is common, are located along the Awash Valley in the Southern Afar region and those districts located adjacent to Oromia, Amhara and Tigray regions, which include Argoba special, Afambo, Assayita, and parts of the Aba'ala, Megale and Koneb districts (Sonneveld *et al*., 2009). The inhabitants are also involved in other off-farm activities for income, such as charcoal making. The Afar Region is both the hottest and driest part of the country. The major part of the region falls within the arid agro-ecological zone below 500 masl. The mean annual temperature of the region as a whole is 35 °C. Rainfall is rather sparse and erratic. The mean annual rainfall varies from 500 mm in the south-west with less than 200 mm in the north-eastern part of the region.

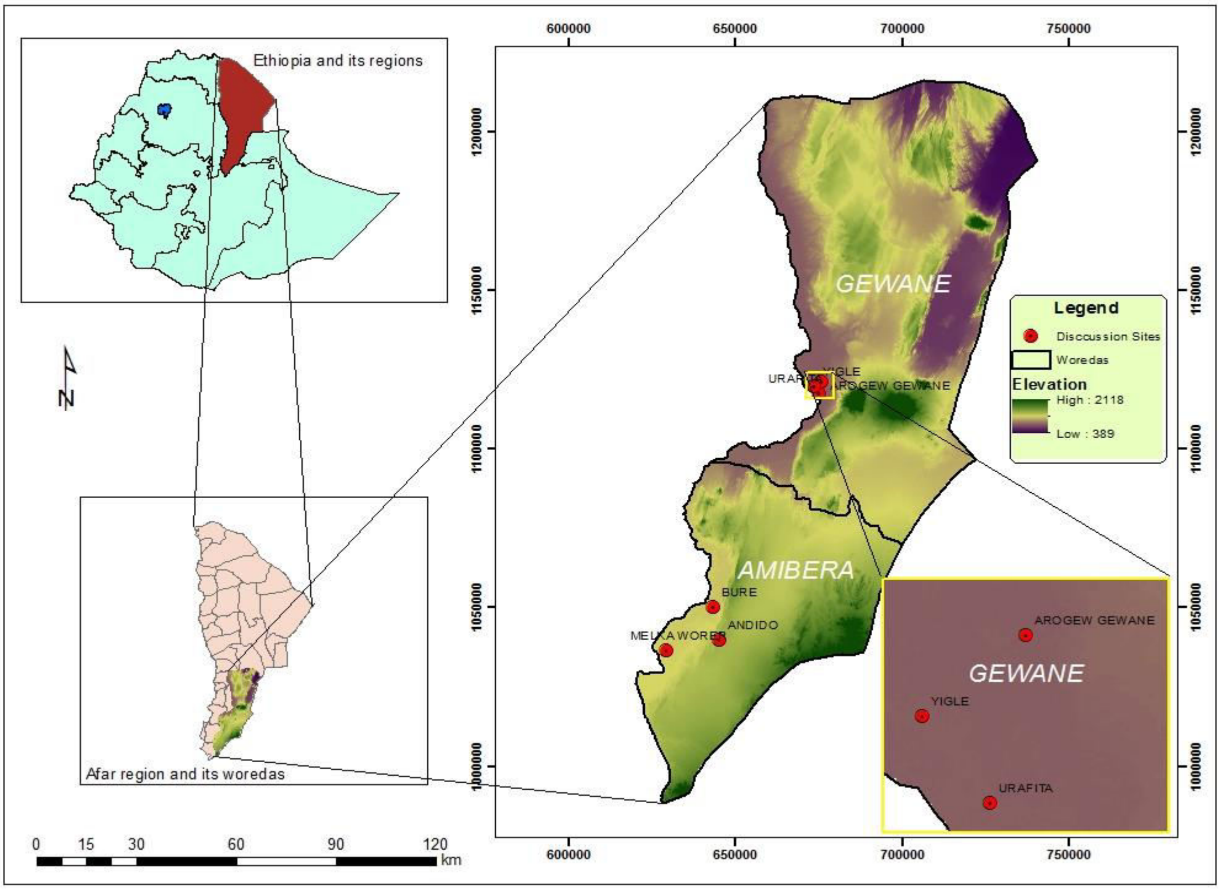


Figure 4.1Map of the study area

The study areas, Amibara and Gewane districts, frequently have been hit by droughts causing a loss of livestock assets due to feed scarcity (Smith *et al.,* 2014). Agro-ecologically the climate of Amibara is generally semi-arid, with a temperature level that falls between 25 °C and 35 °C with an average temperature of 30 °C and an average annual rainfall below 600 mm. The altitude of Amibara ranges from 720 masl to 1 100 masl. Gewane's temperature falls between 28 °C and 42 °C, with a mean temperature of 35 °C and a mean annual precipitation below 500 mm and altitude ranging from 550 m asl to 650 m asl (Population Census Commission, 2008).

4.2.1 Natural resources base

Ecologically, the Afar region is one of the unfriendly regions in the Horn of Africa. It is also one of the globe's active volcanic areas and its depression is composed of lava, commonly basalt (ARS, 2004). Furthermore, because of this volcanic activity, the Afar region is known for the occurrence of major minerals such as sulfur, potash, bentonite, gypsum and salt. There are likewise encouraging sources of geothermal energy and hot springs in various areas of the Afar region. Afar is home to particular wildlife species, which outstandingly involves the Grévy's zebra, African wild ass, wild cat, wild fox, ostrich, and cheetah (ANRS, 2010). Volcanic rocks, with lava flows, sand deserts and salt lakes, characterise the grazing lands. According to Abiyot and Getachew (2006), however, most of the Afar region is arid and semi-arid; its capability to support the pastoral communities is mostly linked to the existence of the Awash River which is the life of the Afar people and their herds. Furthermore, most of the commercial farming in the Afar region and sustenance irrigation crop farming have been possible due to the Awash and other rivers in the region. Natural resources such as water and forage vegetation play a key role in providing fodder and water points for livestock production in the region. The wetlands, which are found along the Awash River, are classified as seasonal swamps and marshy areas. The seasonal swamps found in Zones II, III and IV serve as dry season grazing areas (Oba, 2009). The Awash River floods the Afar land during the months of July to September due to the heavy rainfall in the main water areas. Pastoralists move away from the flood plains usually to the escarpments on the west or to the Alledeghi plain on the east (Oba, 2009).

4.2.2 Vegetation and land cover

The main vegetation covers are mostly associated with patterns of temperature and precipitation, with spatial variability due to soil and drainage factors. The southern and central parts of the western hills and plains have dense shrub and bushlands with a declining altitude and rainfall. The northern part of the region is characterised by declining rainfall and very low vegetation density (ARS, 2004). According to Zerga (2015), grasses and browse species in a rangeland are the key sources of feed for livestock in the Southern Afar region. According to Simenew *et al*., (2013), out of the total area of the Afar region, shrub and bushland accounts 18.62%, forest 1.54%, marshy land 2.74, grassland 1.56%, cultivated land 5.24%, water bodies 0.63% and bare land 63.7%.

4.3 Research Design

A stratified random sampling approach was adopted to select sampling villages and households. Stratification was based on dominant livelihood activities practiced by households in the two districts, Amibara and Gewane. Firstly, villages were identified and stratified into pastoralists (those households solely dependent on livestock production) and agro-pastoralists (those households dependent on both livestock and crop production). Accordingly, from the Amibara district involving ten pastoralist villages and five agro-pastoralist villages, three villages consisting of two pastoralist villages (Andido and Bure) and one agro-pastoralist village (Melka-Worer) were randomly selected. Similarly, from the Gewane district, which involves six agro-pastoralist and two pastoralist villages, three villages consisting of two agro-pastoralist villages (Yigle and Urafita) and one pastoralist village (Arogew Gewane) were randomly selected. Overall, six villages were sampled from the two districts.

After random selection of the study villages, the total number of households was obtained from the district pastoral and agricultural development officer. The sample size in each of the villages was using a sample size formula by Krejcie and Morgan (1970), see the equation. A random start was used in selecting the first household to be interviewed. For the selected households whose heads were absent, next household was chosen and interviewed, a total of 250 households were interviewed from Amibara and Gewane districts.

$$S = X^2 NP(1-P) \div d^2 (N-1) + X^2 P(1-P) \qquad \text{(i)}$$

Where:

S = required sample size

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841)

N = total population

P = the population proportion (assumed to be 0.50 since this would provide the maximum sample size)

d = the degree of accuracy expressed as a proportion (0.05)

A semi-structured questionnaire was administered through individual interviews with the heads of the households within six villages of the Amibara and Gewane districts from December 2016 to April 2016. Data were collected regarding household characteristics, household's access to basic services, livelihood assets and their trends, the householders' annual income, and sources of income, climate change information, climate impacts, adaptation and coping strategies, constraints to the household's coping and adaptation strategies, farm labour, social networks and remittances. The collected data were coded and thereafter analysed using SPSS (version 20) and STATA software (version 13.0). The PCA and regression analysis were also employed to achieve the objectives of this study. To complement the household questionnaire data, 29 individuals from sampled villages and various organisations were interviewed as key informants. Four focus group discussions were piloted separately with gender equality (six men and six women) from the sampled villages.

Furthermore, 31 years' data of the two climate variables, rainfall and temperature, were collected between 1983 and 2014 from the Ethiopian National Meteorology Agency (NMA) to determine the trend of these variables in the study area. According to the IPCC (2007), the classical period of time to take data of temperature and rainfall for analysing the pattern and trend of climate change and variability is thirty years. On the other hand, Landsat images, field observations and household interviews were employed to analyse the trends of land-use/land-cover changes of the study area and its impacts on the livelihood of pastoralists.

4.4 Data Collection

4.4.1 Reconnaissance

An initial reconnaissance survey of the study area was conducted prior to commencement of the actual study. The objective was to meet relevant stakeholders and to introduce the study objectives and discuss its relevance to decision-making processes. The stakeholders involved in the introductory meeting were local administrators, extension officers and local elders. The pre-study session was very useful as it helped in building local community trust as well as providing more insights into areas that the stakeholders prioritised for the study assessment. This enabled a better understanding of the peculiarities of the study area, the size of the sample frame that was considered and identification of the local enumerator for the household's interview.

4.4.2 Training of local field assistants

In total, ten field assistants were employed locally with the assistance of district extension officers based on their previous research experiences, knowledge of the local language and qualifications. The training was conducted over two days before starting with the household interviews. The purpose of the training was to reduce biases and errors in data collection, and to familiarise the field assistants with the objectives of the research questions, interactive ways to ask questions and tools to be used.

4.4.3 Focus group discussions

Four focus group discussions were conducted separately with gender equality (six men and six women) from each district. During the focus group discussions, we included clan leaders and elders who had long experience about the region's climate, vegetation, politics and other situations. The discussions held with different groups of the community aimed at capturing the local knowledge on climate change and variability and its impacts on local communities, adaptation and coping strategies, the main drivers of the land-use/land-cover changes and its impacts on their livelihood. A total of 29 individuals from the sampled villages and local organisations were interviewed during the study period.

4.4.4 Questionnaire pre-testing

A pilot test-run was undertaken with local enumerators and key informants before the beginning of the household interviews, and the final questionnaire were revised and rewritten accordingly. The questionnaire used for the pre-test was excluded from the final data entry and analysis. The piloting was done to check the suitability of the tools and also whether the field assistants could manage the questionnaire without difficulty.

4.4.5 Questionnaire interviews

A semi-structured questionnaire with open-ended, multiple-response and dichotomous questions was employed during data collection (see Appendix A). Information on various aspects was collected through interviewing of the selected household head. The survey addressed information about household characteristics, household access to basic services, livelihood assets and their trends, income per household, and sources of income, climate change information, climate impacts, adaptation and coping strategies, constraints to the household's coping and adaptation strategies, farm labour, social networks and remittances, drivers of land-use/land-cover changes and impacts on pastoralist's livelihood. To avoid misunderstanding, the household interviews were undertaken in the local language by the local field assistants. In addition, secondary data were obtained from national and regional offices, online sources and existing literature, including published reports from relevant sources, journal papers.

4.5 Determining Trends of Climate Variability and Change in the Study Area

4.5.1 Data sets

The study was depending on merged gauge–satellite recorded rainfall and minimum and maximum temperature time series data on a ten-daily time scale which was obtained from the Ethiopian NMA for the period 1983–2013 for rainfall and 1983−2014 for temperature. Staff members of NMA who had been qualified on satellite rainfall and temperature retrievals, data quality control, as well as merging gauge and satellite data did most of the work at NMA. Historically, weather stations measurements have been the major sources of climate data managed by NMA. However, in Southern Afar region, rain gauge measurements suffered from a number of limitations. There were few stations over the study areas. Only Awash Shelko and Gewane were active stations in the study areas. Although, these stations were active, they were frequently suffered from data gaps and poor quality data availability. Therefore, there were spatial and temporal gaps in climate observations. The spatial gaps were a consequence of meagre station network, while temporal gaps were a result of interrupted observations or lost data. Satellite proxies have been used as options due to their accessibility even over remote parts of the world. However, satellite rainfall estimates also has its own limitations which involve short time period of observation, heterogeneous time series and poor accuracy mostly at higher temporal and spatial resolutions. To solve this problem, the NMA was offering merged gauge–satellite recorded rainfall and temperature data since 1983- up to the present time over Ethiopia at a spatial resolution of 10km and a ten-daily time scale. Merged-satellite rainfall and temperature data are extensively employed in various hydro-climatological analyses in Ethiopia (Dinku *et al*, 2011; Wagesho *et al.,* 2013) and other different parts of the world (Baigorria *et al.* 2007; Ghosh *et al.* 2009; Mair & Fares 2009; Rajeevan *et al*. 2006; Tazalika, 2004) and are promoted as appropriate for climate variability studies. A rainfall data set starting from 1983 up to the present is produced for Africa from the archives of Meteosat TIR imagery, which is calibrated against ground-based observations by Tropical Applications of Meteorology using SATellite and local gauge data [TAMSAT] (Dugdale *et al.,* 1991; Milford *et al.,* 1994; Grimes *et al.,* 1999; Tarnavsky *et al.,* 2014). In this study, the local gauge data were merged with a locally calibrated version of the TAMSAT satellite rainfall estimates to generate 30-years (1983-2013) of rainfall estimates over the Southern Afar region at a spatial resolution of 10 km. This included quality control of rain gauge data, producing a local calibrated version of the TAMSAT rainfall estimates, and merging these with local gauge data. Qualified NMA staff on satellite retrieval, data quality control, as well as merging gauge and satellite data did most of the work at NMA. For this study, the NMA performed quality control of the gauge data including identifying suspicious rainfall values. The consistency of a given dekadal rainfall value was compared with values for the same dekad of different years at a similar station (Eischeid *et al.*, 1995). Rainfall values that were identified as outliers according to criteria for temporal checks were marked as a suspect. Rainfall values that were considered suspicious were then recorded as missing data in the quality-controlled gauge archive. In the present study, the gridded data of each study area were aggregated in one value. The satellite based rainfall estimates and rain gauge observations were merged using the bias adjustments employed by Dinku *et al*. (2014).

4.5.2 Data analysis

In this study, seasonal rainfall analysis was based on three seasons, namely: (i) Karma (summer season), a long rainy season, which occur from June to September; (ii) Sugum (spring) season, a short rainy season, which occurs from March to May; (iii) Dadda season, which occur from October to February. The Dadda season offers little but critical rain showers that enable the transit of pastoralists from Karma to the Sugum season.

In this study, the Mann-Kendall statistical test was undertaken to the monthly, seasonal and annual temporally distributed rainfall and temperature data trends at 0.1%, 1% and 5% level of significance. The Mann-Kendall test method can be employed for data which are not normally distributed. Similarly, the test is a non-parametric statistical procedure that is well-suited for analysing trends in data over time. A non-parametric test is preferred over the parametric in view of its ability for analysis of data that is not normally distributed (Babar & Ramesh, 2013; Hamed, 2008; Mondal *et al.,* 2012). According to Mann-Kendall test, the null hypothesis H_0 states that the deseasonalized data (X1……Xn) is a sample of (n) independent and identically distributed random variables while alternative hypothesis H_1 states that the distributions of x_k and x_j are not identical for all k, $j < n$ with $k = j$. The test statistic S, which has mean zero and a variance computed by Equation (iv), is calculated using Equations (ii) and (iii), and is asymptotically normal (Hirsch *et al,* 1984). Positive values of Z show increasing trends, while negative values of Z indicate decreasing trends.

$$S = \sum_{K=1}^{n-1} \sum_{j=K+1}^{n} sgn(x_j - x_k) \qquad \text{(ii)}$$

$$sgn(x_j - x_k) = \begin{cases} +1 \text{ if } (x_j - x_k) > 0 \\ 0 \text{ if } (x_j - x_k) = 0 \\ -1 \text{ if } (x_j - x_k) < 0 \end{cases} \qquad \text{(iii)}$$

$$Var(S) = \frac{\lfloor n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i-5) \rfloor}{18} \qquad \text{(iv)}$$

where n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and t_i is the number of data points in the i^{th}group. In cases where the sample size n > 10, the standard normal variable Z is computed by using Eq.(iv) (Douglas *et al.*, 2000):

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(s)}} \text{ if } S > 0 \\ 0 \quad if\ S = 0 \\ \frac{S+1}{\sqrt{Var(s)}} \text{ if } S < 0 \end{cases} \qquad \text{(v)}$$

On the other hand, the magnitude of rainfall and temperature trend is measured using Sen's estimator. If a linear trend is present in a time series, the change per unit time (the true slope) of all data pairs (Q_i) can be estimated following the equation developed by Sen (1968).

$$Q_i = \frac{X_j - X_K}{j - k} \qquad \text{(vi)}$$

Where: i = 1, 2, 3…, N; x_j and x_k refer to data values at times j and k (j > k), respectively. The median of these N values of Q_i is Sen's estimator of slope. If N is odd, then Sen's estimator is calculated as follows:

$$Q_{med} = \frac{Q_{N+1}}{2} \qquad \text{(vii)}$$

If N is even, then Sen's estimator is calculated as follows:

$$Q_{med} = \frac{1}{2}\left(Q_{N/2} + \frac{Q_{N+2}}{2}\right) \qquad \text{(viii)}$$

Lastly, Q_{med} is estimated by a two sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test Q_{med} .

In this study, inter-annual and seasonal fluctuations of rainfall and severity of drought were estimated for the observation periods, using the Standardised Precipitation Index (SPI) McKee *et al*. (1995). The SPI estimation for any area is depending on the long-term rainfall record for a given period. The long-term rainfall record is fitted to a gamma distribution as it has been found to fit the precipitation distribution well. The gamma distribution parameters are estimated using the maximum likelihood. The gamma cumulative probability gamma function is then transformed into a standard normal random variable Z with mean of zero and standard deviation of 1 (Edwards & McKee, 1997). Positives SPI values reveal greater than average rainfall and negative values show less than average rainfall. Since the SPI is normalized, drier and wetter periods can be estimated in the same way. Therefore, SPI can also be employed to monitor wet periods. In this study, seasonal rainfall analysis was based on three seasons, namely: (i) Karma (summer season), which occurs from June to September; (ii) Sugum (spring) season, which occurs from March to May. Hence, a 3-month SPI at the end of May (spring season) and 4-month SPI at the end of September (summer season) were employed to analyse the seasonal rainfall variability in Southern Afar region. A 3-month SPI at the end of May for spring season compares the March-April-May rainfall total in that particular year with the March-April-May rainfall totals of the years on record for the study area. The same holds true for 4-month SPI. The drought severity of the study area was analysed based on a 12-month SPI which reflects the long-term rainfall patterns. The magnitude of drought effects is firmly associated with the timing of the start of the rainfall deficiency, its duration and intensity of the drought hazard. A drought starts when the SPI value becomes negative and ends when it becomes positive. The drought severity (magnitude) is then the aggregate values of SPI within the duration of drought (McKee *et al*., 1993). The SPI values are indicated in Table 4 1 below.

Table 4.1 Drought classes and corresponding Standardized Precipitation Index values

SPI values	Drought classes
≥ 0	No drought
0 to –0.99	Mild drought
−1.00 to –1.49	Moderate drought
–1.5 to –1.99	Severe drought
≤ –2	Extreme drought

Source: McKee *et al*. (1993)

The SPI is a widely-used index to determine drought severity over time (Andreu *et al*., 2007). This indicator was produced by McKee *et al*. (1993) and since then has been employed widely in various regions across the globe, including the United States (Hayes *et al*., 1999), Australia (Barros & Bowden, 2008), Europe (Cancelliere *et al*., 2007) and Africa (Ntale & Gan, 2003).

The ratio of standard deviation to the mean represents the coefficient of variation (CV) (NMSA, 2001) which was used to identify the spatial and temporal variability of rainfall during the observation periods. In order to study the monthly distribution of seasonal and annual rainfalls in the study area during the observation periods, PCI was employed (following Oliver, 1980). The PCI is a robust indicator of the temporal distribution of rainfall. The equation to calculate PCI at an annual scale is described as follows:

$$PCI_{annual} = \frac{\sum_{i=1}^{12} Pi^2}{(\sum_{i=1}^{12} pi)^2} \times 100 \qquad \text{(ix)}$$

Where:

Pi = the rainfall amount of the i^{th} month

Σ = summation over the 12 months

The PCI was also analyzed on seasonal scale for spring (March-April-May), summer (June-July-August-September) and dry season (October-November-December-January-February).

$$PCI_{Spring} = \frac{\sum_{i=1}^{3} Pi^2}{(\sum_{i=1}^{3} pi)^2} \times 25 \qquad \text{(x)}$$

$$PCI_{Summer} = \frac{\sum_{i=1}^{4} Pi^2}{(\sum_{i=1}^{4} pi)^2} \times 33 \quad \text{(xi)}$$

$$PCI_{Dadda-season} = \frac{\sum_{i=1}^{5} Pi^2}{(\sum_{i=1}^{5} pi)^2} \times 42 \quad \text{(xii)}$$

According to Oliver (1980), the rainfall is uniformly distributed if the PCI value is less than 10. If the PCI values are in the range of 11–20, then it indicates an irregular rainfall distribution, and values above 21 indicate a very irregular rainfall distribution

4.6 Assessing Vulnerability of Pastoralists to Climate Variability and Change

This study used vulnerability indicators to assess vulnerability of pastoralists to climate shocks and stresses. The method for selection of vulnerability indicators is discussed as follows: Vulnerability to perturbation involves different dimensions and is influenced by interrelated multiple components. Most indicators of vulnerability are latent variables and, hence, difficult to measure. However, based on vulnerability indices, the vulnerability levels of households can be assessed which is very significant for decision makers to give priority to the most vulnerable groups during development interventions. In order to develop indices, the appropriate indicators of social, economic and environmental vulnerability must first be selected before weights can be assigned for each indicator. Lastly, these indicators are combined to develop an index. Indicators and indices are valuable to represent a complex reality in simpler terms. However, the approach employed to select indicators is very significant, as the selection of non-representative indicators can cause a development of the wrong index of vulnerability. Theory-driven and data-driven are the two approaches in the choice of indicators (Vincent, 2004). The choice of appropriate indicators can be carried out depending on certain theories that offer understanding of the determinants of vulnerability. Nevertheless, even theory-based methods are influenced by data restrictions and subjectivity is mostly a problem during the selection of indicators. The appropriate alternative is to validate the representativeness of the theory-based indicators based on focus group discussions with key informants. The present study employed this approach while choosing the indicators to determine vulnerability of households in the study area.

Having selected the appropriate vulnerability indicators, the values of the vulnerability indicators had been normalised in order to make the indicator's value within a similar range (Gbetibouo & Ringler, 2009; Nelson *et al.,* 2010; Vincent, 2004). Normalisation is done by subtracting the mean from the observed value and dividing by the standard deviation for each indicator.

$$Normalised\ value = \frac{Observed\ value - Mean}{Standard\ deviation} \quad \text{(xiii)}$$

The next step was to assign weights to the selected vulnerability indicators. In this study, the PCA was employed to assign weights to the indicators (Filmer & Pritchett, 2001). The normalised variables were then multiplied by the weights of the corresponding indicators, using the following formula:

$$I_j = \sum_{i=1}^{K} b_i \left(\frac{a_{ji} - x_i}{s_i}\right) \quad \text{(xiv)}$$

Where:

I = the index value

b = the weights from PCA

a = the individual value of the indicator

x = the mean value of the indicator

s = the standard deviation of the indicators

Lastly, the vulnerability index of each household was calculated using the following equation (following IPCC, 2012):

$$V = AC - (E + S) \quad \text{(xv)}$$

Where:

V = the vulnerability index of each household

AC = the adaptive capacity index

E = the exposure index

S = the sensitivity index for the corresponding household

The model specification is further described as follows:

$$V_i \quad = \quad \left(A_1X_{1j} + \ A_2X_{2j} + \cdots + A_n \ X_{nj}\right) - \left(A_{n+1}Y_{1j} + \ A_{n+2}Y_{2j} + \cdots A_{n+n}Y_{nj}\right) \qquad \text{(xvi)}$$

Where:

V_i= the vulnerability index

X_s = elements of adaptive capacity

Y_s = elements of sensitivity and exposure

A_s = the factor score of each variable computed using PCA

The values of X and Y are obtained by normalization using their mean and standard errors (see equation xi). This study used an integrated approach, which combined social, economic and environmental indicators to construct vulnerability indices for each household as suggested by Madu (2012) and employed by Tesso *et al.* (2012) in Ethiopia. The vulnerability index was suggested after the definition given by the IPCC (2012) that vulnerability is considered as a function of adaptive capacity, sensitivity and exposure of the system.

When the sensitivity and exposure of the households are lower than that of its adaptive capacity, the household come to be less vulnerable to climate-induced hazards and the opposite holds true. The assessment of the socio-economic vulnerability approach gives emphasis to the socio-economic and political conditions of the local people. Vulnerability levels among people in a given area can differ according to their level of knowledge and skills, income level, welfare, access to affordable credits and inputs such as improved varieties, access to EWI, social capital and political ability (Füssel, 2007). The biophysical approach measures the degree of harm due to climate perturbations and stresses on the systems (Jones *et al.*, 2005). The biophysical, or impact assessment, approach is mostly focused on the physical influence of change in climate on various features of the system.

4.7 Quantitative Assessment of Pastoralist's Resilience to Climate-Induced Shocks

In recent years, the quest to quantify individuals, households and society's resilience to disasters or extreme events beyond their control remains a challenge from a quantitative point of view. Given the fact that the resilience of individuals, households and societies are not observed by the analyst, quantifying resilience demands a detailed modelling approach.

Various authors have employed different modelling approaches (Alinovi *et al.,* 2008, 2010; Carter *et al.,* 2006; Demeke & Tefera, 2010). Alinovi *et al.* (2008, 2010) as well as Demeki and Tefera (2010) employed a latent variable approach to quantify resilience. These authors quantified resilience among households in Kenya and Palestine using a latent variable approach. Carter *et al.* (2006) adopted a proxy variable approach by employing an observable variable to represent resilience. These authors assessed resilience and expressed it in six dimensions, which included social safety nets, public service accessibility, assets, income and food access, stability and adaptive capacity. They expressed these dimensions as latent variables. Following this, resilience was estimated in a two-stage procedure. The first estimation procedure involves the use of factor analysis to identify the set of latent variables explaining resilience. The identified latent variables in the first stage are then used to calculate an index for resilience for the sampled households.

Additionally, the latent variable approach and PCA were employed by Demeke and Tefera (2010) to examine resilience to food insecurity in Ethiopia. These authors used panel data at a household level. They first identified four components that explained resilience to food security using PCA. These components included household access to food, liquid assets, level of education, and social network. Secondly, the authors employed panel fixed effect and dynamic panel modelling approaches to find factors that influence household resilience.

In Ethiopia, different coping strategies have been adopted by resilient households. Carter *et al.* (2006) revealed that resilient households in Ethiopia relied on their assets and also depleted their stock in periods of drought, especially during the 1998–1999 drought periods. Similar strategies were employed in the Honduras in 1998 to minimise the impact of the Mitch hurricane. Households, who are not resilient, tend to cope by cutting down on their consumption level as a way of keeping their assets or properties.

Based on the above discussion, it is clear that using a proxy variable approach is the straightforward method for calculating resilience. One limitation of this approach is the difficulty in identifying variables which will act as proxies for resilience. This is because resilience is a multifaceted concept. Additionally, there is difficulty in defining the levels or categorising resilience and finding its determinants if the proxy variable approach is employed. For these reasons, it was decided to adopt the multi-stage modelling approach developed by Alinovi *et al.* (2010), building on its flexibility to adapt to very different real cases. The use of this approach depended on the premise that the alternatives accessible to a household to make a living, would determine the household's resilience at a given point in time.

Empirically, the resilience index (RI) for a household (i) is described as:

$$\mathrm{R_i} = f\left(IFA_i,\ A_i,\ APS_i,\ SSN_i, S_{i,}, AC_i\right) \qquad \text{(xvii)}$$

Where:

R = resilience

S = stability

SSN = social safety nets

AP = access to public services

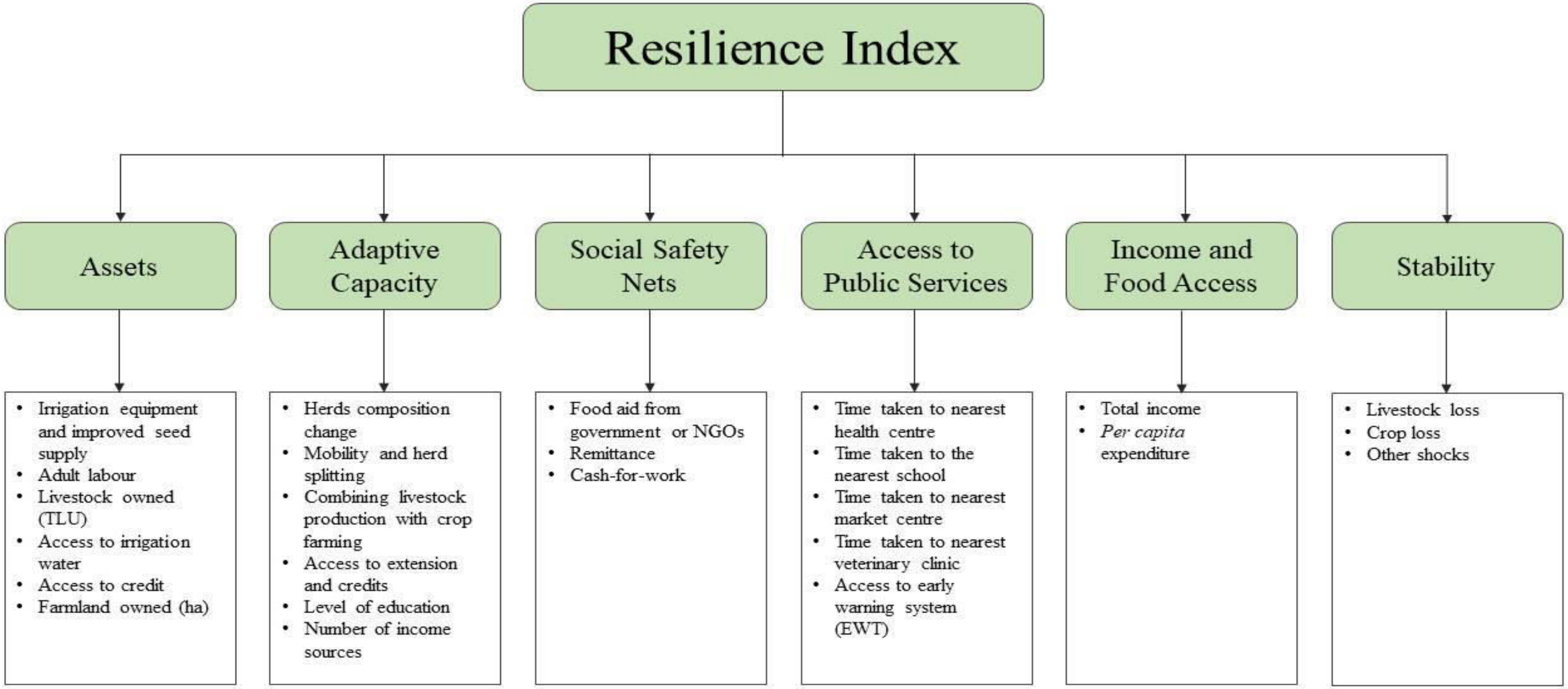
A = assets

IFA = income and food access

AC = adaptive capacity.

During the research, household resilience was not observed by the researcher, and hence it is regarded as a latent variable. In measuring resilience (R), it was essential to calculate IFA, S, SSN, APS, A and AC separately. These indicators are also latent because they were not directly observable during the survey, but can be computed using multivariate techniques. The household resilience model diagram is presented in Figure 4.2.

According to Alinovi *et al.* (2010), two options are adopted to estimate resilience of households. The first approach is structural equation models which are the utmost suitable models to determine resilience of households based on latent variables. This approach is based on regression and factor analysis. According to this model, observed variables are employed to estimate the latent variables using a factor analysis model, and concurrently a regression analysis is employed to determine relations amongst the latent variables (Bollen, 1989). A multi-stage strategy is the second alternative proposed by Alinovi *et al.* (2010) to estimate the latent variables separately using observed variables.



Source: Author's own (2016)

Figure 4.2 The household resilience model diagram

In this study, a two-step approach was employed to estimate the RI of households. The first procedure involved the identification and measurement of observed variables or indicators for the estimation of dimensions of the resilience. Secondly, the RI for each household was determined based on the estimated values of the latent variables (dimensions of resilience). PCA was used to examine the components of resilience and the percentage variance explained by each of the components, as well as their commonalities. According to the approach proposed by Alinovi *et al*. (2010), the factor variance obtained for each factor from the PCA was multiplied by the generated factor to develop the RI of each household (see equation xiv). The formula is described as follows:

$$R = V_1 * F_1 + V_2 * F_2 + V_n * F_n \qquad \text{(xviii)}$$

Where:

R = resilience

V_1 = variance of proportion explained by factor 1 (F_1)

V_2 = variance of proportion explained by factor 2 (F_2)

V_n = variance of proportion explained by factor n (F_n) with eigenvalues >1

4.8 Analysing the Trends of Land-use/Land-cover Changes, Drivers and Impacts on Livelihood of Afar Pastoralists

Landsat images, field observations and household interviews were used to examine the trends of land-use/land-cover changes between 1985 and 2015. In the present study, the driving factors of land-use/land-cover changes and its impact on the livelihood of pastoral communities were identified using focus group discussions and interviews. The steps and sources of information in analysing land use/cover changes are indicated in Fig. 4.3.

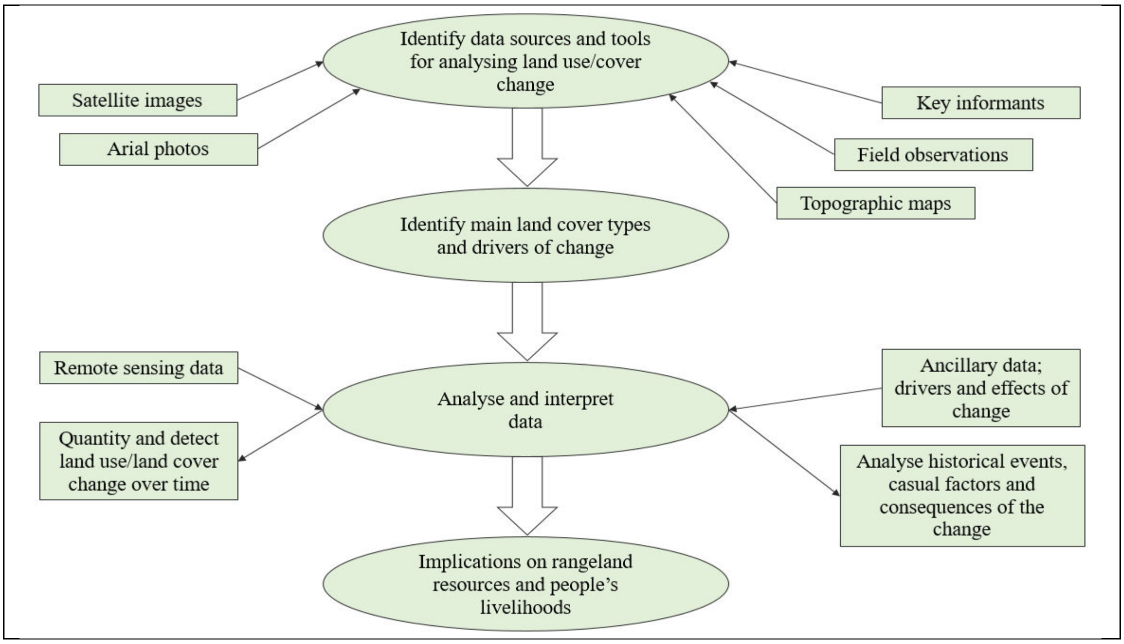


Figure 4.3 Conceptual framework for analysing land-use/land-cover trends

4.8.1 Determination of the land-use and land-cover types

Five major land-use and land-cover categories were identified depending on classification standards for East African rangelands (Pratt *et al.*, 1996), namely bushland and shrub land, cultivated land, grassland, water body and bare land (Table 4.2). As visually observed, the study area was dominated by embedded rocks and sandy bare lands. The dominant vegetation type in the area was shrubs and bushes with the intensification of the alien shrub called *P. juliflora*.

Table 4.2 Description of the existing land-use/land-cover of the Southern Afar region

Land-use/land cover patterns	Descriptions
Shrub and bushlands	Areas covered by bushes and shrubs which are not palatable for sheep and cattle
Cultivated land	Areas allocated for crop production either using rainfall or irrigation schemes
Grasslands	Portion of a rangeland covered by grass species used for livestock grazing
Water body	Portion of a rangeland occupied by lakes, rivers and open water
Bare land	Rangeland areas without any vegetation such as gullies and exposed rocks without vegetation cover

4.8.2 Determination of the assessment years and selection of image types

Based on event-based criteria, three periods were selected to assess the land-use/land-cover changes in the Amibara and Gewane districts. These were 1985, 1995 and 2015. The year 1985 was selected due to the occurrence of the severe drought of 1984/85 in Ethiopia. At the time, the land cover was changed and many people died as a result of severe famine, which incurred the involvement of people worldwide. The droughts recurred again in 1987, 1991 and 1994/95 which was severe in pastoralist areas. Droughts also occurred during 2002, 2009, 2012 and 2013. Furthermore, the aggressively spreading invasive species, *P. juliflora*, was introduced to the Afar region during the 1970s as drought resistant soil conservation mechanisms and it was planted over large areas of the Afar region by campaigns such as the Food for Work Programme until 1988. This was another reason for selecting the three periods to assess the land-use/land-cover changes in the study areas.

In addition, before the 1970s the intervention of Ethiopian governments to allocate the Afar rangelands for commercial farming was limited. However, starting from the 1980s, the government intervention to allocate dry season grazing areas for commercial farming was increasing. Lastly, the land-use/land-cover of the area in 2015 was assessed to analyse the current existing land-use/land-cover. The images used for change detection needed to be similar in character. Therefore, Landsat was the better image with better resolutions, which can be used in all these years. Thematic Mapper (TM) Landsat images for 1985 and 1995, and Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Landsat images for 2015 were used (Table 4.3).

Table 4.3 Characteristics of the data collected using remote sensing for this study

Image type	Year	Path and Row	Spectral resolution	Spatial resolution	Date of acquisition	Landsat Series	Source
Landsat (TM)	1985	167/052	7 bands	30 m × 30 m	28-01-2015	Landsat 8	USGS
		167/053			28-01-2015	Landsat 8	
		167/054			28-02-2015	Landsat 8	
Landsat (TM)	1995	167/052	7 bands	30 m × 30 m	29-02-1995	Landsat 5	USGS
		167/053			02-03-1995	Landsat 5	
		167/054			23-01-1995	Landsat 5	
Landsat (OLI & TIRS)	2015	167/052	11 bands	30 m × 30 m	17-01-1985	Landsat 5	USGS
		167/053			17-01-1985	Landsat 5	
		167/054			15-05-1985	Landsat 5	

4.8.3 Classification of the land-use and land-cover

For the land-use/land cover classification, dry season images were used in order to avoid cloud cover problems in the rainy season and over flooding of water over the mainland. The classification was done using a maximum likelihood supervised classification by using ERDAS Imagine 2010, Version 10.1 software.

Three scenes of Landsat images for each year were downloaded from the United States Geological Survey (USGS) website. The separated bands (layers) of each scene were layer-stacked. However, the classification was done without mosaicking the scenes in order to avoid reflectance variations. The scenes were then displayed with a band combination of the false colour composite of 7, 4 and 2 in the ERDAS viewer for signature editing. It was important for the identification of covers during the taking of control points for the classification. Enough amounts of representative points were taken in each cover type based on the ground control points collected during the field survey. Lastly, a supervised classification was applied, which includes the 1 km buffer area around the study area. This was important for minimising the losses of an area during raster processing.

The thematic raster classification result was brought to ArcGIS 9.3 software and converted to vector format. The conversion resulted in a huge number of polygons and was dissolved to the number of cover classes using the gridcode values of the polygon result. The names of the cover type were again assigned based on their gridcode relationship in the thematic result. The area of each land uses/land-cover types was calculated. Then, the cover distributions and existence were analysed.

4.8.4 Accuracy assessment

Accuracy assessment allows one to evaluate a thematic raster layer (classified image file). The cell array for accuracy assessment lists two sets of class values for the random points in the thematic raster layer. One set of class values was automatically allocated to these randomly selected points as they were chosen, and the other reference values were put in by the user. For the present study the reference values were based on ground truth points and computer digitisation (digitised signatures from the image of the time). A total of 250 ground truth points for the five cover types were collected during the field survey for 2015 image classification. Computer digitisation (digitised signatures from the image of the time) had been used for the 1985 and 1995 image classification.

4.8.5 Application of change detection

The change detection analysis was done for three periods: 1985–1995, 1995–2015 and 1985–2015. Two methods were used for change detection analysis, using a loss or gain table and transitional matrix. The loss or gain method only used simple arithmetic calculations and statistics. It is a result of the subtraction of the area of a specific cover in an earlier image from a recent image. The result may be positive, which indicates the expansion of that cover/use, or negative to quantify its shrinking or minimisation of the area coverage.

The transition matrix analysis is the result of the automatic analysis of the ERDAS Imagine tool called 'Matrix'. The transition matrix is used extensively for analysis of land-use and land-cover change (Brown *et al.*, 2000; Weng, 2002). The tool produced the conversion of one type of land-use/land-cover to another through the given period using the coded value of the land-use/land-cover types. It enables one to know how much of the area of a specific cover transformed to others and how much remained unchanged in the time period. This method of analysis is important to support the identification and analysis of the causes of the change which can be outlined through socio-economic studies.

The annual rate of change between two periods was calculated following the formula adopted by Long *et al.* (2007):

$$\Delta = \frac{A2-A1}{A1} * 100 \div T2 - T1 \qquad \text{(xix)}$$

Where:

Δ = Average annual rate of change (%)

A1 = Amount of land-cover type in time 1 (T1)

A2 = Amount of land-cover type in time 2 (T2)

4.8.6 Land-use/land-cover change analysis

At this stage, many types of questions provided solutions and answers. Which cover was highly transformed to other types? Which land-use/land-cover received more extra land from other types of cover throughout the period? The analysis was used in a cause-and-effect relationship, which means any change happening in the area needs to be event-based and must be causal effects. The field observation, the discussion with the society and the image classification results, in combination, answered such questions at this part of the analysis. On the other hand, severe losers and dominant receivers or expansionists were described and explained based on their causes which triggered the change to happen.

Chapter 5
RESULTS AND DISCUSSION

5.1 Introduction

The chapter starts by discussing the findings of trends of climate variables (rainfall and temperature) in the Southern Afar region which were analysed based on the data obtained from the Ethiopian NMA for the period 1983–2013 for rainfall and 1983–2014 for temperature. In this chapter, the impacts of rainfall variability and anomalies and increasing temperature on livelihood of Afar pastoralists are discussed. The results and discussions of the present study also continues in Chapter 6 by discussing the findings on the livelihood assets and their trends in the Southern Afar region, households' perception on climate variability and change, impacts of climate change and variability on Southern Afar communities based on the perception of local respondents, adaptation and coping strategies employed by Afar pastoralists, resilience and vulnerability status of households to climate-induced shocks and stresses. The results and discussions of this study also continue in Chapter 7 with discussions about land-use/land-cover changes, drivers and their impacts on livelihood of pastoralists.

5.2 Rainfall Trends in the Southern Afar Region

5.2.1 Monthly rainfall trends

The maximum monthly rainfall (222.6 mm) and (205.5 mm) were observed in the Amibara and Gewane districts during the month of August 2007 and 2006, respectively. The basic characteristics of monthly rainfall time series in the study areas for the period 1983–2013 are summarised in Table 5.1.

Table 5.1 Average monthly aggregated rainfall data in the Amibara and Gewane districts: Descriptive statistics for 1983–2013 (mm)

Study area	Rainfall level	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Amibara	Minimum	0	0	0	7.3	0.9	0.5	6.2	39.9	17.6	0	0	0
	Maximum	76	179.6	121	151	117.8	73.9	141.9	222.6	99.3	168.3	69.5	73.7
	Average	16.2	28.7	45.8	64.9	31.2	23.0	90.5	141.2	51.7	24.6	14.6	11.6
	SD	22.0	46.5	32.0	42.3	34.3	18.0	36.3	40.8	25.1	44.3	20.4	20.7
	CV (%)	136	162	70	65	110	78	40	29	49	180	140	179
Gewane	Minimum	0	0	0	0.7	0	0	4.3	4.2	4.9	0	0	0
	Maximum	45	163.7	99.1	133.3	134.4	34.2	204.4	205.8	92	88.1	59.6	59.8
	Average	10.3	26.7	40.8	54.3	25.5	7.0	85.7	138.2	40.0	12.7	7.3	8.4
	SD	12.4	38.5	31.2	36.0	30.0	7.8	39.3	39.0	19.6	19.6	13.8	14.4
	CV (%)	120	144	77	66	118	111	46	28	49	154	188	170

CV = Coefficient of Variation; SD = Standard deviation

The highest rainfall was recorded in July and August and contributed 42.6% to the annual rainfall totals in Amibara and 49% in Gewane, followed by April and September with 20.6% and 21.4% contribution of the annual rainfall totals in Amibara and Gewane, respectively.

The results of the Mann-Kendall statistical tests for the monthly rainfall at 95% and 99% confidence level are given in Table 5.2. The results indicated that July and November revealed a significant increasing trend at a rate of 1.73 mm and 0.62 mm per year, respectively. On the other hand, the months of February, April and May depicted a significant decreasing trend at a rate of –0.82 mm, –1.48 mm and –0.85 mm per year, respectively, in the Amibara district for the period 1983−2013.

Table 5.2 Monthly rainfall Mann-Kendall's trend test results for 1983–2013

Study area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Amibara	0	–0.82*	0.16	–1.48*	–0.85*	0.46	1.73*	0.70	–0.35	0.06	0.62**	–0.33
Gewane	0	–0.008	0.06	–1.22	–0.82*	0.09	1.70*	1.6*	–0.58	0.007	0.03*	0.00

**Significant trend at α = 0.05 with positive for increasing & negative for decreasing monthly rainfall trends*
***Significant at α = 0.01 with positive for increasing & negative for decreasing monthly rainfall trends*

In the Gewane district, significant increasing trends were observed for the months of July, August, and November at a rate of 1.7 mm, 1.6 mm and 0.03 mm per year, respectively, while a significant decreasing trend was observed in May at a rate of -0.82 mm per year.

5.2.2 Seasonal rainfall trend and variability

The results indicated that in the Amibara district, the summer and spring seasons contributed 56.3% and 26.1% to the annual rainfall totals, respectively. Similarly, the summer and spring seasons contributed 59.3% and 26.4% to the annual rainfall totals, respectively in Gewane district. At the normal times of the year, *Dadda* rainfall was also very critical to transit pastoralists from the *Karma* to the *Sugum* season without problems regarding rainfall availability. *Dadda* rainfall also contributed 10% and 6% to the annual rainfall totals in the Amibara and Gewane districts, respectively.

Coefficients of variation (CV) have been computed for Amibara and Gewane in order to investigate the inter-seasonal rainfall variability. According to Hare (1983), CV is used to classify the degree of variability of rainfall events as less (CV < 20), moderate (20 < CV < 30), and high (CV > 30). In this study, the CV ranged from 39.3% (spring season) to 22.5% (summer season) in Amibara, while the CV in Gewane ranged from 42.7% (spring) to 25.2% (summer) for the period 1983–2013 (Table 5.3). High annual CV in spring season has been observed in both study areas. This study was in agreement with Kassie (2014) who indicated that the CV in summer season (28%) and in spring season (41%) for rift valley of Ethiopia. However, higher CV was reported by Hadgu *et.al* (2013) as compared to the CV of the rainfall seasons observed in the present study who revealed that the CV in summer and spring seasons was 30% and 50%, respectively, in northern Ethiopia. Several studies on rainfall indicated that the rainfall exhibited higher intra-seasonal variability in Africa (Boko et al., 2007; Conway et al., 2007; Cooper et al., 2008; Cooper & Coe, 2011; Rosell, 2011). The results also showed higher inter-seasonal rainfall variability in Gewane than in Amibara during the observation period.

Table 5.3 Descriptive statistics of seasonal rainfall in the Amibara and Gewane districts for the period 1983–2013 (mm)

Study area	Rainfall level	*Sugum*	*Karma*	*Dadda*
Amibara	Minimum	57.5	303.7	4.6
	Maximum	304	409.3	213
	Average	164.2	284.5	50.8
	SD	64.6	63.9	47.5
	CV (%)	39.3	22.5	93.5
	PCI	48	33	71.2
Gewane	Minimum	42.2	75.2	0.2
	Maximum	289.7	397.9	127
	Average	127.7	263.9	28.5
	SD	54.5	66.5	33.5
	CV (%)	42.7	25.2	117.7
	PCI	54	41	79

SD = Standard deviation, CV = Coefficient of Variation, PCI = Rainfall concentration index

The coefficient of variation for Dadda rainfall was extremely high (CV > 90) indicating very high variability among Dadda rainfall seasons for the observation periods. This indicated that since pastoralists are highly dependent on bio-modal rainfall, the high rainfall variability during spring and *Dadda* rainfall seasons could affect their resilience to food security.

As discussed in chapter six, section 6.4, in detail, the key informants reported that due to seasonal rainfall variability, pastoralists in the Afar region were forced to move long distances during the dry season. This, in turn, caused their livestock to be physically emaciated and exposed to diseases, resulting in loss of livestock and low market price which led to food insecurity and a less resilient community. Similarly, when pastoralists move long distances in searching for food and water, they lack social services such as education and health services.

The seasonal rainfall distribution was analysed following Oliver's (1980) precipitation concentration index (PCI). According to Oliver (1980), the rainfall is uniformly distributed if the PCI value is less than 10. If the PCI values are in the range of 11−20, then it indicates the irregular distribution of rainfall, and values above 21 indicate a very irregular rainfall distribution. Accordingly, the result showed that PCI values were 12, 11 and 30 for *Sugum*, *Karma* and *Dadda* rainfall, respectively, in Amibara indicating very poor monthly distribution of rainfall. Similarly, the PCI values for the *Sugum, Karma*, and *Dadda* seasons were 13, 14 and 33, respectively, in the Gewane district; highlighting strong irregular rainfall distribution (Table 5.3). This suggested that the study areas showed very high rainfall concentration which implies the seasonal rainfall totals was concentrated in few months of the year. This study is in agreement with the reports of Hadgu *et al.* (2013) who indicated very high concentration in northern Ethiopia. However, Ayalew *et al*. (2012) and Kassie (2014) reported moderate to high concentration in Amhara region and central rift valley of Ethiopia, respectively. The PCI values obviously indicated that rainfall distribution was more irregular in order of *Dadda* seasons > *Sugum* seasons > *Karma* seasons. Similar observations that spring rainfall is more irregular than summer rainfall have been reported by Bewket and Conway (2007) and Merasha (1999).

Furthermore, the SPI for seasonal rainfall is presented graphically to identify seasonal rainfall anomalies in the study areas for the period 1983–2013 (see Figure 5.1 and Figure 5.2). Rainfall analysis at annual level may not indicate rainfall deficits in pastoralist areas where rainfall is an erratic and large share of the total rainfall over a few days and lost rapidly through runoff and evaporation (Ellis & Galvin, 1994). Therefore, seasonal rainfall distribution and amount is the better indicator of rainfall shortages than the total annual rainfall in arid and semi-arid areas (Ellis & Galvin, 1994).

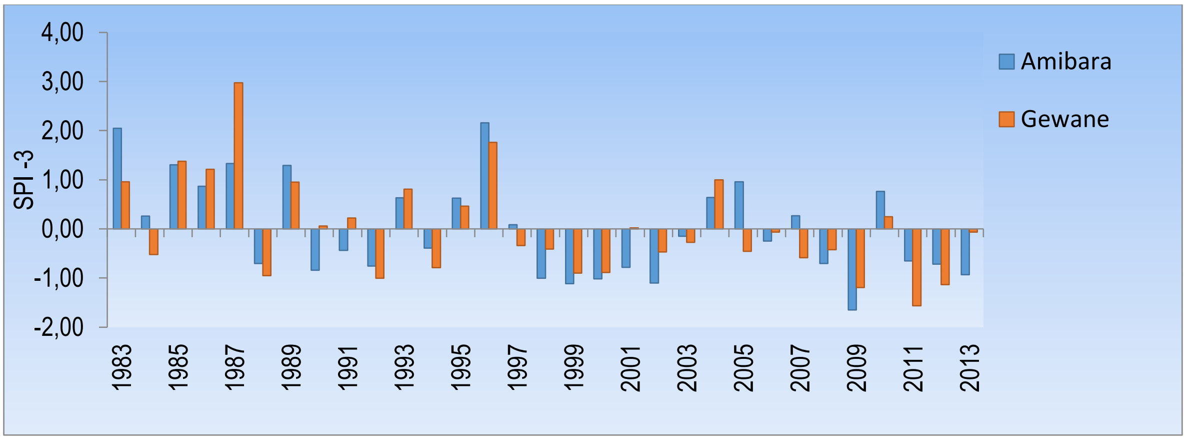


Figure 5.1 Three months SPI for Sugum rainfall season

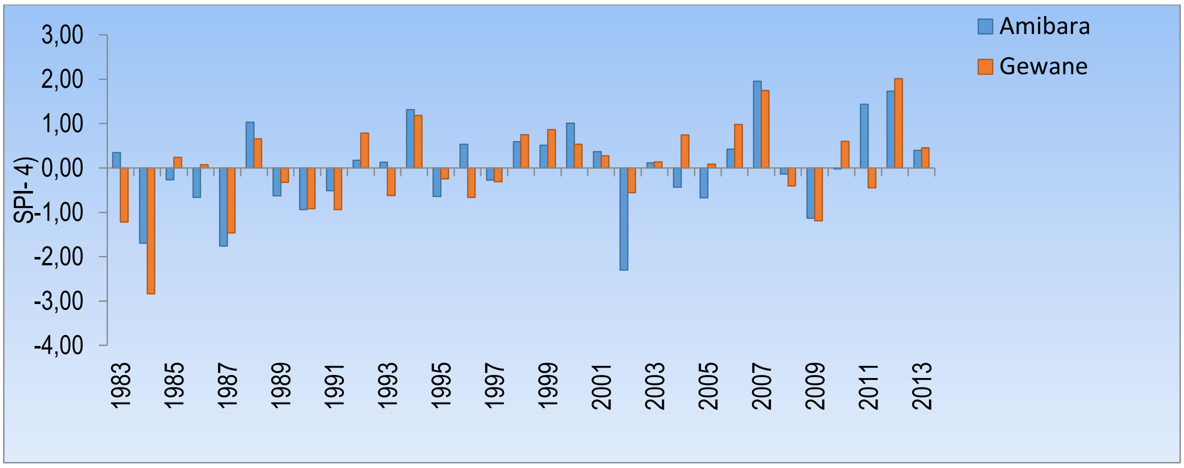


Figure 5.2 Four months SPI for Karma rainfall season

Analysis of SPI indicated that the total percentage of dry spring season (negative anomalies of spring rainfalls) ranged from 57% (at Amibara) to 60% (at Gewane) most of which occurred starting from 1997 (Figure 5.1). This indicates that pastoralism in the study area appears to be a risky enterprise as the bimodal rainfall pattern in the region is changed and concentrated towards two months of the summer season, mostly on the months of July and August, leaving grass for the livestock not fully-grown. This, in turn, could result in a shortage of pasture and water for their livestock after early cessation of the summer season. Ellis and Swift (1988) indicated that a lengthier bimodal pattern favours grasses, browses and pastoralism in Africa. In the dry lands of Eastern Africa, there is a long history of specialised pastoralism and limited agro-pastoralism, since the bimodal rainfall regime prevails there (Ellis & Galvin, 1994). From the present study, it was observed that the bimodal rainfall regime is changing and rainfall is more concentrated towards the few months of the summer season; hence pastoralism in the Southern Afar region is at great risk to continue as a major livelihood for the pastoralists.

The Mann-Kendall test on seasonal rainfall data is indicated in Table 5.4 and graphically represented in Appendix 4a, b, c, d, e and f. The results showed a significant declining trend of *Sugum* rainfall and a significant increasing trend of *Karma* and *Dadda* rainfall (at α=0.05) in the Amibara district, indicating poor performance of *Sugum* rainfall. Similarly, *Sugum* and *Karma* indicated both significant negative and positive trends for Gewane district, respectively. The Sen's slope estimator indicated that the *Sugum* rainfall decreased by

3.036 mm and 2.814 mm per season in the Amibara and Gewane districts, respectively, while the *Karma* rainfall increased by 2.533 mm and 3.181 mm in Amibara and Gewane, respectively. Evidence of decreasing trends of rainfall in the spring season (*Sugum*) in Ethiopia was also indicated by Jury and Funk (2013), Seleshi and Camberlin, (2006), Viste *et al.,* (2013) as well as Williams and Funk (2011). However, the analysis was inconsistent with the findings indicated by Seleshi and Sanke (2004) who indicated that the seasonal rainfall trends in the central, northern and north-western parts of Ethiopia was non-significant during the period 1965–2002. The present results were not in line with the findings of Meze-Hausken (2004) who reported that no rainfall trends have been observed in the northern and north-eastern parts of Ethiopia.

The significant decreasing trend of *Sugum* rainfall implies a reflection of disastrous effects on Afar pastoralists as they are dependent on the seasonal availability of rainfall to access forage and water for their livestock. During normal times, the Afar region receives two main rainfalls: *Karma* that occurs in the period July!September and *Sugum* in the March!May. These are the two seasons that determined the productivity of rangelands in the study areas. In other words, the productivity of pasture and browsing trees depends to a great extent on the amount and patterns of rainfall distribution during the long and short rainy seasons. As can be seen from the monthly rainfall trends in Table 5.2, the months of April and May depicted a significant decreasing trend indicating the failure of *Sugum* rainfall, while a decreasing trend in the month of September indicated shrinkage of *Karma* rainfall.

Table 5.4 Mann-Kendall-derived trend values for seasonal rainfall estimates: 1983–2013

Variable	Study area	*Sugum*	*Karma*	*Dadda*
Seasonal rainfall trend (Mann-Kendall* Test stat)	Amibara	–3.036*	2.533*	1.04*
	Gewane	–2.814*	3.181*	0.519[ns]

*Significant trend at α = 0.05, ns=non-significant
Positive numbers indicate an increasing trend of seasonal rainfall, while negative numbers reveal a decreasing trend

Generally, significant decreasing trend of *Sugum* rainfall and poor performance of *Karma* and *Dadda* rainfalls could have a significant negative effect on regional pastures and water availability which may lead to food insecurity. This is supported by the findings of Van de Steeg *et al.* (2009) who stated that the change in patterns of rainfall availability and a rising trend of temperature could make rain-fed agriculture riskier and exacerbate food insecurity in

Ethiopia. Similarly, Fischer *et al.* (2002) also indicated that rainfall anomalies, in addition to changes in temperature regimes, impact the annual and seasonal water balances of the region. Moreover, the agricultural sector in Ethiopia is also very susceptible to rainfall anomalies, and the country's ability to react to climate-related shock is very low. Consequently, a small shift in patterns and trends of rainfall will have a significant influence on the economic performance of the country (Fraser, 2007).

Although the *Karma* rainfall showed a significant increasing trend, the rainfall amount seemed to be concentrated towards the June and August months (very high PCI). From the average monthly rainfall data analysis, September showed a decreasing trend, while June depicted a small and insignificant increasing trend. Therefore, the *Karma* rainfall showed an uneven distribution of rainfall, late onset and early cessation dates of rainfall in the study areas. Overall, the significant decreasing trend of *Sugum* rainfall and late onset and early cessation of *Karma* rainfalls could have disastrous effects on the seasonal availability of pasture and water for livestock which may impact the resilience of pastoralists in arid and semi-arid areas of the Southern Afar region.

5.2.3 Trend and variability of annual rainfall

The results showed that the average total rainfall from 1983–2013 was 543.8 mm and 458 mm in Amibara and Gewane, respectively. The mean, minimum and maximum rainfall during the observation periods are indicated in the Table 5.5.

Table 5.5 Descriptive statistics of annual rainfall in Amibara and Gewane districts for 1983–2013

Study area	Number of years	Minimum (mm)	Observation year	Maximum (mm)	Observation year	Mean (mm)	SD	CV	PCI
Amibara	30	337.2	2002	717.5	1996	543.8	89.2	16.4	17
Gewane	30	182.2	1984	573.9	2004	458.0	80.7	17.6	21

SD = Standard deviation, CV = Coefficient of Variation, PCI = Precipitation concentration index

The coefficient of variation of annual rainfall indicated less variability of annual rainfall (CV < 20) as compared to seasonal rainfall variability (Table 5.5). Furthermore, the annual rainfall distribution was analysed using PCI, and the result showed that PCI values were 17 and 21 for the Amibara and Gewane districts, respectively, highlighting the irregular distribution of annual rainfall (Table 5.5). However, very strongly irregular rainfall distribution was observed in seasonal rainfalls than annual rainfalls. Therefore, impacts of seasonal rainfall variability on pastoralists in the Southern Afar region could be more pronounced than annual rainfall variability. Hence, in order to improve pastoralists' livelihood, the regional government and local extension workers should work in favour of strengthening seasonal mobility of pastoralists to utilise the seasonally available heterogeneous rangeland resources (pasture and water). Furthermore, the pastoralists' indigenous knowledge on seasonal and annual rainfall variability should be updated and guided by the regional and local experts through predicting the upcoming temporal and spatial rainfall variability.

The Mann-Kendall test statistic results indicated that the long-term rainfall trend was not significant (Appendix 5). The results of the present study is not in agreement with the findings reported by Funk *et al.* (2008) who indicated that Ethiopia, Kenya, Burundi and Tanzania revealed significant rainfall decline trends during the 1979–2005 periods. On the other hand, the studies by Woldeamlak and Conway (2007) in north-western Ethiopia, Seleshi and Sanke (2004) in central, northern and north-western Ethiopia, Conway *et al.* (2004) in the central Ethiopian highlands and Conway (2000) in the north-eastern Ethiopian highlands, reported non-significant and unclear trends of annual rainfall.

Results from SPI indicated that severe and extreme droughts for Amibara occurred in 1984 and 2002, respectively, while moderate droughts occurred in 2001, 2009 and 2013 (Table 5.6). On the other hand, one extreme drought for Gewane occurred in 1984, while two severe droughts occurred in 2009 and 2011 (Table 5.5). This is supported by Seleshi and Sanke (2004) who showed that the most devastating disaster that occurred in Ethiopia was the 1984 famine due to the failure of the long rainfall season (June to September), which caused a decline of the GDP by 97% and agricultural products by 21%. Due to its widespread coverage across the region, much has been said for the 1984 famine in Ethiopia. However, for this particular study area, the analysis showed that the rainfall recovered and faintly progressed during the years 1985 and 1986; hence, pastoralists had time to recover after the 1984 famine.

After close analysis of the SPI, it was observed that the 2002 drought was more severe than the 1984 drought in the Amibara district, as the 2001 and 2003 rainfall showed a negative anomaly (Figure 5.5) (that means the rainfall was below average for three consecutive years from 2001–2003); hence, the pastoralists had no time to recover during these extended drought periods. Similarly, droughts that occurred in Amibara during 2009 and 2013 were also severe as the dry period extended from 2008–2009 and from 2012–2013 through which pastoralists left with no time to bounce back to their original livelihood activities.

Table 5.6 Standardised Precipitation Index values and drought categories which indicates negative values in the Amibara and Gewane districts for 1983−2013

Amibara			Gewane		
SPI	Year	Category	SPI	Year	Category
–1.89	1984	Severe	–0.5	1983	Mild
–0.08	1986	Mild	–3.4	1984	Extreme
–0.918	1987	Mild	–0.8	1991	Mild
–0.202	1990	Mild	–0.2	1994	Mild
–0.906	1991	Mild	–0.1	1998	Mild
–0.079	1994	Mild	–0.4	2001	Mild
–0.073	1995	Mild	–0.6	2002	Mild
–0.138	1998	Mild	–0.7	2005	Mild
–1.031	2001	Moderate	–0.3	2008	Mild
–2.32	2002	Extreme	–1.8	2009	Severe
–0.324	2003	Mild	–2.0	2011	Severe
–0.27	2005	Mild	–0.2	2013	Mild
–0.656	2008	Mild			
–1.23	2009	Moderate			
–0.21	2012	Mild			
–1.026	2013	Moderate			

The drought occurred during 1984 and 2009 were also the worst in the Gewane district as it was extended from 1983–1984 and 2008–2009 (Figure 5.4). The results indicated that the frequency and duration of droughts has increased in the Southern Afar region, which could further complicated food insecurity and famine in the area.

For example, the frequency of drought occurrence before 2000 was eight times in seventeen years (47% probability) while it occurred nine times in thirteen years after 2000 in Amibara district (69% probability) (Figure 5.3). Similarly, the probability of drought occurrence before 2000 was 29% while it was 53.8% after 2000 in Gewane district (Figure 5.4). This is supported by Conway (2000), Conway and Schipper (2011), Demeke *et al.* (2011), Hulme *et al.* (2001), Roselle *et al.* (2011), Seleshi and Sanke (2004) and Tadege (2007) who reported that rainfall anomaly, especially droughts, have been increasing and were the main reason for food insecurity and famine in Ethiopia.

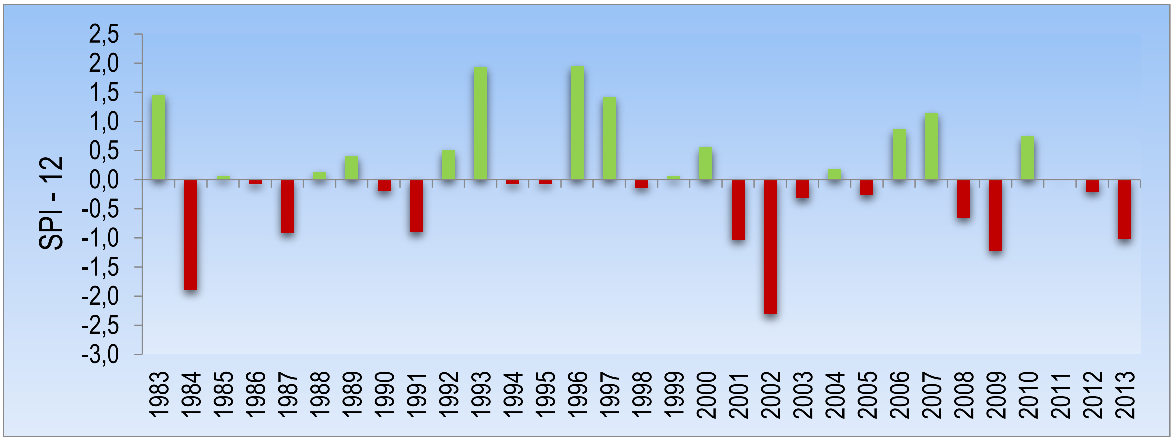


Figure 5.3 Twelve-months SPI in the Amibara district for 1983-2013

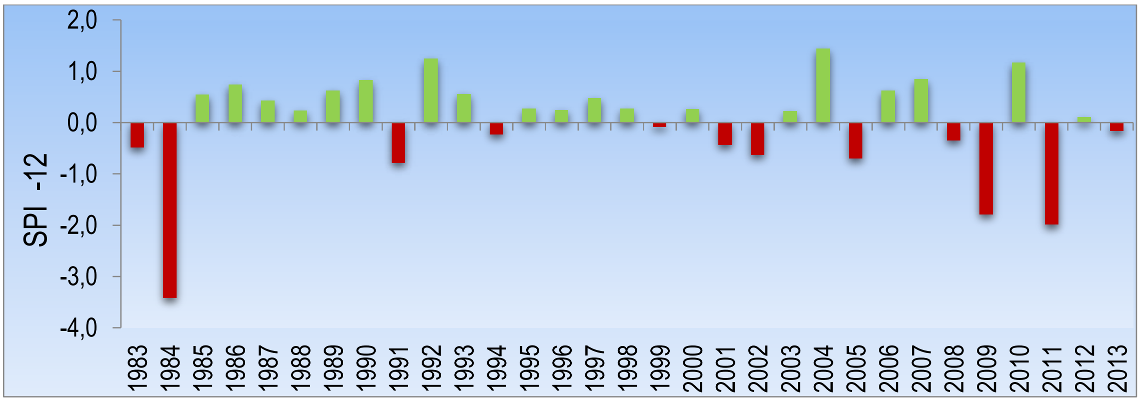


Figure 5.4 Twelve-months SPI in the Gewane district for 1983-2013

The total percentage of drought years ranged from 53.3% (at Amibara) to 43.3% (at Gewane) indicating more drought periods in Amibara than in Gewane (Table 5.5). However, the percentages of severe/extreme drought years were from 6.7% (at Amibara) to 10% (at Gewane). The total percentage of moderate drought years was 10% in Amibara, although it was not observed in Gewane (Table 5.5).

Generally, the time series analysis of normalised annual rainfall data showed the episodic fluctuation of rainfall, which could be a great risk to pastoralists' livelihood over the studied agro-ecological zone, where the majority of the people have been left vulnerable to hunger and famine. Devereux and Edward (2004) reported that East African countries are already among the most food insecure as compared to the rest of the countries on the globe and climate-induced shocks and stresses could exacerbate loss of agricultural outputs.

Overall, the temporal and spatial rainfall variability in the Southern Afar region has been increasing over time. The region is increasingly receiving irregular and insufficient annual rainfall, although the long-term rainfall intensity has not decreased significantly. The question is: Why have pastoralists of the region suffered from shortage of forage and water when there has been no significant declining in long-term rainfall? Although there are other reasons that led to shortage of pastures in the area, such as problems associated with rangeland management such as the invasion of *P. juliflora* and other external pressures from outside, for instance, allocation of dry-season grazing areas to investors and state farms, the answer to this question can be given and analysed from three perspectives associated with climate-related impacts (because other discussions will be outside the field of the topic):

The first perspective is associated with significant changing of the bimodal rainfall regime in the Southern Afar region which is more critical in determining rangeland productivity than long-term rainfall. As was discussed above on the seasonal rainfall trend analysis, *Sugum* rainfall has declined significantly and rainfall was more concentrated towards the few months of the *Karma* season, indicating significant changing of the bimodal rainfall regime.

The second perspective is inconsistency in the duration, beginning, and end of the rainy season. For a seasonal and monthly rainfall analysis, it can be seen that during *Sugum* rainfall, the rainfall started early in March and ceased early, leaving April and May with scanty rainfall, while during *Karma* rainfall, the rainfall started late in June and ceased early, leaving September with insufficient rainfall. Information gathered through the questionnaire, which is discussed in detail in chapter six, also confirmed that delay or early onset of rainfall has become a common phenomenon in the area for many years. This, in turn, could result in the shortage of pasture and water for their livestock, forcing the pastoralists of the area to either stay for a long time until the next rainy season comes or move a long distance in search of forage and water.

In the Southern Afar region, it is unfortunate that the rainwater that falls during the rainy season was allowed to escape without any deliberate attempt to harvest and store, and then start looking for water after the rainy season.

The third perspective is attributable to increasing temperature, which is discussed below in section 5.3. The region is increasingly becoming hotter and receiving scanty annual rainfall. It is obvious that with increasing temperature and declining rainfall, the consequence of pasture and water resources will worsen. Evaporation from water bodies, soil surfaces and transpiration from plants will increase due to the increasing temperature. This, in turn, leads to water stress and droughts (Bruhn, 2002).

5.3 Temperature Trends in the Southern Afar Region

In the present study, four seasonal calendars were identified to analyse the seasonal temperature trends. According to the local calendar, the relatively cold season of the year occurred from October to February, locally called Gilal; the second and warm season of the year occurred from March to April, locally called Sugum; the third season, which was the warmest of the year, occurred from May to June, locally called Hagai; and the last warmer season of the year occurred from June to September, locally called Karma. Accordingly, the temperature series was investigated for monthly, seasonal and annual temporal trends to provide a micro-scenario for temperature variability and change in the Amibara and Gewane districts between 1983 and 2014.

5.3.1 Monthly temperature trends

The statistical description of minimum, maximum and mean temperature of the study area is indicated in Table 5.7. Results showed that the mean monthly highest and lowest temperatures were observed in June 2003 (31.5 °C) and January 1986 (21.6 °C), respectively, in Amibara, while the mean monthly highest and lowest temperatures were recorded in June 2010 (34.1 °C) and December 1985 (22.4 °C), respectively, in Gewane.

Table 5.7 Mean monthly temperature descriptive statistics in the Amibara and Gewane districts: 1983!2014

Temperature (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Amibara (32 years)												
Minimum	21.6	22.5	24.8	25.7	26.5	28.4	26.9	23.6	25.8	24.4	22.1	21.7
Maximum	24.7	26.3	27.8	29.4	30.8	31.5	30.6	29.2	29.4	27.5	25.4	25.0
Mean	23.3	24.6	26.2	27.7	29.0	30.3	28.6	27.4	27.6	26.0	24.1	23.3
SD	0.87	1.00	0.76	1.02	1.19	2.86	0.95	1.03	0.89	0.78	0.73	0.93
CV (%)	3.7	4.0	2.9	3.7	4.1	9.4	3.3	3.8	3.2	3.0	3.0	4.0
Gewane (32 years)												
Minimum	23.3	23.9	25.5	26.3	27.3	29.7	28.0	27.6	27.3	25.1	23.3	22.37
Maximum	25.8	28.2	29.3	32.0	32.8	34.1	32.6	30.9	31.3	29.9	27.3	26.92
Mean	24.6	26.1	27.6	29.1	30.7	32.3	30.6	29.2	29.4	27.8	25.7	24.37
SD	0.78	1.14	0.99	1.53	1.54	1.11	1.09	0.90	1.08	1.23	1.16	0.98
CV (%)	3.2	4.4	3.6	5.2	5.0	3.5	3.6	3.1	3.7	4.4	4.5	4.0

SD = Standard deviation, CV = Coefficient of Variation

The results further indicated that highest variations of mean monthly temperatures were observed in the months of June in Amibara. Similarly, highest variations of mean monthly temperatures were observed in the months of April and May, respectively, for the Gewane district (Table 5.7). The lowest of the maximum temperatures and the highest of the minimum temperatures were observed in January 1983 (29.1 °C) and June 2003 (23.9 °C), respectively, in Amibara. Similarly, the lowest of the maximum temperatures and the highest of the minimum temperatures were recorded in February 1990 (29.9 °C) and July 2010 (26.4 °C), respectively, in the Gewane district. The highest variation in the monthly maximum temperature was observed during the months of February (CV = 4.5) and April (CV =5.8) in Amibara and Gewane, respectively. Variations in the monthly minimum temperatures were very high as compared to variations in the monthly maximum temperatures (Table 5.8 and Table 5.9).

Table 5.8 Monthly maximum temperature descriptive statistics in the Amibara and Gewane districts: 1983–2014

Temperature (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Amibara (32 years)												
Minimum	29.1	30.1	32.1	32.5	33.8	36.2	34.4	32.7	33.1	32.8	30.7	29.8
Maximum	33.1	35.8	36.2	38.1	39.5	40.0	39.0	37.6	37.3	35.9	34.3	33.3
Mean	30.6	32.0	33.3	34.3	36.0	36.9	35.3	34.0	34.2	33.4	32.1	31.0
SD	0.9	1.4	1.3	1.5	1.5	1.0	1.2	1.2	1.1	0.9	1.0	0.9
CV	3.1	4.5	3.8	4.2	4.1	2.7	3.3	3.4	3.2	2.6	3.0	2.7
Gewane (32 years)												
Minimum	30.3	29.9	32.2	32.5	35.3	38.3	36.6	33.8	35.0	34.2	32.0	30.8
Maximum	34.1	37.3	38.3	41.0	41.9	42.1	40.4	38.7	39.6	39.1	36.0	34.6
Mean	32.5	34.0	35.6	37.3	39.3	40.4	38.5	37.0	37.7	36.7	34.5	33.0
SD	0.92	1.82	1.74	2.16	1.95	1.18	1.01	1.18	1.15	1.20	1.07	0.82
CV	2.81	5.34	4.87	5.79	4.95	2.92	2.62	3.18	3.05	3.27	3.09	2.47

SD = Standard deviation, CV = Coefficient of Variation

Table 5.9 Monthly minimum temperature descriptive statistics in the Amibara and Gewane districts: 1983–2014

Temperature (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Amibara (32 years)												
Minimum	12.2	12.9	16.0	18.1	18.3	20.3	19.0	12.8	17.8	15.3	12.3	12.3
Maximum	17.0	18.6	19.7	21.6	22.6	23.9	22.7	21.1	22.7	19.8	16.7	17.8
Mean	14.6	15.9	17.7	19.4	20.2	21.1	20.2	19.1	19.3	17.2	14.7	14.2
SD	1.4	1.5	0.9	0.8	1.1	0.9	0.9	1.4	0.9	1.0	1.0	1.5
CV	9.5	9.5	5.3	4.3	5.2	24.4	4.6	7.1	4.4	5.8	6.5	10.8
Gewane (32 years)												
Minimum	13.7	14.5	16.6	18.2	18.5	21.1	19.1	19.4	18.5	15.4	13.7	13.3
Maximum	18.7	21.1	21.6	23	24.4	26.0	26.4	23.1	23.4	21.1	20.4	19.5
Mean	16.7	18.3	19.7	21.1	22.1	24.2	22.7	21.5	21.2	18.9	17.0	15.9
SD	1.5	1.5	1.1	1.2	1.3	1.3	1.5	1.0	1.3	1.7	1.5	1.7
CV	8.7	8.2	5.4	5.9	6.1	5.2	6.5	4.8	6.0	8.8	9.0	10.5

SD = Standard deviation, CV = Coefficient of Variation

The results of the Mann-Kendall test statistics on a monthly basis for both minimum and maximum temperatures are summarised in Table 5.10, Table 5.11 and Table 5.12. The Mann-Kendall test showed that significant increasing rates in monthly maximum temperature fall in the range of 0.044 °C per month for the month of November to 0.108 °C dec^{-1} for the month of April in the Amibara district Table 5.10). Similarly, significant monthly daytime warming (maximum temperature) trends were observed in the range of 0.046 °C per month for the month of August to 0.164 °C per month for the month of April in the Gewane district (Table 5.11). Similar observations were reported by Kassie *et al.* (2013) indicating an increasing trend for maximum and minimum temperatures in the central Rift Valley of Ethiopia. The results further showed that relatively cold months of the year in the study area (October, November, December, January and February) revealed significant warming trend during the observation periods. Stronger warming trends of maximum temperatures were observed in the Gewane district than in Amibara, indicating spatial variability of temperature trends over the Southern Afar region.

In general, the Mann-Kendall test result as indicated in Table 5.10, confirmed a statistically significant increasing trend in monthly maximum temperatures across the study area and in all months of the year implying a greater amount of sensible heat in the daytime.

Table 5.10 Monthly maximum temperature trend: 1983–2014

	Amibara			Gewane		
	Mann-Kendall trend		Sen's slope estimate	Mann-Kendall trend		Sen's slope estimate
Month	Test Z	Sig.	Q	Test Z	Sig.	Q
Jan	3.03	**	0.057	3.26	**	0.058
Feb	3.83	***	0.090	3.91	***	0.106
March	2.92	**	0.067	3.39	***	0.118
April	3.70	***	0.108	4.14	***	0.164
May	4.01	***	0.107	3.29	***	0.142
June	4.14	***	0.078	4.35	***	0.097
July	3.05	**	0.069	3.21	**	0.069
Aug	2.79	**	0.064	2.01	*	0.046
Sept	3.83	***	0.082	4.64	***	0.095
Oct	3.04	**	0.054	4.15	***	0.094
Nov	2.74	**	0.044	4.30	***	0.087
Dec	3.17	**	0.057	4.15	***	0.055

*Note:-*** if trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance,* if trend at α = 0.05 level of significance*

A significantly increasing trend of monthly maximum temperature might cause increased evaporation from water bodies and soil moisture, but may not be compensated as a result of decreasing rainfall trends in the region. According to Giertz *et al.* (2006), higher temperature and decreased rainfall due to climate variability will impact water sources and prolonged dry weather which may lead to water stress in the region.

The results of the Mann-Kendall test on the trend of monthly minimum temperatures are indicated in Table 5.11. The results showed that the monthly minimum temperature trend was significant in all months of the year except for January, February and March in both study areas, as well as in December for the Amibara district. Significant warming trend rates in the monthly minimum temperature series were in the range of 0.028 °C in August and 0.115 °C per month in November in the Amibara and Gewane district, respectively (Table 5.11). The results further indicated that the increasing trend of monthly minimum temperatures exceeds the monthly maximum temperature by 0. 028 °C and 0.007 °C per month in the Gewane and Amibara districts, respectively, during the months of November, indicating a decrease in diurnal temperature range. Similarly, stronger warming night-times were also observed in April and May for the observation periods. This study is also in agreement with Bryan et al. (2009) and Nasrallah et al. (2004), who showed that even though spatial variability was observed in the mean monthly minimum temperature trends, globally a general rise of mean monthly minimum temperature trend was observed.

Table 5.11 Monthly minimum temperature trend: 1983–2014

Month	Amibara			Gewane		
	Mann-Kendall trend		Sen's slope estimate	Mann-Kendall trend		Sen's slope estimate
	Test Z	Sig.	Q	Test Z	Sig.	Q
Jan	0.60		0.017	0.89		0.033
Feb	–0.29		–0.011	0.36		0.010
March	0.60		0.014	0.94		0.018
April	3.85	***	0.058	3.67	***	0.074
May	3.38	***	0.065	3.34	***	0.092
June	2.77	**	0.046	3.75	***	0.086
July	2.64	**	0.050	2.71	**	0.055
Aug	2.37	*	0.028	2.21	+	0.048
Sept	2.74	**	0.036	3.73	***	0.095
Oct	1.91	+	0.045	2.69	**	0.098
Nov	3.05	**	0.051	4.31	***	0.115
Dec	0.54		0.013	1.75	+	0.056

**** = 0.001 significance level, ** = 0.01 significance level, * = 0.05 significance level, + = 0.1 significance level*

Table 5.12 Mean monthly temperature trend: 1983–2014)

Month	Amibara			Gewane		
	Mann-Kendall trend		Sen's slope estimate	Mann-Kendall trend		Sen's slope estimate
	Test Z	Sig.	Q	Test Z	Sig.	Q
Jan	2.61	**	0.042	3.12	**	0.049
Feb	2.35	*	0.052	3.21	**	0.071
March	2.17	*	0.035	2.97	**	0.064
April	4.23	***	0.086	4.15	***	0.118
May	3.76	***	0.084	3.86	***	0.119
June	3.92	***	0.063	4.35	***	0.089
July	2.95	**	0.058	3.41	***	0.066
Aug	3.08	**	0.044	2.51	*	0.047
Sept	3.75	***	0.058	4.56	***	0.095
Oct	3.24	**	0.046	4.22	***	0.100
Nov	4.02	***	0.050	5.13	***	0.103
Dec	1.86	+	0.031	2.84	**	0.050

**** = 0.001 significance level, ** = 0.01 significance level, * = 0.05 significance level, + = 0.1 significance level*

The further indicated that significant warming trends in the mean monthly temperature series were observed and ranged from 0.031 °C per month in the months of December in Amibara, to 0.119 °C per month in the months of May in Gewane (Table 5.12).

5.3.2 Seasonal temperature trends

The descriptive statistics of seasonal mean temperatures are summarised in Table 5.13. According to the local calendar, normally the warmest season of the year is *Hagai* (May to June) followed by *karma (*July to September*)* and *Sugum* season (February to April). The *Gilal* (October to January) season is relatively cold seasons of the year.

Table 5.13 Descriptive statistics of seasonal mean temperature: 1983−2014

Study area	Season	T_{min} (°C)	T_{max} (°C)	Mean (°C)	SD
Amibara	*Karma*	20.1	35.0	27.5	0.818
	Sugum	19.1	34.0	26.5	0.758
	Hagai	21.3	37.6	29.4	1.117
	Gilal	15.6	32.7	24.2	0.640
Gewane	*Karma*	21.3	37.7	29.5	0.910
	Sugum	20.3	36.5	28.4	1.147
	Hagai	23.1	39.8	31.5	1.297
	Gilal	17.0	34.2	25.7	0.825

The Mann-Kendall test results showed that all seasons in both the Amibara and Gewane district depicted increased trends of maximum and minimum temperatures (Table 5.14, Table 5.15 and Table 5.16). Stronger warming trends of day-time and night-time temperatures were observed almost in all seasons in Gewane compared to the Amibara district. Therefore, it is obvious that with increasing temperature and decreasing rainfall, the consequence on water resources, agricultural yields and income of the farmers could be devastating in the study area. This is supported by the results of Bruhn (2002) who reported that the rise in temperature triggered loss of water from the soil surface and water bodies through increased evaporation and from plants via transpiration. This study is also supported by the reports of Türke∏ and Sümer (2004) who indicated that warming seasons can cause more irrigation services and an increase in water consumption.

Table 5.14 Seasonal maximum temperature trend: 1983–2014

Study area	Season	Test Z	Sig.	Q	Study area	Season	Test Z	Sig.	Q
Amibara	*Gilal*	4.64	***	0.060	Gewane	*Gilal*	5.53	***	0.086
	Sugum	3.84	***	0.089		*Sugum*	4.40	***	0.152
	Hagai	4.01	***	0.088		*Hagai*	3.75	***	0.120
	Karma	4.10	***	0.070		*Karma*	3.50	***	0.061

**** = 0.001 significance level, ** = 0.01 significance level, * = 0.05 significance level*

The results further indicated that the change in night-time temperature exceeded the daytime temperature by 0.008 °C in the *Karma* season in the Gewane district, while the daytime temperature change exceeded the night-time temperature by 0.032 °C for the same season in the Amibara district, highlighting the spatial variability of the temperature trend (Table 5.14 and Table 5.15).

Table 5.15 Seasonal minimum temperature trend: 1983–2014

Study area	Season	Test Z	Sig.	Q	Study area	Season	Test Z	Sig.	Q
Amibara	*Gilal*	2.06	*	0.026	Gewane	*Gilal*	2.84	**	0.054
	Sugum	2.19	*	0.033		*Sugum*	2.53	*	0.047
	Hagai	3.67	***	0.056		*Hagai*	3.62	***	0.092
	Karma	3.03	**	0.038		*Karma*	3.11	**	0.069

**** = 0.001 significance level, ** = 0.01 significance level, * = 0.05 significance level*

The significant warming trend in the seasonal maximum temperature was in the range of 0.06 °C during the *Gilal* season in the Amibara district to 0.152 °C during the *Sugum* season in the Gewane district (Table 5.14). On the other hand, the seasonal minimum temperatures also varied from 0.026 °C during *Gilal* in Amibara to 0.092 °C during *Hagai* in the Gewane district (TT 5.15). The seasonal mean temperature series also showed a significant warming trend in all seasons of the year during the observation periods, which ranged from 0.044 °C during the *Gilal* season in the Amibara district to 0.102 °C during the *Hagai* season in the Gewane district (Table 5.16).

Table 5.16 Seasonal mean temperature trend: 1983–2014

Study area	Season	Test Z	Sig.	Q	Study area	Season	Test Z	Sig.	Q
Amibara	*Gilal*	3.65	***	0.044	Gewane	*Gilal*	5.08	***	0.072
	Sugum	4.17	***	0.057		*Sugum*	4.43	***	0.093
	Hagai	3.84	***	0.071		*Hagai*	4.04	***	0.102
	Karma	3.94	***	0.058		*Karma*	3.81	***	0.071

**** = 0.001 significance level, ** = 0.01 significance level, * = 0.05 significance level*

5.3.3 Annual temperature trends

The mean annual temperatures were 26.5 °C and 28.1 °C in Amibara and Gewane, respectively. The annual mean minimum and maximum temperatures were 18.3 °C and 35 °C, respectively, for Amibara, while the annual mean minimum and maximum temperatures were 19.9 °C and 36.3 °C, respectively, for the Gewane district. Relatively high variability was observed in the annual minimum temperature (CV = 4) than the annual maximum temperature (CV = 3). The Mann-Kendal test results of annual minimum, maximum and mean temperature are presented in Appendix 6a, 6b and 6c.

The Mann-Kendall test indicated that a significant increasing trend of annual maximum temperatures was observed and ranged from 0.083 °C per year in Amibara to 0.095 °C per year in the Gewane district. The rate of the increasing trend in annual maximum temperatures obtained in the present study exceeded the findings reported by NMSA (2001). The findings reported by NMSA showed significant increasing trends of mean annual temperature during the past 50 years in Ethiopia by 0.010 °C per year.

The annual time series of minimum and maximum temperature for the period 1983–2014 is shown in Figure 5.5 and Figure 5.6. In general, the annual maximum temperature increased in both the Amibara and Gewane districts from about the mid-1997s to present. The annual mean minimum temperature also indicated a rising trend at a rate of 0.035 °C and 0.06 per year in the Amibara and Gewane districts, respectively.

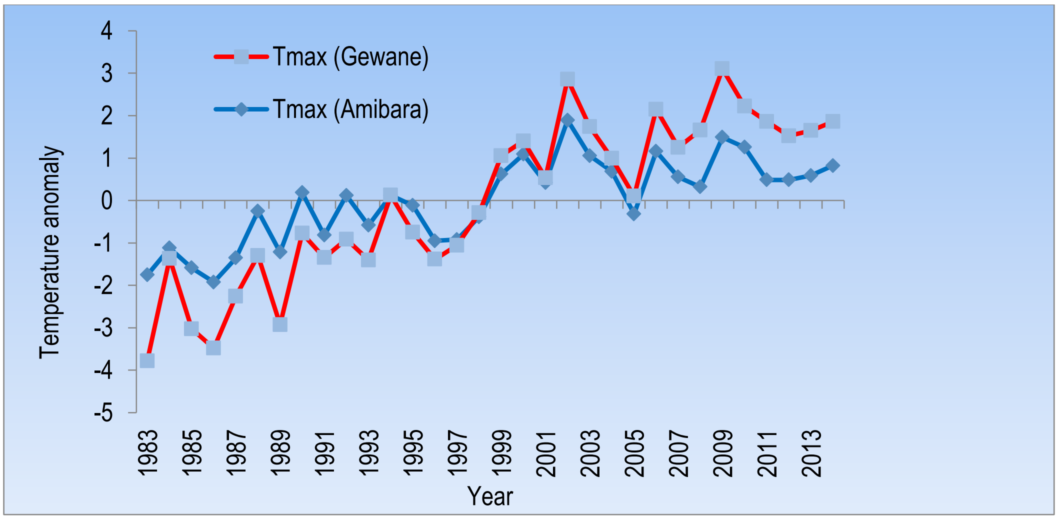


Figure 5.5 Time series of annual maximum temperature in the Amibara and Gewane districts

A rise in mean annual minimum temperature showed that the heat interchange between the atmosphere and the earth has been declined. Even though both the mean annual maximum and minimum temperatures showed an increasing trend, it was observed that the maximum temperature have risen at a faster rate than the minimum temperature (0.083 °C versus 0.035 °C per year in Amibara and 0.09 °C versus 0.06 °C per year in Gewane); hence, an increasing trend of diurnal temperature range (DTR) was observed during the observational periods.

The findings are in agreement with Kruger and Shongwe (2004) and Jung *et al*. (2002) who reported a DTR increase in both South Africa and Korea. However, the analysis did not corroborate with the worldwide and country level findings reported by Vose *et al.* (2005) who indicated that the night-time temperatures increased at a quicker rate than the daytime temperatures, leading to a decreasing trend of DTR. Increased daytime temperature leads to heat stress to livestock, which affect livestock productivity and health (Reilly *et al.,* 1996; Walter *et al.,* 2010). Livestock suffering from heat stress could have reduced appetite for feed, leading to low productivity (Walter *et al.,* 2010). On the other hand, night-time warming (minimum temperature) could affect forage quantity and quality, palatability and digestibility. According to Wan *et al.* (2009), night-time warming increases the rate of respiration while it decreases the rate of photosynthesis and results in a low-level total non-structural carbohydrate cycle, minerals and protein as compared to the built-up of structural carbon through the accelerated growth of plants. Forage plants with a low non-structural carbohydrate cycle and protein are of low quality, palatability, and digestibility. Hence, in this study, the rising trend of both maximum and minimum temperatures may have a negative effect on forage quality and quantity and livestock production and productivity.

The annual mean minimum temperature of the study area, which ranged from 0.035 °C (in Amibara) to 0.06 °C per year (in Gewane) exceeded the findings reported by NMSA (2001) who indicated that the mean annual minimum temperature over Ethiopia increased by 0.025°C per year. Hence, the Southern Afar region was warming at a faster rate than the country's warming trend. Tadege (2007) also indicated that the average annual mean minimum temperature change over the country was 0.037 °C. The results were consistent with those of Gebrehiwot and Van der Veen (2013) who indicated that annual mean night-time temperature was increased by 0.072 ℃ per year in northern Ethiopia (Tigray region). Similarly, in the Sahel region, a significant increasing trend of night-time temperature was observed since the mid-1960s (Ben Mohamed *et al.,* 2002).

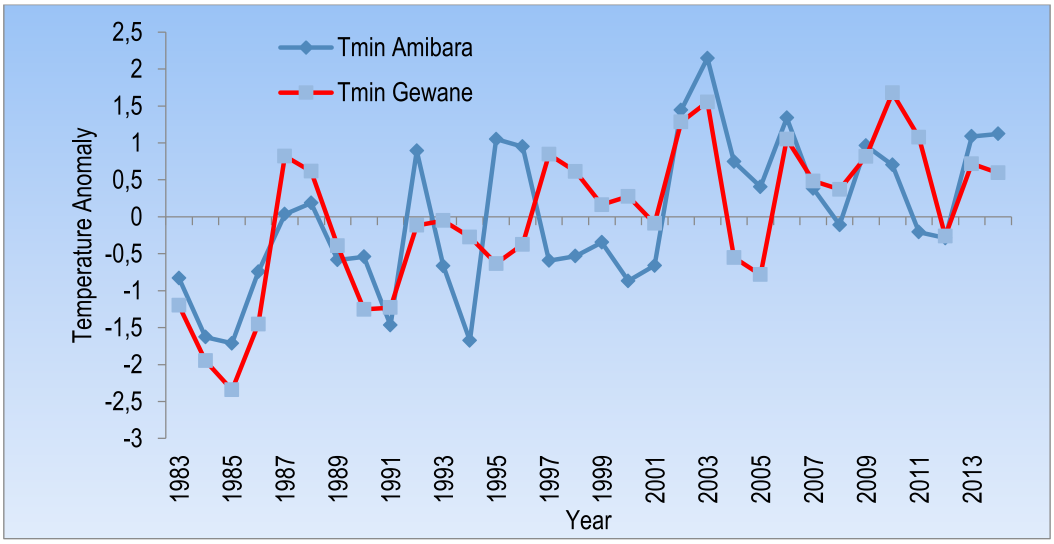


Figure 5.6 Time series annual minimum temperature in the Amibara and Gewane districts

The Sen's slope estimator indicated that the annual mean temperature increased by 0.54 °C and 0.8 °C dec^{-1} in the Amibara and Gewane districts, respectively. This analysis is supported by the results of the African Climate Change Resilient Alliance (ACCRA) (2012) who indicated that the mean annual temperature in Ethiopia has risen in the range of 0.5–1.3 °C since the 1960s. The present findings confirmed the reports of the IPCC (2007a) who indicated that mean temperatures of the world have increased by 0.74 ºC ±0.18 ºC throughout the past century (1906–2005). The results also corroborated with the findings reported by the IPCC (2001) who showed that the mean temperature of the world has increased at about 0.5 °C during the twentieth century. Overall, even though temporal and spatial variability have been observed in the rates of increase, most findings reported increasing trends of temperature in Ethiopia and globally during the previous decades.

5.4 Summary

This study indicated a significant increasing trend of monthly, seasonal and annual temperatures, including mean, maximum and minimum temperatures, and a significant declining trend of *Sugum* rainfall which occurred from March to May, and a significant increasing trend of *Karma* rainfall which occurred from June to September, but the rainfall was concentrated towards July and August highlighting late onset and shrinkage of the longer rainy season in the Southern Afar region which could lead to deterioration of the region's water and pasture availability. The research further indicated the significant increasing trend of temperature in the study areas, and agreed with the recent trends of global warming as reported by the IPCC (2013). However, the long-term rainfall trend from 1983–2013 indicated a non-significant declining trend. The study showed an uneven distribution of rainfall, late onset and early cessation dates of rainfall in the study areas. Sometimes the rain stopped early, or it fell at higher intensity, but for limited months. The increasing temperature trend in the region, which could lead to higher evaporation of water bodies and soil moisture together with significant decreasing of *Sugum* rainfall and poor performance of *Karma* and *Dadda* rainfalls, could have disastrous effects on the seasonal availability of pasture and water for livestock which may impact the resilience of pastoralists in the Southern Afar region. It can be concluded that there was an adequate confirmation to recommend that there have been climate change over the Southern Afar region. Therefore, the policymakers should develop an adaptation strategy to the changing climate variability and extremes.

Chapter 6
IMPACTS OF CLIMATE VARIABILITY AND CHANGE ON THE LIVELIHOODS OF PASTORALISTS AND THEIR ADAPTATION/COPING MECHANISMS

6.1 Introduction

Pastoralism is the main livelihood strategy of Southern Afar households that seek to sustain an optimal equilibrium between livestock, pasture and the society in unreliable and variable environments. However, climate variability and extremes has posed a great challenge for sustainability of pastoralism in the region. The temporal and spatial variability of natural resources such as pasture, water, and the quantity and quality of forages are mostly controlled by rainfall. In Chapter 5, the results from meteorological data showed a significant seasonal and annual rainfall variability and decreasing trends of seasonal rainfall. In this chapter, from the perspective of local households' perceptions, the main livelihood assets and trends, the consequences of climate variability and extremes on pastoralists' livelihood and their coping and adaptation mechanisms, are discussed.

6.2 Livelihood Assets and Trends in the Southern Afar Region

The resilience of pastoralists depends on the livelihood assets accessible to make a living, such as access to natural resources, public services, infrastructures and affordable credits (Alinovi *et al.,* 2010; DFID, 2011). Access to these assets and the environment governs the overall livelihood strategies of societies in which these assets are merged for production and consumption functions (Ellis, 2000; Rass, 2006). The following sections discuss assets identified by the local people to pursue their livelihood.

6.2.1 Rangeland

Rangeland represents the key resources for pastoral livelihoods. It is the main sources of feed and water for their livestock. It also provides charcoal, fuelwood and house construction materials. During the household survey, respondents were asked to mention the feed sources they used for their livestock. The major feed sources identified by the households are summarised in Table 6.1. Rainfall is the most important factor that determines rangeland productivity. During normal season of the year when there is a normal rainfall distribution in the longer and shorter rainy season, herders can get grasses/browses around their villages. However, during the dry season when shortage of feed occurs, herders compensate the deficiency through moving herds to dry season grazing areas/reserves.

Table 6.1 Livestock feed sources reported by respondents (multiple responses were possible)

Sources of feed	Respondents (n=250)	Percent
Browse (trees and bushes)	235	94
Grazing (grass)	220	88
Crop residue	88	35
Hay	13	5

Source: Author's field survey (2016).

Whenever the dry season prolonged, herders moved long distances in search of feed and water. The respondents complained that mobility was highly restricted due to the appropriation of dry season grazing areas to commercial farmers, loss of palatable forages associated with bush encroachment and prolonged and frequent drought. This caused pastoralists to move long distances outside the Afar region in search of feed and water.

6.2.2 Water resources

Pastoralist movement/settlement followed water sources such as rivers and streams. Afar pastoralists were dependent on seasonal and permanent water sources for livestock and human consumption. The dominant water source for the study area was the Awash River, especially during the dry season. It was also a source of water for irrigation crop farming. During the household survey, the water sources for livestock and human consumption were identified by local people and described in Table 6.2. The respondents further noted that during the wet season, the ponds and other water points were full and enough for livestock and human consumption. Water contamination was a prevalent problem in the Afar region as water consumption for livestock and people was from the same source, thus clean potable water for human consumption was not available in the study area, resulting in health problems.

Table 6.2 Water sources reported by respondents (multiple responses were possible)

Water sources	Respondents (N=250)	Percentage
River (*Dahara)*-mainly the Awash River	245	98
Traditional shallow water (*Ela)*	76	30.4
Springs (*Derra)*	50	20
Ponds	34	13.6
Cisterns	22	8.8

Source: Author's field survey (2016).

During the field survey it was observed that dead bodies of wild animals were left near the Awash River, while some distance below these dead animals, people were drinking water from the same contaminated water as they had no option other than the Awash River for human consumption. Therefore, the problem with water in the community was not only quantity, but also quality since it poses a health risk for the people. Health technicians as key informants also agreed with the household's complaints. The health technicians noted that most patients who come to the health centre were usually attacked by waterborne diseases such as Amebiasis, Giardiasis and bacterial diseases. Therefore, access to safe water was also a major problem for the Afar people, although the availability of unsafe water was very scarce during prolonged dry seasons.

6.2.3 Farmland

Since the 1980s, due to a recurrent and prolonged drought, rangeland degradation, declining of livestock holdings and increasing population pressure, people in the Southern Afar region faced a challenge to sustain their lives through pastoralism alone, as reported by the key informants. Hence, pastoralists in the study area suffered from severe malnutrition, particularly their children. To overcome these problems, pastoralists started small-scale irrigation crop farming along the Awash River. Therefore, having plots of land along the banks of the Awash River became critical to grow crops like maize and vegetables as a supplementary source of food.

6.2.4 Livestock assets

In the study area, the major animals kept by the respondents were cattle, small ruminants (sheep and goats) and camels. Livestock were the primary source of pastoral income, apart from savings, loans, gifts, investments and insurance. During the household survey, the respondents noted that milk, meat and butter were their main food sources 20 to 30 years ago when water availability did not limit the supplements of grasses and browses. They also exchanged their oxen for grain from highlanders. Since there was no local market during the time, crop cultivators came with locally-made clothes and grains to the pastoralist area in exchange for live animals and animal products. Recently, as a result of rangeland degradation and drought-related livestock mortality, the production of livestock products such as milk and meat declined and grain became the main source of diet for pastoralists. At the same time pastoralists' needs for manufactured goods such as clothing, grains and coffee have increased. Consequently, they have become dependent on the market for selling livestock, and purchasing grain and other goods and services. As a result, livestock marketing increased in order to fulfil the increased demand for grain and manufactured goods. Subsequently, pastoralists shifted to rearing of small ruminants such as sheep and goats as these could be sold at local markets in the nearby towns. Since sheep and goats can be easily converted into cash in the nearby markets in times of need, they represented the main financial sources of the households in the study area.

Furthermore, the respondents noted that grasslands were increasingly replaced by bushes and shrubs due to bush encroachment and prolonged and recurrent droughts. As a result, most households kept more goats and camels than cattle and sheep in response to this ecological change as goats and camels can survive on browsing trees and bushes. Due to the loss of grasslands, the number of cows per household declined, and currently most pastoralists in the study area are dependent on camels for milk consumption as camels yield more milk than cows and can better survive on browsing trees and bushes. In the past 20 to 30 years, the wealth status of an individual in the Afar community was measured based on the number of cattle he/she had. Recently, in response to ecological change and increased demand of the livestock market to fulfil the purchasing power of grain, local people were keeping more goats and camels than cattle and sheep. Hence, recently, an individual was wealthy if he/she had a large number of camels, relative to other households. The respondents further noted that the changing emphasis from grazers to more browsers was not only in response to ecological changes (loss of grasslands and drought-related hazards), but also in response to the increasing demand for purchasing grain and manufactured goods. Therefore, shifting from grazers to more browsers indicates the flexibility and adaptive response of pastoralists to the ecological changes, adverse influences of climate-induced shock and economic demands.

6.2.5 Social capital

Social capital is the social resources upon which people make in pursuit of their livelihood activities. The rangeland, farmland, water resources, and livestock assets are basic components for the sustenance of livelihoods. However, the livelihood is more than getting an income and it involves intangible assets as well as social institutions such as family, village and social relations which are important to support and sustain a living. Therefore, social capital, which involves informal transfers, social support networks and participation in social institutions, is a key asset for the sustenance of pastoral livelihood.

In the context of the Southern Afar pastoral community, social capital was manifested in many ways. Five of the most salient ones were food sharing between households, livestock loans, cash transfers, labour sharing and information exchange. Many informants noted that begging was a shameful act in the Afar culture. According to the informants, the community members helped each other, and no one was expected to beg. Instead, he/she could call to his/her kinship or clan groups for support in times of need.

Milk provisions by surplus producing families to food-deficit households were the routine practice in the Afar region. Livestock was the principal assets of Afar pastoralists and, therefore, larger mutual help provisions usually took the form of livestock transfers, mainly milk cows, sheep, goats and camels. The traditional institutions in the community also forced the rich households to restock the poor households who experienced livestock losses. There was also a religious obligatory rule (*Zeka*) that enforced the rich to give livestock and livestock products to the poor. According to the informants, an individual practiced *Zeka* once a year in such a way that if he/she had one camel, he/she would give one goat to the poor. Furthermore, if someone was sick or his/her livestock was sick and unable to afford medication, a cash transfer from the rich was common practice. Labour support to the elders by the clan members or relatives of the elders, such as bringing water and firewood from a distance, livestock keeping and farm activities, was also a social obligation in the study area. Regarding information exchange, almost all households had a traditional information exchange network, called *Dagu*. It was the main information gathering and exchanging system among the Afar. According to the *Dagu*, when two or more individuals meet on the road or elsewhere, they will spend some time on exchanging information about the market and price, disease outbreaks, conditions of grazing, water and security.

However, since recently, the respondents complained that the mutual support arrangements in the Afar community were degraded due to the declining of livestock numbers and increasing price of grains and manufactured goods. Due to poverty in the community, most households were dependent on government and non-government aid, while their informal social support system had been degraded. The regional government had focused to strengthen the formal institutions by undermining the customary or informal institutions, which were the basic units to make mutual support arrangements in the community. Hence, the role of a mutual support system towards enhancing resilience of the Afar pastoralists has recently been degraded.

On the other hand, the households' access to credit was very poor in the study area. The results showed that only 14.8% of households had access to credit. Furthermore, 90% of households received market information about the price prior to selling through an informal local information exchange system (locally called *Dagu*). Only 2% of households received formal market information through district extension officers and the radio. Therefore, there is a need to provide affordable credit access, market information and to strengthen the local norms, knowledge, culture and customary institutions and incorporate it into the development strategies of the government in order to enhance the resilience of pastoralists towards shocks and stresses.

6.2.6 Human capital

Human capital refers to the skills, knowledge, capability to labour and well-being that together support household to practice various livelihood activities and attain their livelihood intentions (Carney, 1999). Pastoralism is a highly skilled practice that requires a high degree of labour input, and human capital is the most important productive input in the system. Human health obviously impacts importantly on this exhausting livelihood, particularly in times of stress when labour demand increases (for example, during a drought when migrations can increase and bringing of water from a distance is more challenging). In the Southern Afar community, mobility and herd splitting based on the type of animal (whether browser or grazer), physiological status (whether milking cows, dry cows or pregnant cows), age and productivity of the animal, were the most important strategies of pastoralists to utilise the spatial and temporal variable resources of a rangeland and to cope with climate-related hazards such as droughts. The success of these strategies was highly dependent on the availability of adult labour, skills and health status of the household.

The results also indicated that the average size of the family in the study area was 7.9. This was relatively higher than the national average rural household size. Such large family size in the region might be associated with the polygamy culture that is commonly practiced in the Afar region. The average age of household heads was 52.7 years and most of them were found to be male (58.8%). A considerable number of the respondents (72.2%) were found to be illiterate, which means that only 28.8% of the respondents could read and write with a formal educations ranging from 1 to 10 years (Table 6.3). Furthermore, the results revealed that only 28.8% of households had access to extension services, indicating that access to extension services in the Southern Afar region was very poor.

Table 6.3 Characteristics of surveyed households

Characteristic	N	Minimum	Maximum	Mean	Standard deviation
Age	250	40	80	52.7	11.011
Household size	250	1	17	7.9	3.3
Dependency ratio	250	.00	5.0	2.0	0.942
Years of education	250	.00	10	.86	1.86

Source: Author’s field survey (2016).

6.2.6.1 Availability of labour

Adequate labour availability is very essential for pastoral households to manage their livestock and the heterogeneous rangeland resources. As a coping strategy, households kept different livestock species with different grazing requirements. The different livestock species required different grazing areas allowing seasonal availability of grasses for grazers (cattle and sheep) and browse for browsers (camels and goats). Therefore, these different animal species should be managed differently in different types of rangeland vegetation covers –

camels and goats in bush and shrub types of vegetation cover, and cattle and sheep in grassland types of rangeland. These arrangements require adequate availability of adult labour in the pastoral household family. In the study area, the task divisions among household members are described in Table 6.4. According to the key informants, labour was not a problem for the pastoral households 10 to 15 years ago as they could get labour from their relatives and clan members in the community. The respondents complained that, recently, their herding strategy was highly limited by labour availability as young people increasingly became involved in non-pastoral activities such as seasonal labour employment, animal trading, or in an urban business. Although these non-pastoral activities were an important source of livelihood to accommodate the increasing population pressure in the region, it shared labour input of pastoralism activities.

Table 6.4 Activities and task divisions among household members

Type of activity	Women	Men	Children
Constructing hut	✓		
Preparing food	✓		
Fetching water	✓		✓
Collecting firewood	✓		✓
Milking cows, goats, camels	✓		
Selling camels and cattle		✓	
Selling small stock (goats and sheep)	✓	✓	
Keeping cattle and camels		✓	
Keeping goats and sheep	✓		✓
Marketing	✓	✓	

Source: Author’s field survey (2016).

6.2.6.2 Education

Some respondents and key informants perceived that education provides a pathway to an alternative livelihood other than pastoralism. They further noted that the sustainability of pastoralism in the Afar region was under question due to increasing trends of droughts and deterioration of rangeland resources. The population pressure is increasing and pastoralism could not accommodate all the people contained in the Afar region and, hence, livelihood diversification is the best option to enhance the resilience of the local people, education being one of the best options for livelihood diversification. Although the literacy level was very low in the study area as in other pastoralist regions of the country, the attitude of local people to send their children to school has recently increased. Those people with a positive attitude to send their children to school noted that education is a key issue in creating job opportunities and the educated children can assist their parents in the form of cash transfer during bad times and they can be an input for the development of the region in general. In contrast, there were also households who had a negative attitude to send their children to school for the reason that children were an important source of labour to keep livestock and other activities, inaccessibility of schools near to their village and inability to afford for school materials. The results indicated that those households who sent their children to school counted 45% (N=250), whereas those with negative attitudes counted 55% (N=250) of the total households surveyed. In general, the literacy level in the study area was very low. Focus group discussions and interviews with local households indicated that the low level of literacy in the study area was associated with the inaccessibility of educational facilities such as a lack of trained teachers, distance from the school, and inability of households to afford school material, low awareness of local people towards education and shortage of labour in the household family.

6.2.6.3 Health

The health status of an individual is another important aspect of human capital in pursuing livelihood activities. If a household head or his family member is sick, he cannot accomplish his livelihood activities at the right time in addition to the cost incurred for medication. Therefore, illness besides having a direct impact on the welfare of individuals, has repercussions on productivity and, hence, on food security of households. The main diseases observed during the one-year period prior to the survey and during the survey period in the study area were diarrhoea, (locally named as *atet*), malaria, watery lesions on the skin (*guduf*) and measles (*hemaki*). Respondents noted that the outbreak of *guduf*, which is characterised by watery lesions on the skin of the patient, and measles *(hemaki)* occurred following the occurrence of the extended drought in the area. Malaria affects the local people seasonally, especially during the months of October and November. Informants from the health centre noted that the community has no clean and safe water for domestic consumption and diarrhoea is a common disease throughout the year. In general, due to insufficient health services, frequent and prolonged drought, seasonal food insecurity, lack of clean and safe water and poor road infrastructure and transportation, adversely impacted the health of households in the study area. The survey result indicated that 57.5% of the household heads encountered sickness in their family members during the one-year period prior to the survey and during the survey period.

6.2.7 Physical capital

This sector includes road infrastructure, telecommunication, and transportation, services to water and access to market opportunities in urban centres. These infrastructures facilitate integration of remote pastoral groups with other areas for better market exchanges, health care and cereal supplies. In the study area, roads that connect villages to urban centres or village to village, were not developed and the road network remains largely poor, hampering access especially during the rainy season. Although the telecommunication system had improved in urban centres of the region as compared to the previous years, it was still inaccessible in rural areas of pastoralists.

On the other hand, access to basic services in the Southern Afar region was generally poor. For example, only 22.2% of the households had access to markets near their villages. The rest of the households (77.8%) usually travel long distances to sell their cattle and camels. According to the respondents, on average they travel for more than 12 hours across other adjacent districts or regions (Amhara and Oromia regions) to get to the market for selling large animals (cattle and camels), which is costly in terms of time and labour. During such long-distance travelling, pastoralists lose their livestock due to stresses associated with long travelling, feed and water scarcity and car accidents. Finally, the remaining animals that reach the market lose weight with an adverse effect on prices. Sheep and goats are sold in a nearby small daily village market but because of a lack of bargaining power and not enough purchasers they cannot sell their livestock at a reasonable price. The results further showed that 30% of the households had access to veterinary clinics and services and 32% households had access to the health centre and health services (Table 6.5).

Table 6.5 Household access to basic services

Basic services	Percentage of households
Access to market	22.2
Access to veterinary services	30
Access to health centres	32

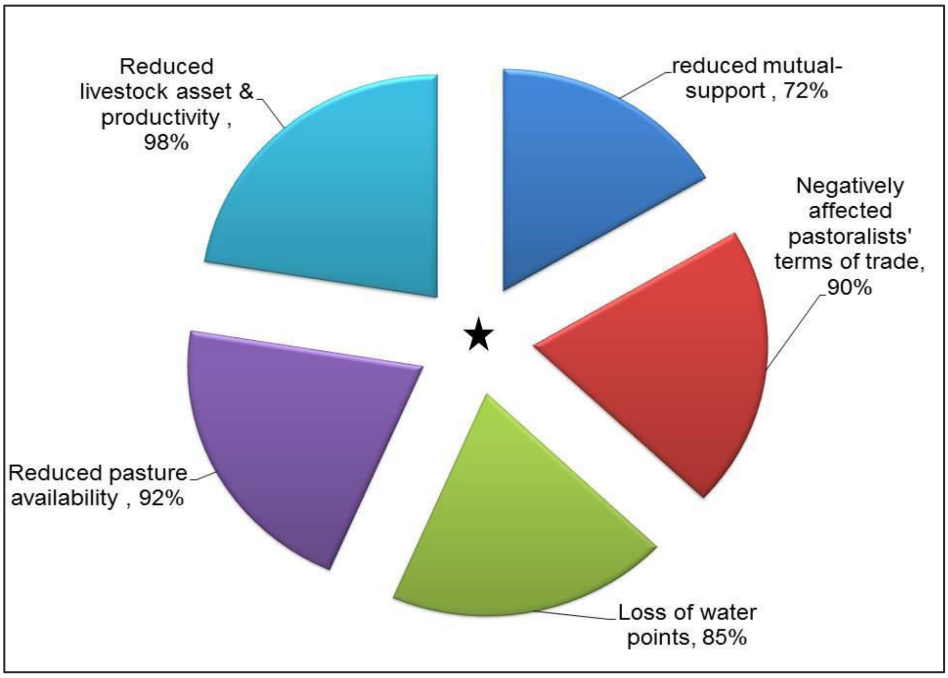
Source: Author's field survey (2016).

6.3 Local People's Perception on Climate Change and Variability

It is essential to understand the local people's perception of change in climate and climate variability before discussing its adverse impacts from their perspective. In the Southern Afar region, the elders divided the year into four different seasons, namely spring, summer, cold and hot season, and this indicates that the elders are more experienced and knowledgeable about the climate of the region, whereas some of the younger generations did not know all of the seasons. The elders complained that the inability of young generations to identify the seasons was due to their detachment from herding activities and shifting to non-pastoral activities such as seasonal employment and trading. Ninety-eight percent of the respondents perceived that the rainfall has been decreasing over time; rainfall occurs early/late and stops short from the normal rainy season, while 95% of the households explained that the temperature of the region was increasing, especially over the last three decades. Furthermore, the results revealed that there have been frequent and prolonged droughts in the study areas as reported by 100% of the respondents. Fourty-two percent of the respondents also reported the occurrence of flood hazards in the study areas. The respondents' perception of rising temperature, occurrence of frequent and prolonged droughts, decline and seasonal variability of rainfall is in line with the results of the recorded meteorological data analysis of the present study which was described in Chapter 5. The principal concern of the local households was about seasonal changes and variability of the rainfall, which impeded their capacity to envisage rainfall patterns and plan their grazing managements accordingly.

6.4 Impacts of Climate Change and Variability

The respondents were asked to explain the impacts of climate shocks and stresses such as droughts, floods, climate variability in the Southern Afar region, which is discussed in the following sections. Figure 6.1 below gives a summary of the impacts of climate shocks and stresses on Afar pastoralists' livelihoods based on the perception of local respondents. According to respondents, the impacts of climate change and variability included: (i) reduced livestock asset and productivity, (ii) reduced pasture availability, (iii) loss of water points, (iv) adverse effects on pastoralist's terms of trade and (v) reduced mutual-support systems.



* *The numbers do not aggregate up to 100, due to multiple responses*

Source: Author's field survey (2016).

Figure 6.1 Impacts of climate variability and change on livelihood assets of Afar pastoralists

6.4.1 Impacts on livestock

The Afar pastoralists explained the impacts of climate shocks and stresses on livestock in terms of drought, unreliability and the erratic nature of rainfall and floods. The majority of the respondents (90%) complained that the recurrent and prolonged droughts reduced livestock numbers and productivity by increasing mortality and morbidity rate, decreasing fertility rate and increasing weaning time of different animals (Figure 6.2). Similar results were reported by Amsalu and Adem (2009) who indicated that livestock productivity and reproduction rates have been decreasing from time to time in pastoral communities, due to the adverse impacts of climate extremes, especially drought. Death of animals in the study areas was also caused by disease outbreaks and raiding which all exacerbated the impact of recurrent droughts.

Respondents also reported that crop yields reduced due to the drying up of water points and reduced flow of the Awash River.

Source: Own field survey (2016).

Figure 6.2 Remnants of dead animals, due to the drought

Drought reduced the number of animals per household. In this study, data regarding the number of livestock per household were collected before the drought (2014) and during the drought period (2014–2015). Even though the survey was conducted at the beginning of 2016, respondents were asked to report the number of livestock they had before the drought and during the drought period. The total herd size was measured in a standard unit called Tropical Livestock Unit (TLU), where 1 TLU is equivalent to 250 kg of livestock. The total number of cattle, shoat (sheep and goat) and camels were computed into TLU using factors 0.7, 0.1 and 1.25, respectively (ILCA, 1990). According to the informants, three to four decades ago the number of cattle per household ranged from 56 to 350 TLU, camel numbers ranged from 30 to 100 TLU and sheep and goat numbers ranged from 50 to 200 TLU. However, recently, the findings indicated that on average, the number of livestock per household before the occurrence of the drought was 44.2 TLU, while the number of livestock per household during the drought period was 29.87 TLU. Therefore, 32% reduction of livestock assets occurred associated with the drought. The livestock holdings per household for each livestock species before and during the drought period are indicated in Table 6.6. This study is supported by the findings of Bekele and Amsalu (2012) who indicated that the number of livestock owned by a household has been declining over time linked with climate-induced shock, mainly droughts.

Table 6.6 Average livestock holdings per household in TLU before and after drought

Herd	Before drought		After drought	
	Mean	Standard deviation	Mean	Standard deviation
Cattle	3.6	2. 3	1.87	1.2
Camel	12.5	5.7	8	4.2
Sheep	6.1	3.4	4	1.3
Goat	22	9.3	16	6.8

Source: Author's field survey (2016).

According to Sanford and Habtu (2000), a 5–15% decline of livestock assets happened in Afar due to the drought of 1999/2000. During a severe drought, the mortality of livestock was estimated to range between 15% and 45% (FEWS-NET, 2002; UN-EUE, 2002). Disaster impact assessment reports of different non-government organisations showed that the extended drought of 2002/2003 was even more severe for Afar pastoralists (FEWS-NET, 2002; UN-EUE, 2002). For instance, between June and July 2002 a team of experts from the UN-EUE and the FAO observed thousands of emaciated animals and several carcasses in different parts of the Afar region (UN-EUE, 2002). Likewise, Hazell *et al.* (2003) indicated that droughts caused significant loss of livestock and push many herders into poverty. On the other hand, the percentage of livestock loss reported in the UNDP field report (2012) by Karrayu pastoralists was 45% of their livestock due to drought.

On the other hand, the recurrent drought also reduced the amount of yield per animal. For example, during normal conditions in the last three to four decades, the numbers of people supported by one lactating cow were four to eight individuals, while recently; one lactating cow can support only two people. This was associated with the reduction in the milking time per day and reduction of milk yield per milking time. Under normal conditions, a lactating cow can be milked three times per day, but recently only once or twice per day. Apart from the impacts of the drought, as reported by 42% of the respondents, pastoralists were also negatively affected by floods. The informants complained that the floods during 1994 and 2000 were very destructive. Floods that came from highland areas in October 2014 (when the region was in a severe drought) caused massive loss of livestock and other properties at their residences.

6.4.2 Reduced pasture availability

Afar elders explained in a deep sense of reminiscence about the abundant availability of pastures around their home three to four decades ago. They explained that livestock used to graze around their home and return to home with the rumen filled after a few hours of grazing and browsing in the morning. In the afternoon, when the animals are hungry again, they would walk to the plentiful pastures for grazing and browsing. The majority of the respondents (92%) reported that since the drought has become severe and frequent, the palatable grass and browse species have recently been disappearing from the rangelands, while the non-palatable bushes and shrubs were expanding.

Informants also noted that before the pastures recovered from the previous drought, another drought affected the new growth. This situation caused loss of pastures from the rangelands. Similar findings were reported by Bekele and Amsalu (2012) who indicated that the increased incidence and prolonged nature of the drought adversely affected the growth and development of pastures, leading to loss of palatable forages. The authors further noted that the seasonal, annual and spatial variability of rainfall also caused deterioration of natural forages. According to the FAO (2008), the productivity of arid and semi-arid rangelands of Ethiopia decreased and has failed to support the existing livestock. Key informants also reported that as natural grazing areas deteriorated due to recurrent droughts and unreliable and erratic rains, herders concentrate around water points such as along the sides of perennial rivers, which in turn led to overgrazing of the existing forage resources. As a result of overgrazing, unpalatable or low forage valued plants have expanded around water points. On the other hand, informants noted that the widespread occurrence of drought throughout the Afar region restricted mobility of the pastoral people, which in turn led to settlement of the people in villages. Settlement, in turn, caused the impoverishment of grazing areas and cutting of trees for fuel. Therefore, though water, pasture, livestock and the community have interconnected for centuries, recently, the recurrent droughts disconnected this relationship in the Southern Afar region.

6.4.3 Loss of water points

Afar elders noted that without water (rains) there are no pasture, and, hence no livestock which are their main livelihood. In other words, productivity of rangelands is highly correlated with rainfall. Studies conducted by Opiyo *et al.* (2011) indicated that water is a critical factor in pastoral production systems. Eighty-five percent of the respondents reported that water points have either dried up or supply was reduced due to recurrent droughts over the past three decades. The reduction in water availability and drying up of water points are indicators of a hydrological drought. The shallow wells, ponds and cisterns were the key sources of water for pastoral communities as the perennial rivers, such as the Awash River, was far from their villages, except the Yigle and Urafita villages who resided around the Awash River. Respondents noted that previously there were no shortage of water during the rainy season as the ponds, shallow wells and cisterns were full. These seasonal water points are highly susceptible to drought and they have disappeared from the area due to the frequent and prolonged droughts. For example, *Berita elaa* and *Yoso elaa,* which were the main sources of water for both livestock and human consumption, dried up because of the recurrent droughts in the area. The respondents complained that they travelled long distances, more than 20 km, to access water from perennial rivers, even during normal dry seasons of the year. Therefore, water scarcity was becoming a serious problem for Afar pastoralists due to the drying up of many water points associated with recurrent droughts, and the declining water flow of the Awash River.

A woman in Amibara district noted:

> *When the rain falls, the ponds are full and enough for us. During the drought season, most water points dried up and we have to travel long distance to reach permanent water sources such as Awash River. We walked up to 8 hours looking for water.*

6.4.4 Impacts on pastoralists' terms of trade

As discussed above in section 6.2.4, three to four decades ago, the major sources of food for pastoral households were milk, meat and butter. They used milk to drink instead of water and ate meat and butter as food. Recently, livestock assets and their outputs have significantly declined due to ecological/environmental changes and, hence, the grains became the major source of food for pastoral households in the study area. In the present day, pastoralists raise livestock, mainly for exchange of grains and manufactured goods for their survival.

Most of the respondents complained that they sold their livestock not by preference or timing for selling, but they were forced to sell as a result of shortages of cash, feed and fodder for animals. Ninety percent of the respondents confirmed that during droughts, pastoral households had been forced to sell their livestock, but demands were very low due to poor body conditions of animals and oversupply. Respondents noted that the last three decades, drought cycles were relatively long and, hence, they had enough time to recover from the impacts of the previous drought. The price of inputs and outputs were also fair as pastoralists started to get a sufficient amount for animal products. In recent years, drought cycles were short, droughts occurred every two three years and pastoralists had no time to recover from the impacts of the previous drought and, hence, the price of livestock continued to decline while the food grain price was increasing. This condition has increased food insecurity and poverty in the area. According to the UN assessment mission in the Afar region (UN-EUE, 2002) more than 50% decline in livestock prices was observed after the drought of 1999/2000. Similar findings were reported by Davies and Bennett (2007) who indicated that the price of livestock declined by 50–60%, linked with the drought of 2002, while the price of maize increased by about 235%. The informants noted that during normal seasons of the year (when there is no drought), the rainfall starts late and stops early and/or it would rain for a few days with high intensity and then disappear, which is not sufficient for the growth of pastures and, hence, livestock assets still continue to decline while the price of grains is rising. Overall, climate change and variability in terms of recurrent drought, short rainy days, changes in the timing of rainfall and erratic nature of rainfall and increased temperature resulted in negative terms of trade and threats the resilience of pastoralism in the Southern Afar region.

6.4.5 Impacts on mutual support systems

In response to climate-related shocks and stresses, pastoralists in the Afar region were largely depended on the reciprocal links that tie them to extended families and the larger society for the interchange of services, sharing of food, lending of assets, pooling of resources and other forms of support in times of need. Seventy-two percent of respondents reported that pastoralists relied on an informal mutual support system in response to shocks, such as seasonal food deficiencies and droughts for centuries. However, recently, changes in timing of rainfall a few days of rainfall, increased temperature and recurrent droughts decreased the livestock assets of the Afar pastoralists and increased the price of food grain. Hence, most pastoral households had no surplus food, livestock and cash to transfer to others. Therefore, recently, individualism was replacing the mutual support system in Afar, and pastoralists were dependent on formal support systems such governmental or NGO food aids.

6.5 Adaptation and Coping Strategies of Afar Pastoralists

6.5.1 Adaptation strategies

The long-term changes in livelihood strategies refer to adaptation, while the short-term adjustment in reaction to shocks and stresses on livelihood of people refers to coping (Migosi *et al.,* 2012). The coping and adaptation strategies of pastoralists to climate variability and ecological changes have been studied over decades (Campbell, 1999; Ellis, 1994; McCabe, 2006). These studies indicated that through the course of hundreds of years, pastoral households have deployed different strategies to adapt and cope with unreliable and variable environments such as livestock mobility to grazing areas less influenced by drought, changing planting dates and mixed livestock–crop farming (Thornton & Gerber, 2010). However, recently, pastoral communities in Africa are faced with socio-economic, political and environmental marginalisation while the drought cycles have been decreasing (Schilling *et al.,* 2012). According to Notenbaert *et al.* (2012), shocks and stresses posed by climate variability and change, particularly climate extremes such as droughts and floods, are becoming beyond their indigenous coping and adaptation strategies to sustain their livelihood. Similarly, like in other African countries, the intensity and frequency of droughts have been increasing since the 1980s in pastoral communities of the Afar region. Therefore, it is essential to understand how pastoralists respond to adapt or cope with shocks and stresses in order to design appropriate development interventions. In the study areas, pastoralists have been using many adaptive and coping mechanisms to escape negative influences of climate-induced hazards. The strategies that Afar pastoralists deployed against climate-induced hazards are discussed below.

6.5.1.1 Combining livestock production with crop farming

Since livestock numbers and productivity declined over time, some households started cropping using small-scale irrigation along the banks of the Awash River. Pastoral households practiced small-scale crop cultivation using traditional irrigation methods such as furrows and channels using ground gravity. Recently, the pastoralist and agricultural development office began organising households into cooperatives and delivers agricultural inputs such as motor pumps for irrigation, improved crop varieties and fuel. Some of the cooperatives in some villages started to buy fuel and maintain the motor pumps by themselves. According to district extension experts, and local respondents, the improved crop varieties suitable for the area were *Gaabo* (wheat variety which was drought resilient and reached maturity within three months for harvest), *Melkasa 2, BH140 and 540* (three improved maize crop varieties), and *Ashenti* (tomato variety which is known for its yield, disease and drought resistance). There were also other crops produced in the area such as cotton, sorghum, onion, pepper, vegetables, spices and fruit trees like mango and avocado. The results indicated that out of 250 households, 40% practiced crop cultivation along the banks of the Awash River (Table 6.7).

Table 6.7 Household groups based on livelihood strategies

Groups	Frequency	Percent
Pastoralists	150	60
Agro-pastoralists	100	40
Total	250	100.0

Source: Author's field survey (2016).

On average, the agro-pastoral households owned 1.94 ha plots of farmland. The respondents noted that crop farming was undertaken to complement pastoralism rather than to substitute livestock production. The informants also complain that total shifting to crop farming is risky as practicing irrigation farming along the river banks involves the risk of flash floods due to high run-off from the highland or change of the Awash River course. On the other hand, livestock production as the sole livelihood strategy is also becoming a risky enterprise associated with recurrent drought and high seasonal, annual and spatial variability of rainfall.

In this study, the annual income of households was calculated and the results revealed that the minimum annual income of pastoral households as Ethiopian Birr (ETB) was 1 000 and the maximum was 14 300, while the minimum annual income for agro-pastoral households was 3 960 and the maximum was 8 640 (Table 6.8). The average annual income of the pastoral households was 4 281, while that of the agro-pastoral households was 5 932.80 (Table 6.8).

Table 6.8 Average income (ETB*)/year of pastoral and agro-pastoral households

	Minimum	Maximum	Mean	Standard Deviation
Pastoralist	1 000.00	14 300.00	4 281.00	2629.38632
Agro-pastoralist	3 960.00	8 640.00	5 932.80	1 269.42449

**Exchange rate for March 2016: Ethiopian Birr (1 US$= 20.98 ETB)*

Furthermore, the average livestock holding of pastoralists and agro-pastoralists was 16.8 TLU and 13.07 TLU, respectively, which showed a significant difference between the two livelihood groups in terms of livestock holdings (Table 6.9). The low livestock holdings of agro-pastoralists might be associated with sharing of production inputs such as labour, land, between livestock and crop production. However, the total annual income of agro-pastoral households was significantly higher than pastoral households, indicating the positive effect of livelihood diversification on income level of households (Table 6.9).

Table 6.9 Average livestock holding (TLU) and income (ETB) differences between pastoralists and agro-pastoralists

		Paired Differences			T	Sig. (two-tailed)
		Mean	Standard deviation	Standard error mean		
Pair 1	Pas_LS – Agro_LS*	3.726	6.49508	.64951	2.23	0.028
Pair 2	Pas_IN – Agro_IN**	–1 651.8	3 403.2	340.3	–4.85	0.001

* *Refers to livestock size difference between pastoral and agro-pastoral households*
** *Implies income difference between pastoral and agro-pastoral households*
Source: Author's field survey (2016).

6.5.1.2 Diversification of herds and changing herd composition

Changing herd composition and diversification were key strategies to adapt to the changing environment and recurrent drought. According to the local respondents, over the past years the types of herds kept by the local people were cattle, camels, sheep, goats, donkeys, mules and horses. The dominant number of the herd was cattle during the past times when grass availability was abundant. During the survey period, no households were observed having mules and horses, while donkeys were rarely kept by a small number of households. As shown in Table 6.10, goats were the dominant population in the herd, followed by camels. The numbers of cattle owned were very small as compared to other livestock species. The respondents noted that the reason for keeping large numbers of goats and camels was that camels and goats are tolerant to the impacts of drought and can survive on browsing trees and bushes during feed scarcity, while keeping large number of cattle was difficult since palatable grass species have been lost due to frequent and prolonged droughts as well as bush encroachment. At the same time the pastoralists still continued in keeping diverse livestock species in order to reduce the disaster risks and use the heterogeneous resources of rangelands. Informants further reported that if grass availability was abundant, pastoral households preferred to keep cattle rather than camels. The reason for this was that in the Afar culture, cow milk can be processed into butter, yogurt and other milk products, while milk from camels is not processed and is used for drinking only.

Table 6.10 Livestock holding per household (TLU)

Herds	Mean	Standard deviation
Cattle	1.87	1.2
Camels	8	4.2
Sheep	4	1.3.
Goats	16	6.8

Source: Author’s field survey (2016).

6.5.1.3 Herd mobility

Herd mobility was a well-known strategy pursued by pastoralists in the Afar region in response to feed and water shortage. The elders noted that pasture availability was highly variable, both temporally and spatially, and because of their experience they knew where and when the pastures were available. The respondents reported that forages were temporally available and especially the grasses were short-lived in arid and semi-arid areas of the Afar region. Therefore, before the forages disappear, the local people would move their livestock on time and on the right place to utilise these short-lived forages. This indicated that mobility was a key strategy for pastoralists in response to the seasonal, annual and spatial variability of rangeland resources. Recently, mobility was highly restricted due to the uniform occurrence of the recurrent droughts in the Afar region, shrinkage of rangelands due to expansion of commercial farms and bush encroachment such as *P. juliflora*. The respondents complained that since forage was not available in the immediate environment and most regions of Afar, the local people were forced to travel long distances into neighbouring regions of Afar such as in highland regions of Amhara and Oromia. Although herd mobility was challenged by the aforementioned factors, the majority of the respondents (65%) were still using it as a strategy to reduce risks and for other economic purposes such as to access livestock markets and urban centres.

6.5.1.4 Development of water points

In response to water scarcity in the study area, local people dig shallow holes for domestic consumption. Recently, the government started with the installation of hand pumps and development of deep wells in some villages. During the fieldwork, the government, in collaboration with NGOs, were working on the development of underground water to use it for small-scale irrigation and domestic purposes; however, water scarcity was not reduced in the study areas.

6.5.2 Coping strategies

In the study area, households were pursuing some form of coping strategies to cope with the negative influences of climate-induced hazards. The most important coping mechanisms employed by the local people are discussed as follows:

6.5.2.1 Mutual support

In addition to the herd and resource management, pastoral households employed mutual support mechanisms in response to drought and livelihood shocks. The key informants noted that in the Afar culture, when somebody lost his/her livestock due to drought, diseases or raiding, he/she has a right to claim to the clan members or relatives and there was a social obligation to build up his/her herds and to recover from crisis. Other mutual aids such as cash transfers and labour sharing were also common practices in the community. Individuals/households linked by decent also exchange gifts (in kind of cash) at birth, marriage and during other ceremonies (circumcision, funerals, religious feasts). The migrants outside the Afar region such as from Djibouti and Saudi-Arabia also sent remittances to their families. The respondents noted that recently, since poverty was rising at household and community level, individualism was increasing, especially among the youth. The amount of support and strength of social ties in the community was declining and the local people were relying mostly on formal social support mechanisms like food/grain aid and cash-for-work from NGOs during crisis. The informants complained that because of the deepening of poverty at the household and community level, mutual support has been a pressure for those who have assets as they have a social obligation to support the poor.

During the household survey, the local people were asked if they have received assistance from the community during a crisis. The results indicated that 72% of the surveyed households confirmed that they received assistance from their relatives, clan members and bond friends. Twenty-eight percent of households have never asked for assistance during the 12 months before the survey in the Gewane district, while in the Amibara district, 88% of the respondents have received assistance from their relatives, community and bond friends. The results are summarised in Table 6.11. The results indicate that the number of households participated in assisting the poor were smaller in the Amibara than in the Gewane districts, while the numbers of households calling for assistance were greater in Amibara than in the Gewane district.

Table 6.11 Number of donor and recipient households involved in a mutual support system in Gewane and Amibara districts

Gewane (N=100)			Amibara (N=150)		
Donors	Recipient		Donors	Recipient	
	Frequency	Percent		Frequency	Percent
3	18	18	2	40	26.7
5	22	22	3	32	21.3
7	16	16	4	18	12.0
10	11	11	6	28	18.7
16	5	5	8	15	10.0
Total	72	72		133	88.7

Source: Author's field survey (2016).

6.5.2.2 Non-pastoral / off-farm activities

In response to recurrent droughts, the pastoral households employed various off-farm activities and the results are summarised in Table 6.12. The results indicated that cash-for-work was the dominant off-farm activity practiced by 64% and 48% households in the

Amibara and Gewane districts, respectively. The cash-for-work programme which was provided by humanitarian assistance organisations gave temporary employment for the poor pastoral households. The households accomplished activities such as road maintenance, *P. juliflora* clearing and school fencing in the community, and 180 ETB was paid for each household per month. The second dominant off-farm activity in the study areas was charcoal and firewood selling (Table 6.12). This result is supported by the findings reported by Little *et al.* (2001) who indicated that fuelwood and charcoal selling is an occupation of the poor pastoralists across East Africa. Charcoal burning was forbidden by the informal laws in the past years. Recently, as the formal institutions replaced the customary institutions and poverty was mounting in the community, deforestation and charcoal burning was becoming a common practice in the study areas. Following over-exploitation of the indigenous trees in the study areas due to charcoal burning, the regional government officially banned charcoal burning in the area since the middle of 2015 and guards were employed to protect the remaining trees. However, the respondents noted that due to the deepening of poverty and food insecurity in the area and limited availability of options to address it, most pastoral households were pursuing charcoal burning against the banning of the regional government.

Table 6.12 Off-farm activities employed by pastoral households in the Amibara and Gewane districts (multiple responses were possible)

District	Off-farm activities					
	Salary	Wage labour	Petty trading	Cash-for-work	Charcoal burning	Firewood selling
% households in Amibara (N=150)	5.3	24	10	64	20.6	25.3
% households in Gewane (N=100)	3	16	13	48	19	23.0

Source: Sample household survey (February 2016).

Furthermore, the results indicated that salary was one of the off-farm activities that supplemented pastoralism in the study area. For example, 6% and 4% of the sampled households in the Amibara and Gewane distinct, respectively, were employed in government offices as guards and some were employed for protection of forests. They reported that the money obtained from this off-farm activity was allocated for consumption, to buy animal feed and drugs and children's school expenses. The other off-farm activities pursued by 23% of the local people in both the Amibara and Gewane districts were petty trading such as shopping, livestock and *khat* trading. There were also some pastoral households, usually from the younger generations, who sold some of their livestock and invested the money into non-climate sensitive livelihood activities such as buying a motorcycle and rented it out at a rate of 200 ETB per day to transport local people from the rural area to urban centres during the dry season. Transportation using vehicles during the rainy season was impossible due to the poor quality road infrastructure, with road that connects rural areas to urban. It was observed that involvement in such types of business activities as a means of livelihood was for the rich and middle-income groups in the community as the poor were constrained by lack of capital to engage in such business activities. Wage labour was another important source of income for the poor and destitute pastoral households. Only 20% and 16% of the households in Amibara and Gewane, respectively, pursued wage labour as the source of income for their subsistence. The destitute households are hired by the rich and medium-income households for farm work, fencing of barns, fetching water. The poor and destitute households also hire out their children to the rich and medium-income households and earn income from their children's wage labour.

6.5.2.3 Reducing consumption, food aid and remittance

The results further revealed that the pastoral households in the study area employed coping strategies during seasonal food deficiency crisis. Some of the strategies included reducing food consumption, relief food aid and remittance. The results are summarised in Table 6.13. Fifty-six percent of the respondents noted that in response to food deficiencies during droughts, pastoral households decrease their number of meals per day. According to the respondents, during the worst times of the year such as the prolonged drought during 2014 and 2015, some adult households ate only one meal per day (41%), others two meals per day (54%) and very few adult households had three meals per day (5%). With regard to children's food consumption, most children (68%) had only two meals per day and 32% three meals per day. The respondents further reported that during the drought the pastoral households reduced not only the number of meals per day, but also the expenditure for clothing, social events and medication. On the other hand, 93% and 68% of the pastoral households depended on free distribution of food from the humanitarian organisations and remittance from the clan members or friends from outside the community, respectively, to overcome the seasonal food deficiency (Table 6.13).

Table 6.13 Local people's coping mechanisms during food crisis (multiple responses were possible)

	Coping strategies			
	Reducing consumption	Relief food aid	Remittance	Livestock selling
Respondents (N=250)	140	233	68	205
% households	56	93	27	82

Source: Author’s field survey (2016).

6.5.2.4 Livestock selling

The results indicated that due to the 2014 and 2015 droughts in the Southern Afar region, 82% of pastoral households participated in livestock selling within the 12 months preceding the survey period (Table 6.13). Livestock selling is normal in the region in order to fulfil their requirements, but most pastoralists had been forced to sell their livestock during the drought periods as the requirement for food grains raised due to the decline of milk and butter yields from their cows and camels as well as feed shortages. The respondents noted that households first sold their older animals that have given birth two or more times; then their lambs, sheep and goats. As the drought escalated and became worse, they sold cows and camels as a last option. The results further revealed that the majority of the households (95%) sold their livestock to buy food grains and manufactured goods, while the rest of the households (5%) sold their livestock as a destocking mechanism and saved the money for future pastoralism activities.

6.6 Early Warning System

6.6.1 Formal early warning system

Since 2009, the collection, analysis, interpretation, and dissemination of EWI on disasters that affect rural livelihoods were the responsibility of the Disaster Risk Management and Food Security Sector (DRMFSS) in Ethiopia. The Early Warning and Response Directorate under DRMFSS collected EWI on a weekly and monthly basis from district levels through regional states of the country. After data analysis, early warning was distributed to regional states. The regional states distributed to the zones, and then the zones to district level early warning centres. The district's early warning centres disseminated the EWI to households at community level. This was the general early warning flow system in Ethiopia for better preparedness, contingency planning, response and recovery of affected communities.

In this study, the focus group discussion with district experts indicated that the early warning centres at regional, zonal and district levels were not well-established in the Afar region. The infrastructure such as the early warning centres, communication systems, and appropriate disaster experts were not well-established in the region where disasters such as droughts frequently occurred as compared to other regions of the country. The main focus of DRMFSS was the highland areas of the country, such as Oromia, Amhara, SNNPR and Tigray regions, where crop faming was the main livelihood of the people. The focus group discussions further indicated that the disseminated EWI such as rainfall patterns, incidences of climate extremes, and prospects of crop production, crop conditions, and disease and pest outbreaks impacting livestock and crops, terms of trade such as price of cereals and livestock were mostly related to communities located in the highland areas of the country. The interviews with local households also indicated that 82% of the households had no EWI, while the rest of the households (12%) had some access about the incidence of drought ahead of time from local agricultural experts and the radio. The results also indicated that the early warning system did not integrate the local knowledge and information for disaster risk reduction to enhance livelihood security in the study area.

6.6.2 Traditional early warning system

Pastoralists were wise in monitoring the heterogeneous resources of rangelands and in predicting weather conditions of the Afar region using their own indigenous knowledge. Elders were more experienced in detecting indicators of droughts/rains which enabled them to forecast the weather conditions of the coming seasons. Informants reported that indigenous weather forecasting assisted them to prepare themselves against a coming drought that allowed them to sell emaciated, old and young male animals before the occurrence of the drought. Accordingly, they forecasted the weather conditions (rainfall or drought) of the region based on observing the behaviour of camels, weather changes and appearance of stars.

During the focus group discussions and an interview with sampled households, it was clear that the local people believe that camels show some behaviour with the coming weather conditions. When camels stand facing in a northward direction, it indicates the availability of rain in the coming season. The local people also use weather changes such as wind and temperature to forecast drought or rain. The informants noted that if the wind blows from a south to north direction in the morning between 7:00 and 11:00 (locally called *sebo*) at the commencement of the long rainy season, then there will be enough rain in the coming longer rainy season. Similarly, if the wind blows, sometimes having dust particles, from an east to west direction at the commencement of the short rainy season, then this indicates the availability of rains during the coming season. Cold wind indicates low rainfall conditions. On the other hand, if *yagulta* stars (six-star groups) appear in the eastern direction at the commencement of the long rainy season, then the rainy season is coming with good rain. Similarly, appearance of the *diraa* star at the beginning of the short rainy season is an indication of good rain. Therefore, indigenous weather forecasting is very important for the Afar pastoralists as pastoral household decisions such as mobility and destocking depend on indigenous weather forecasting and early monitoring of resource availability in the region.

6.7 Barriers to Coping and Adaptation Strategies

As discussed in section 6.5 and 6.6, pastoral households in the Southern Afar region had their own indigenous adaptation and coping strategies against climate-related shocks and stresses. However, they had limitations to adapt/cope with climate variability and climate extremes such as droughts using their indigenous adaptation/coping mechanisms. Lack of water for irrigation and low access to farm inputs and equipment were the factors that limited their adaptation mechanisms as reported by 46% and 57% of the respondents, respectively. The respondents also noted that lack of government support for indigenous rangeland management (53%) and affordable credit access (65%) were also some of the constraints that limited their adaptation capacity against climate shocks. The results further indicated that 34% and 82% of the respondents also complained that lack of skills and knowledge, and formal EWI, respectively, were factors that hindered their adaptation/coping capacity against climate-related shocks and stresses.

The respondents noted that crop farming based on rainfall is difficult in the Southern Afar region due to the unreliable and erratic nature of rainfall and the occurrence of recurrent droughts and, hence, the households relied on small-scale irrigation farming. The equipment for irrigation needed greater investment which was beyond the capacity of the pastoral households. Recently, due to the number of dry spells and recurrent droughts in the study areas, the Awash River flow was decreasing, making traditional irrigation such as furrow irrigation using gravity, difficult. Thus, subsidising of water pumps for irrigation which was not affordable to pastoral households was highly demanded. Therefore, lack of inputs for irrigation such as fuel, water pumps and technical skills were the main constraints to practice small-scale irrigation farming.

Recently, the customary institutions were marginalised by the government and replaced by formal institutions. According to local respondents, the formal institutions made no efforts towards managing and caring of rangeland resources since the government considered pastoralism as a backward and non-viable livelihood strategy. Consequently, rangelands were deteriorated due to overgrazing and grazing during inappropriate time. Therefore, lack of government support for traditional rangeland management and training to strengthen the indigenous knowledge of the local people to manage the rangeland resources were also another constraint to adapt/cope with shocks and stresses induced by the ecological or environmental changes. However, 15 to 20 years ago, the indigenous knowledge of the pastoralists was crucial to manage rangeland resources sustainably, which was part of their resilience to climate shocks and stresses. The clan leaders gave order for the local people when and where to move from one grazing area to another. The pastoral community also had informal laws to penalise those households who violated the rule of the customary institutions such as cutting trees in the rangeland and grazing of the rangeland during inappropriate times. Rotational grazing was the main strategy to allow the grazed areas to rehabilitate, while the reserved grazing areas were allocated for grazing during the dry seasons.

Furthermore, the respondents noted that lack of access to affordable credit constrained them from access and adopting of new technologies. Since the pastoral households were a socially, economically and politically marginalised area, access to credit was very poor in the Southern Afar region as reported by key informants during the focus group discussion. For example, if pastoral households had access to credit, they could buy irrigation materials and other farm inputs such as improved varieties, boost their income through crop farming and overcome the impacts of recurrent droughts and livelihood shocks. The informants further reported that access to credit would assist them during times of drought. However, since they had poor access to credit, they could not wait for better times to sell their livestock at better prices, with less option to buy livestock feed during droughts. As discussed in section 6.2.5, only 14.8% of the households had access to credit. Therefore, poor credit access in the region constrained pastoralists from diversifying their livelihood and boosting up their income level. Restocking of livestock after droughts was also becoming difficult in the area due to lack of credit access. Respondents also noted that illiteracy constrained pastoral households to diversify their livelihood. For example, those households who were illiterate did not have access to jobs, information and market interaction in urban centres. Households were also constrained due to technical skills on how to practice crop farming. Most households did not know how to plough the farmland, to manage and harvest the crop. They were forced to hire or arrange sharecropping with highlanders or private investors.

The majority of the respondents (82%) reported that limited access to formal EWI regarding disaster prediction was the key constraint to reduce livelihood shock and food insecurity. The key informants complained that the national/regional disaster prevention and preparedness centre did not focus on proactive actions. They rather focused on reactive actions that followed droughts. The district experts also noted that assessment of disaster risks by the National Disaster Prevention and Preparedness Centre usually focuses on highland areas of the country where crop farming was the main livelihood source of the people. This indicated marginalisation of pastoralists by the government. The key informants also reported that although the pastoral households had their own traditional early warning system against disaster risks, the formal early warning system lacks integration of the traditional early warning system in disaster risk management and prevention.

6.8 Resilience of the Southern Afar Pastoralists to Climate-induced Shock

As discussed in section 4.7, household resilience to climate-induced shock was determined using a two-step approach developed by Alinovi *et al.* (2010). The first procedure involved the identification and measurement of observed variables or indicators for the estimation of RI. Secondly, the RI for each household was determined based on the estimated values of the latent variables using Thompson's regression method as proposed by Alinovi *et al.* (2010). The RI is discussed by comparing resilience of households based on livelihood strategies (pastoralists versus agro-pastoralists), districts and gender (male-headed household [MHH] resilience versus female-headed household [FHH] resilience). Furthermore, the determinants of resilience of households are also discussed.

Each component of the RI has been determined using the PCA where the value of the component is the loading of the first factor extracted by the analysis. The factors can be considered valid if the Eigen value is >1. Before running the factor analysis, the correctness of the data was assessed based on the Kaiser_Meyer_Olkin (KMO) and Bartlett's tests values. According to Li and Weng (2007), the factor analysis can be run when the KMO value is >0.5; the Bartlett's test value is <0.1. The following sub-section discusses the loadings of the observed variables used to assess the latent variables which represent the components of the resilience.

6.8.1 Observed variables and their factor loadings used to compute components of resilience

This section discusses the findings on how the observed variables contributed to measuring the value of the latent variables representing the resilience components. The PCA was used to estimate the components of resilience (the latent variables). The approach depended on the premise that the alternatives accessible to a household to make a living determined the household's resilience at a given point in time. The RI was determined based on six dimensions (latent variables) including assets (A), adaptive capacity (AC), social safety nets (SSN), access to public service (APS), stability (S), and income and food access (IFA).

6.8.1.1 Asset (A)

One of the most important capitals of households which help them as adaptation/coping mechanism to hazards is assets. Hence, assets should be taken as a key factor in measuring resilience. The indicators for these latent variables are discussed as follows:

i. **Livestock owned in tropical livestock unit (TLU)**: This is a materialised asset owned by a household and having more assets increases a household's resilience to climate-induced shocks. Those households having more livestock will have more opportunity to recover after climate-related hazards.

ii. **Farmland owned**: Households practicing crop farming using irrigation or opportunistic rainfall agriculture and livestock production may have better resilience to climate shocks than households solely dependent on livestock production.

iii. **Adult labour**: Those households with a better working force can have better livelihood outcomes and more resilience.

iv. **Access to irrigation water**: This is also a very crucial asset, especially for pastoralists who are very vulnerable to frequent and prolonged drought and where there is an increasing climate variability. Therefore, households having access to irrigation water can have the opportunity to diversify their livelihood strategies and easily adapt to climate-induced shocks. It is a dummy variable equal to 1 if the household had access to irrigation water over the survey period; 0 otherwise.

v. **Access to irrigation equipment and improved seed varieties**: This is also very critical for agro-pastoralist households. Water pumps for irrigation and improved seed varieties which can resist droughts and diseases and reached early matured for harvest, increases efficiency of households to adapt to the prolonged and recurrent droughts. The value of this indicator is 1 if the household had access to irrigation equipment and improved seed varieties over the survey period; 0 otherwise.

vi. **Access to credit**: The value of this indicator is 1 if the household had affordable credit access over the surveyed period; 0 otherwise.

As shown in Table 6.14 below, all the values of the variables under agro-pastoralist and districts are characterised by a fair degree of similarity. The results indicated that all variables had positive impacts on the assets of households even though the impacts of irrigation equipment and improved seed supply, access to irrigation water, and farmland-owned were very negligible to the assets of pastoralists. On the other hand, the values of labour and livestock were more relevant and important factors for pastoralists to influence their assets. Furthermore, access to credit also influenced assets of both livelihood groups and districts in a similar degree. Farmland, access to irrigation water and irrigation equipment, and improved seed supply were more important for agro-pastoralists followed by the Gewane district, while livestock were more important for pastoralists for their resilience. Labour was equally important for both livelihood groups in both districts.

Table 6.14 Observed variables and their factor loadings to estimate asset (A)

Variables	Livelihood groups		Districts	
	Agro-pastoralist	Pastoralist	Amibara	Gewane
Irrigation equipment & improved seed supply	0.68	0.236	0.504	0.743
Adult labour	0.71	0.775	0.746	0.783
Livestock owned (TLU)	0.754	0.945	0.793	0.610
Access to irrigation water	0.879	0.121	0.515	0.792
Access to credit	0.718	0.717	0.64	0.672
Farmland owned (ha)	0.907	0.350	0.607	0.803

Source: Author's field survey (2016).

6.8.1.2 Adaptive capacity (AC)

Adaptive capacity shows the ability of a household to adapt and cope with a hazard, in this case, to climate-induced shocks and stresses such as drought, floods and climate variability. It enables households to continue performing their basic functions. The following observed variables were included to estimate adaptive capacity for this specific study area.

i. **Diversity of income sources**: Refers to the number of income sources for the household. The more numbers of income sources, the more resilience the pastoralists have to a given disaster risk.

ii. **Changing herd composition**: The value of this indicator was 1 if the household had changed his/her herd composition as an adaptation strategy to climate shock, such as from keeping higher numbers of cattle and sheep, but lower numbers of camels and goats to higher numbers of camel and goat production but lower numbers, of cattle and sheep over the survey period; 0 otherwise.

iii. **Herd mobility**: The value of this indicator was 1 if the household used mobility as coping strategy to climate shock over the survey period; 0 otherwise.

iv. **Irrigation farming**: The value of this indicator was 1 if the household used irrigation farming as an adaptation strategy to climate shock over the survey period; 0 otherwise.

v. **Access to extension service**: The value of this indicator was 1 if the household had access to extension services over the survey period; 0 otherwise.

vi. **Education level**: In this case, households were grouped based on their education level as illiterate (the value of this indicator was 0), only read and write (the value of this indicator was 1), those who completed primary school (the value of this indicator was 2), secondary school (the value of this indicator was 3), and above (the value of this indicator was 5).

Table 6.15 reports the results of the factorial analysis to estimate the adaptive capacity of households by livelihood groups and districts. The results revealed that changes in herd composition, mobility and herd splitting were more important for pastoralists and Amibara district households, while combining livestock production with crop farming and income diversification were more important for agro-pastoral household resilience. On the other hand, education, access to extension and credits influenced the latent variable, AC in a similar degree across the livelihood groups and districts.

Table 6.15 Observed variables and their factor loadings to estimate adaptive capacity (AC)

Variables	Livelihood groups		Districts	
	Agro-pastoralist	Pastoralist	Amibara	Gewane
Herds composition change	0.456	0.955	0.855	0.604
Mobility and herd splitting	0.687	0.927	0.916	0.801
Combining livestock production with crop farming	0.912	–0.17	0.72	0.832
Access to extension & credits	0.665	0.597	0.508	0.609
Level of education	0.632	0.515	0.607	0.678
Number of income sources	0.752	0.543	0.602	0.678

Source: Author's field survey (2016).

6.8.1.3 Social safety nets (SSN)

This is an important dimension of household resilience, particularly for the poor which assisted them to reduce crises. Recently, because of mounting poverty, dependence of households on support from charities, NGOs and international agencies have increased in the Afar region, while the mutual support from relatives and friends was still significant. Therefore, it is important to consider social safety nets to represent the system's ability to reduce climate shocks, and indicators for social safety nets should be involved in the measurement of household's resilience. The indicators or observed variables used to estimate the social safety nets were:

i. **Free distribution of food/grain from government or non-governmental organisations (NGOs)**: The value of this indicator was 1 if the household received food/grain support over the survey period; 0 otherwise.

ii. **Remittance**: The value of this indicator was 1 if the household received cash and in-kind assistance from friends, communities, and relatives over the survey period; 0 otherwise.

iii. **Cash-for-work**: Included transfers received by households from international agencies, charities and NGOs. The value of this indicator was 1 if the household received cash from international agencies, charities and NGOs over the survey period; 0 otherwise.

Table 6.16 Observed variables and their factor loadings to estimate social safety nets (SSN)

Variables	Livelihood groups		Districts	
	Agro-pastoralist	Pastoralist	Amibara	Gewane
Food aid from government or NGOs	0.512	0.79	0.69	0.607
Remittance	0.578	0.738	0.637	0.525
Cash-for-work	0.502	0.884	0.784	0.569

Source: Author's field survey (2016).

The results revealed that pastoralists were more dependent on social safety nets than agro-pastoralists (Table 6.16). Similarly, the SSN was more important for households in the Amibara than the Gewane districts. More dependency on SNN indicated a low level of livelihood outcome, like low food security.

6.8.1.4 Access to public services (APS)

Access to public services provides the pastoral households with numerous essential factors for improving their resilience, for instance, by enhancing the efficiency of pastoral household's access to assets. Consequently, access to public services impacts a pastoral household's ability to manipulate risks and react to climate shocks. The following indicators were considered to estimate access to public services:

i. **Time taken to nearest health centre**: In this case, the value of this indicator is the time that it takes to walk to the nearest health centre. Those households near to the health centre can have better access to health and is important to build their resilience. Households can accomplish their livelihood activities successfully if their household members are healthy.

ii. **Time taken to nearest market centre**: The value of this indicator is the time that it takes to walk to the nearest market centre. Distance to the market also influences resilience of households negatively or positively. Households who are near to the market centre can easily buy and sell their agricultural inputs and outputs. This, in turn, increases their adaptation to shocks and stresses and, hence, more resilient.

iii. **Time taken to nearest veterinary centre**: The value of this indicator is the time that it takes to walk to the nearest veterinary clinic. Households with better access to a veterinary clinic can have a better livestock asset as they have a better opportunity to reduce livestock death associated with disease outbreaks, than households with low access to a veterinary clinic.

iv. **Time taken to the nearest school**: The value of this indicator is the time that it takes to walk to the nearest school. Access to schools increases the number of children to attend education and this, in turn, increases the human capital of households. The higher the human capital of the household, the higher its flexibility and its ability to diversify its livelihood strategies such as non-pastoral/non-farm activities and, hence, the higher the resilience of households.

v. **Access to early warning information (EWI):** This is very important elements of disaster prevention and management by providing information to pastoralists before the occurrence of a climate-related hazard. For example, those households with better information for the coming drought may destock their livestock at a good price before the occurrence of drought and can have a better recovery capacity after drought. The value of EWI was 1 if the household received EWI from the Disaster Prevention and Management Centre of the region; 0 otherwise.

Accesses to public services are beyond the household's control and are important to build household resilience to climate-induced shocks by enhancing economic connectivity through market access. The economic connectivity of a household is its ability to be connected to several markets and income-generating opportunities. Access to public services also increases the household's access to assets by increasing human capital of households through increasing access to health and education. Table 6.17 reveals that all observed variables in both livelihood groups and districts have similar patterns and influenced APS positively. However, the observed variables were more relevant and relatively important factors for enhancing resilience of agro-pastoralists and households in the Gewane district than pastoralists and households in the Amibara district.

Table 6.17 Observed variables and their factor loadings to estimate access to public services (APS)

Variables	Livelihood groups		Districts	
	Agro-pastoralist	Pastoralist	Amibara	Gewane
Time taken to nearest health centre	0.603	0.525	0.581	0.700
Time taken to the nearest school	0.551	0.49	0.53	0.574
Time taken to nearest market centre	0.654	0.589	0.686	0.756
Time taken to nearest veterinary clinic	0.705	0.635	0.607	0.670
Access to EWI	0.691	0.622	0.618	0.638

Source: Author's field survey (2016).

6.8.1.5 Income and food access (IFA)

Income and food access is directly linked to the resilience of a household. Those households with better resilience to shocks have better access to food (Alinovi *et al.,* 2010). Usually, food access is estimated by income; however, to better measure the general feature of access to food, *per capita* expenditure was included in estimating IFA:

i. **Total income**: Refers to the total annual income of a household from all income sources

ii. **Expenditure**: Refers to the annual expenses of a household for consumption.

The communalities of the observed variables to measure IFA in Table 6.18 show that the share of *per capita* income to food access was relatively low for pastoralist groups. This indicated that the role of *per capita* income was too low to estimate the IFA indicator in the case of pastoralists. Similarly, the values of *per capita* expenditure were characterised by a fair degree of homogeneity across clusters, except for pastoralists, which mean that all values of *per capita* expenditure contributed in a similar degree to estimate the IFA dimension.

Table 6.18 Observed variables and their factor loadings to estimate income and food access (IFA)

Variables	Livelihood groups		Districts	
	Agro-pastoralist	Pastoralist	Amibara	Gewane
Total income	0.502	0.46	0.501	0.568
Per capita expenditure	0.623	0.538	0.602	0.657

Source: Author's field survey (2016).

6.8.1.6 Stability (S)

Stability is a significant component for resilience of pastoral households that shows how the livelihood options of the household differ over time. The asset losses experienced by a household were taken into account to measure the value of this variable.

i. **Livestock loss**: Refers to the number of livestock that a household lost as a result of a climate-induced hazard such as drought.

ii. **Crop loss**: This is the crop loss due to climate-induced hazards such as drought and floods.

iii. **Other shocks**: Refer to market shocks, illness and death of the household's family member associated with climate-induced shocks during the surveyed period.

Table 6.19 reveals that stability across clusters was highly influenced by livestock losses, followed by other shocks such as market instability and illness in the household family. The second observed variable that influenced stability of agro-pastoral households was crop loss which was not relevant for pastoralists.

Table 6.19 Observed variables and their factor loadings to estimate stability (S)

Variables	Livelihood groups		Districts	
	Agro-pastoralist	Pastoralist	Amibara	Gewane
Livestock loss	0.762	0.931	0.753	0.611
Crop loss	0.678	0.238	0.732	0.521
Other shocks	0.602	0.684	0.677	0.621

Source: Author's field survey (2016).

6.8.2 Measuring resilience (R)

Following the methodology used by Alinovi *et al.* (2010), the factors of the resilience components have been used to compute the overall RI of households. The latent variables measured in the above sub-topics came to be the explanatory variables to measure RI. Using the iterated principal factor method, factor analysis was run to re-estimate communalities iteratively.

Table 6.20 indicates the first factors that seem to represent the resilience of households fairly well, although SSN is not positively correlated to the first factors indicating its negative correlation with other variables. As households become poorer, the availability of SSN from members of the society, government or NGOs increases. The SSN had a positive contribution to the household's resilience to climate-induced shocks; hence, SNN became positive in the second factor.

Table 6.20 Factor loadings of the components of resilience

Variable	Factor 1	Factor 2	Factor 3
Asset	0.7460	-0.0065	0.1011
Adaptive capacity	0.8690	0.0340	0.0045
Access to public services	0.5740	0.1400	0.0245
Social safety net	-0.4680	0.6670	0.1340
Stability	0.6930	0.3450	0.0040
Income and food access	0.5601	0.0790	0.0450

Source: Author's field survey (2016).

Table 6.21 reveals that factor 1 alone explains 56.3% of the variance, while factors 2, 3, 4 and 5 explained 18.2%, 12.1%, 10.1% and 3.26% of the variance, respectively. For resilience measurement, the first four factors that explained 96.7% of the variance were included.

The Thompson's regression method developed by Alinovi *et al.* (2010) was employed to generate the four factors in order to estimate resilience of pastoral households. Once the four factors had been generated, each factor was multiplied by its own proportion of variance explained:

Resilience = 0.563 * Factor 1 + 0.182 * Factor 2 + 0.121 * Factor 3 + 0.101 * Factor 4

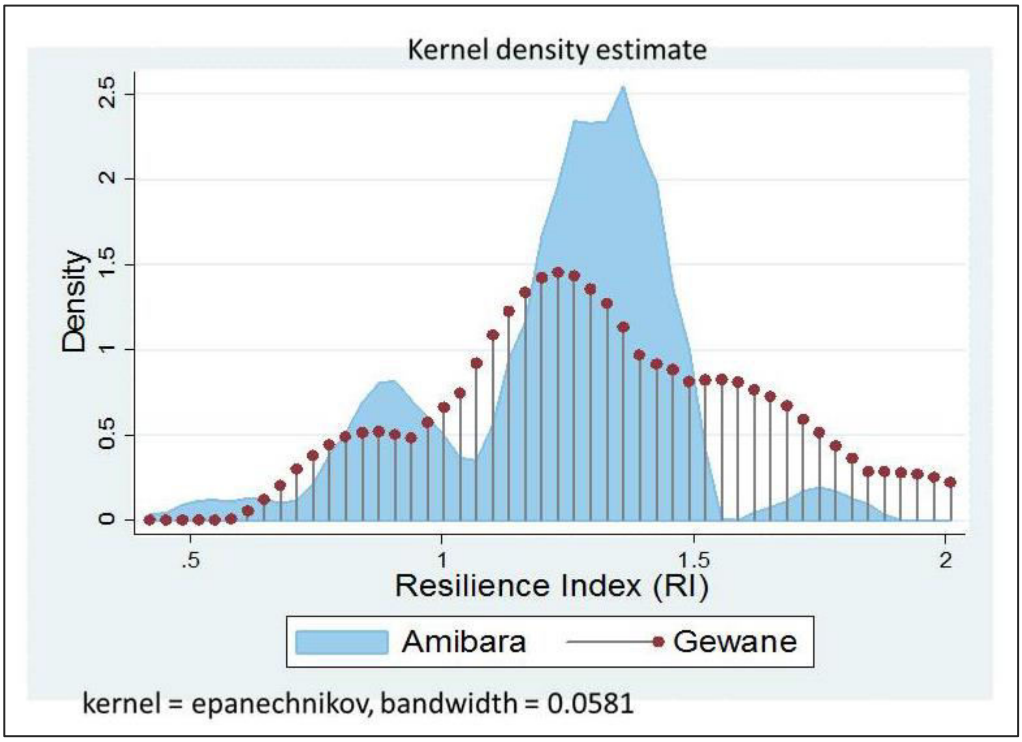
6.21 Eigenvalues and variances explained by the components of the resilience

	Eigenvalues	% variance
Factor 1	2.816	56.321
Factor 2	1.910	18.202
Factor 3	0.906	12.111
Factor 4	0.705	10.105
Factor 5	0.1975	3.261

Factor 1 includes AC and A, while Factor 2, 3, 4 and 5 include SSN, APS, S and IFA, respectively

Source: Author's field survey (2016).

Households were clustered with livelihood groups, gender of the household head and districts to discuss the estimated RI. Figure 6.3 shows Epanechnikov's kernel density estimates of the resilience distribution in the Gewane and Amibara districts of the Southern Afar region.



Source: Author's own (2016).

Figure 6.3 Distribution of resilience of households in the Amibara and Gewane districts

Figure 6.3 reveals that more households with the highest RI, approximately $1.6 < RI \leq 2$, were found in the Gewane than in the Amibara district. However, more households with moderate levels of RI, approximately $1.3 \leq RI \leq 1.6$, were found in the Amibara than in the Gewane district. On the other hand, almost similar proportions of households were found in both districts having lower levels of RI, $0 < RI < 1.3$. The results further indicated that household resilience in the Amibara district revealed the most irregular distribution or high variability, while relatively uniform resilience distribution of households was observed in the Gewane district.

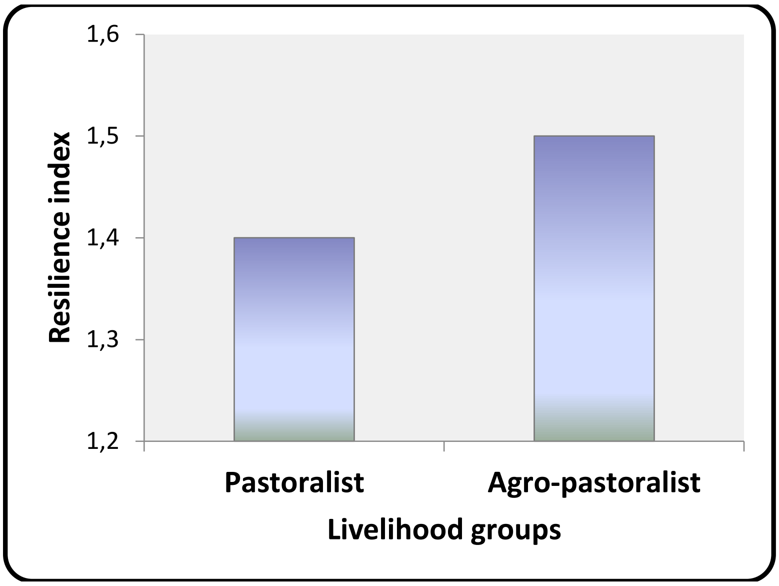
The t-statistics test indicated that, on average, households with a higher RI were observed in the Gewane district than in the Amibara district (Table 6.22). The higher resilience of households in the Gewane district can be explained by the relatively short duration of drought occurrence, better *per capita* income level and assets and better access to agricultural inputs. The findings indicated that there was a prolonged drought in the Amibara district that started in 2014 and lasted until the beginning of 2016 (more than two years), while the Gewane district was hit by the drought from the middle of 2015 until the beginning of 2016 (less than a year). The results further showed that the asset endowment of the Gewane district, such as the number of livestock owned per household, farmland owned per household, access to irrigation equipment, improved seed varieties and per *capita income* level were relatively better than that of the Amibara district. For example, the average *per capita* income of households in the Gewane district was 4 492.70 ETB, while the average *per capita* income of households in the Amibara district was 3 897.5 ETB. Hence, households with a better income level can easily diversify their livelihood options and become more resilient.

Table 6.22 Means variation for resilience between the Gewane and Amibara districts

District	Observed	Mean	Standard error	Standard deviation	df	T	Sig
Amibara	150	1.227074	.0192557	.2358331	248	-2.6540	0.004
Gewane	100	1.317569	.0301738	.3017376			
Combined	250	1.263272	.016906	.2673073			
Difference		-0.090495	.0340979	-.1576534			

Source: Author's field survey (2016).

Analysing resilience by livelihood groups indicated that agro-pastoral households were more resilient than pastoral households (Figure 6.4). The higher resilience of agro-pastoral households can be explained by their small-scale irrigation crop farming activities in addition to livestock production. As explained in section 6.5.1.1, significant differences were observed between the *per capita* income of agro-pastoral households and pastoral households, indicating that the *per capita* income level of agro-pastoral households was significantly higher than those of pastoral households. The mean *per capita* income of agro-pastoral households was 5 932.8 ETB, while those of pastoral households accounted to 4 281.00 ETB. Obviously, those households with a better income level can be more resilient to climate shocks and stress than households with a low level of income.

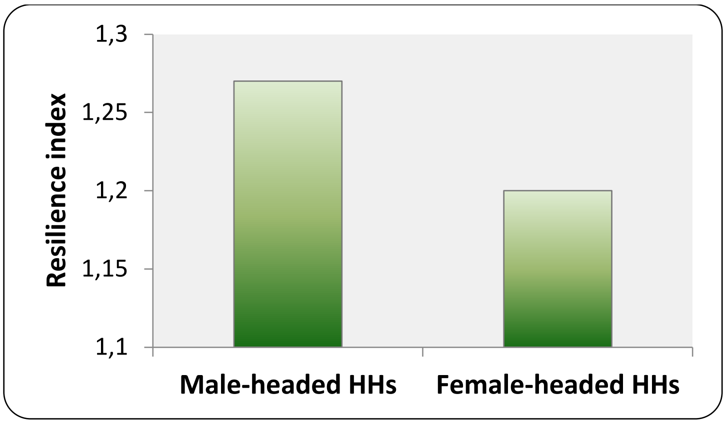


Source: Author's own (2016).

Figure 6.4 Resilience index by livelihood groups

This study also compared resilience of MHH and FHH. The findings indicated that MHH were more resilient than FHH (Figure 6.5). In the study area, though females were more accountable for most of the household's well-being activities, FHH had low access to resources, social services and credits as compared to MHH. This study is in agreement with the findings of Hassan and Nhemachena (2008) who reported that MHH were more resilient than FHH to climate-induced shocks. Similarly, the present result is supported by Haque *et al.* (2012) and Kartiki (2011) who indicated that FHH were less resilient than MHH to climate shocks and stresses.

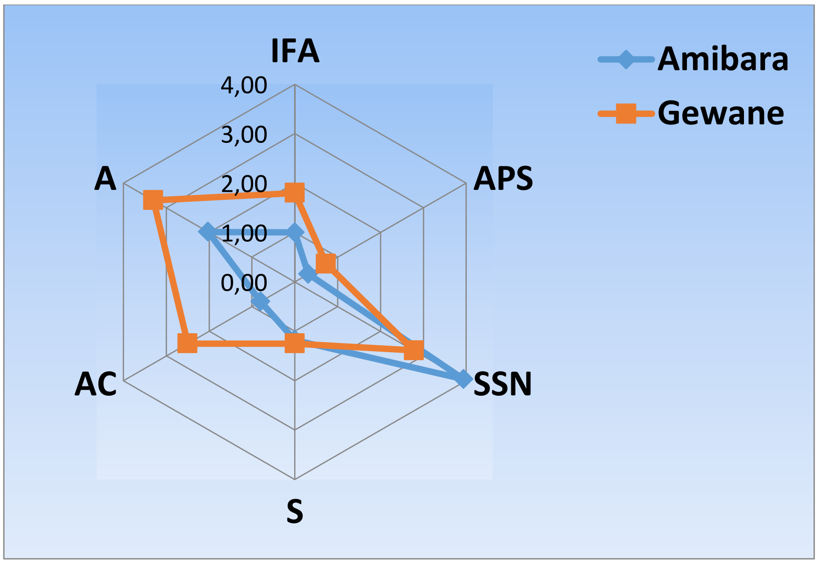
Furthermore, results from analysis of the resilience components are also discussed as discussing the level of household resilience do not express the entire history. In general, the findings indicated that although variations among resilience strategies across clusters were observed, limited access to food and income and poor access to public services (access to market, health, EWI) was observed across all clusters (districts, livelihood groups and gender of household head) (Figure 6.6, Figure 6.7 and Figure 6.8).



Source: Author's own (2016).

Figure 6.5 Resilience index by gender of the household head

The results indicated that the Gewane district showed the high level of resilience which was better in terms of assets (A) such as livestock, farmland and labour, and adaptive capacity (AC) such as combining livestock production with crop farming, mobility, herd splitting and herd composition change (Figure 6.6). In contrast, the Amibara district showed a low level of resilience which had better access to social safety nets (SSN) such as food aid, cash-for-work and remittance.



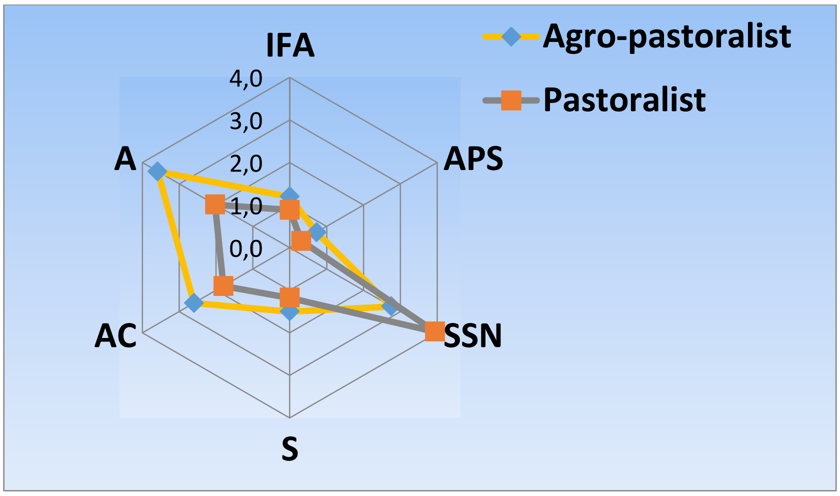
A= Asset, AC= Adaptive capacity, APS= Access to public services, SSS= Social safety nets, S= Stability, IFA= Income and food access

Source: Author's own (2016).

Figure 6.6 Resilience components by district

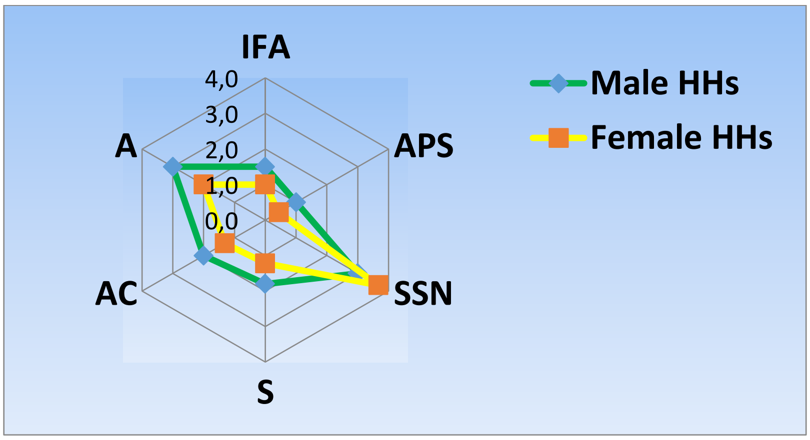
Both districts showed low stability indicating a high loss of livestock, crop and market instability due to the recurrent droughts and unreliable rainfalls in the area. The results also indicated that households in the Gewane district had better income and food access than the Amibara district (Figure 6.6).

The results further indicated that pastoralists showed very low levels of resilience which can be explained by low levels of all resilience components, except SSN indicating the worst situation of pastoralists Figure 6.7). Similar findings were reported by Alinovi *et al.* (2010), a study conducted in Kenya, who revealed that pastoralists were less resilient than agro-pastoralists though the resilience difference was not significant. On the other hand, although agro-pastoral households showed relatively high levels of resilience which were highly dependent on assets and adaptive capacity, they were also characterised by low stability and poor access to public services and limited access to food and income.



Source: Author's own (2016).

Figure 6.7 Resilience components by livelihood strategy groups



Source: Author's own (2016).

Figure 6.8 Resilience components by gender of the household head

Figure 6.8 revealed that FHH are less resilient than MHH. There were large differences between FHH and MHH in terms of access to assets (mainly access to farmlands, labour, access to agricultural inputs and credits), ability to deal with climate-induced shock (mostly due to large differences in terms of access to extension services, education and low capacity in irrigation crop farming), poor access to public services such as access to EWI and health, low stability and limited access to food and income. The only better accessible capital for FHH was SSN that they used to cope with climate-induced shocks such as droughts.

6.8.3 Determinants of resilience of households to climate-induced shocks

The determinants of resilience of households to climate-induced shocks in the Southern Afar region were assessed based on the multiple linear regression (MLR) analysis. The MLR analysis tries to model the relationship between two or more independent variables and a dependent variable by applying a linear equation to observed data. In the present study, the response/dependent variable was the resilience of households. The MLR model has been used to determine the best linear combination of 250 heads of household for envisaging household resilience statuses. The MLR model is described as follows:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n + \varepsilon_i \qquad \text{(xx)}$$

Where:

$Y = \text{Resilience of households}$

$X_1 \ldots X_n = \text{predictor variables}$

$\beta_o \ldots \beta n = \text{Regression coefficients}$

$\varepsilon_i = \text{Random disturbance error}$

The findings showed that the coefficient of multiple determinations is R2 = 0.853 and the adjusted multiple determination is Adjusted R2 = 0.841. Therefore, about 84.1% of the variations in the level of household resilience were due to the explanatory variables included in the model. Based on the value of R2, the regression equation model could be used in making predictions of the factors affecting household's resilience to climate-related hazards. The linear regression's F-test has the null hypothesis that the linear correlation coefficient is zero. In this model it can be accepted that there is a linear relationship between the variables since the F-test is highly significant ($F = 105.23$; $p < 0.001$). Furthermore, in this study the

Durbin−Watson test (d = 2.32) indicated no autocorrelation. Since d is approximately equal to 2 (1 − r), where r is the sample autocorrelation of the residuals, d = 2 showed no autocorrelation (Durbin & Watson, 1971). Furthermore, a formal detection-tolerance and the variance inflation factor (VIF) were carried out to test for multicollinearity among independent variables. The results indicated that multicollinearity among independent variables was not observed as the tolerance levels, on average, were 0.63 which is >0.2 and the VIF were 2.07 which is <5 (Table 6.23). According to O'Brien (2007), multicollinearity among independent variables can be reported if a tolerance of less than 0.20 or 0.10 and/or a VIF of 5 or 10 are detected during regression analysis. Hence, the model used is acceptable.

The results indicated that (i) irrigation crop farming, (ii) livestock ownership, (iii) education level, (iv) *per capita* income, (v) mobility and herd splitting, (vi) herd composition change, (vii) labour, (viii) remittance, (ix) food aid, (x) access to credit, (xi) access to market and (xii) access to formal EWI had a significant impact on the resilience of households to climate-induced shocks. As discussed before, due to the unreliability and erratic nature of rainfall and recurrent droughts in the area, livestock assets and productivity declined and most pastoral households pursued irrigation crop farming as an alternative livelihood option. The regression coefficient of 0.188 in Table 6.23 implies that the odds of those households who practiced irrigation crop farming were 0.188 times more resilient to climate-induced shock than those households who did not practice irrigation crop farming. The present findings are supported by Radeny *et al.* (2006) who indicated that those people who pursued off-farm and farm livelihood activities were more resilient than their counterparts. Similarly, the results showed that livestock assets owned by a household had positive and significant impacts on household resilience, as expected. That is, those households having more livestock will have more opportunities to recover from climate-related hazards.

The analysis showed that the odds of a household to be resilient to climate shocks increase by 0.167 for a unit increase in the number of livestock. This study is also supported by the findings reported by Feleke *et al*. (2003) who indicated that a livestock asset was positively related to the probability of a household being resilient to food insecurity. The results further indicated that the odds of a household to be resilient to climate shocks increase by 0.247 for a unit increase in his/her income level (Table 6.23). A similar study was reported by Omotesho *et al.* (2006) who indicated that the *per capita* income of households significantly affected the household's resilience to food insecurity.

Table 6.23 Estimated results for the determinants of household's resilience

Explanatory Variables	Understandardised Coefficients		Standardised Coefficients	T	Collinearity statistics	
	B	Standard error	Beta		Tolerance	VIF
Constant	0.050	0.02	**	2.500		
Irrigation crop farming	1.239	0.228	0.188***	5.438	0.521	2.432
Livestock ownership (TLU)	0.125	0.040	0.167**	3.125	0.712	3.870
Access to veterinary clinic	0.073	0.288	0.006	0.253	0.631	2.310
Education level	0.796	0.225	0.130**	3.535	0.822	1.743
Access to health	0.246	0.162	0.073	1.518	0.413	1.346
Per capita income	1.774	0.219	0.247***	8.092	0.703	3.203
Access to cash-for-work	0.294	0.211	0.053	1.394	0.737	1.542
Mobility and herd splitting	1.745	0.197	2.43***	8.847	0.624	2.753
Herd composition change	1.303	0.248	0.231***	5.258	0.571	3.541
Access to market	1.337	0.222	0.237***	6.033	0.831	1.327
Adult labour	0.836	0.246	0.116**	3.395	0.452	1.674
Remittance	1.045	0.203	0.159***	5.141	0.565	1.321
Access to early warning	0.862	0.276	0.120**	3.122	0.653	2.351
Access to extension	0.073	0.146	0.013	0.500	0.749	1.282
Food aid	0.1227	0.029	0.369**	4.231	0.682	1.303
Access to credit	0.626	0.154	0.121**	4.068	0.476	1.187

R-Square = 0. 85; Adjusted R-Square = 0.841; F-statistic = 131.6
Prob (F-statistic) = P< 0.001; Number of observations = 250; Durbin−Watson = 2.03

**** and ** indicates significance levels at 1% and 5% probability levels, respectively.*

Source: Author's field survey (2016).

The regression coefficients indicated that education level and *per capita* income were positively and significantly correlated to the odds that a household would be resilient (Table 6.23). The odds of those households who can read and write and those who had primary education were 0.130 times more likely to be resilient than those households who were illiterate. This can be explained by the more years the head of the household spent at school, the more the skill and knowledge the household will have to manage climate-induced hazards.

Educated households therefore have a great opportunity to pursue less climate sensitive livelihoods than uneducated households. Similar studies conducted by Haile *et al.* (2005) indicated that in the Oromia regions of Ethiopia, a change in level of education from illiterate to literate caused an increase in the likelihood of a household being food secure from 0.14 to 0.325. This study is also supported by the findings reported by Deressa and Hassan (2009), Kebede and Adane (2011) and Yesuf *et al.* (2008) who indicated that education enhances the probability of household resilience to climate-induced shocks and stresses. Herd mobility and herd species composition changes were crucial resilient strategies in pastoral communities of the Southern Afar region to utilise the seasonal, annual and spatial variability of rangeland resources and to cope and recover from the recurrent droughts. The results showed that changing the species composition of herds and mobility had an affirmative and important influence on the resilience of the pastoralists. The odds of those households who use mobility and herd splitting, and change in herd species composition as a resilient strategy is respectively 2.43 and 0.231 times more resilient to climate-induced shocks than their counterparts (Table 6.23).

Moreover, households can use cash/livestock transfers from their family, relatives, community and friends outside the community or food aid from charities, NGOs and the government in times of need during climate-induced shocks such as weather-related loss of livestock, death or sickness of family members and during food crisis. Remittance and food aid also positively and significantly impact household resilience to climate-induced shock. The coefficient for remittance of 0.159 in Table 6.23 suggests that those households who received remittance, for a unit increase in the amount of transfers, their probability to cope and recover from climate-induced shocks such as drought, increased by 0.159. Similarly, those households who received food aid are 0.369 times more likely to cope and recover from climate-induced shock. This implies that food aid was significant for households to cope with the food crisis during drought periods. However, it is better to assist households to produce more food than receiving food aid in order to enhance their long-term resilience to climate-induced shocks. Then they can absorb the food crisis by themselves using their own food stock during drought periods. This is in line with the results reported by Omamo *et al.* (2010) who indicated that delivery of food assistance where the recipients do not only receive food but also solutions to combat hunger, may be a better decision for enhancing long-term resilience to food insecurity than food aid alone. Similarly, Frankenberger *et al.* (2012)

reported other strategies that could enhance the resilience of vulnerable populations which include increasing access to communal assets, consolidating the capacities of formal and informal institutions, assisting livelihood diversification, resolving disputes and rehabilitations of degraded ecosystems.

Furthermore, access to family labour enables households to pursue their livelihood activities successfully and use enhanced technologies which can lead to higher yields. The result indicated that labour availability positively and significantly impacted the resilience of households and, as indicated in Table 6.23, the coefficient 0.116 implies that a unit increase in access to labour for a household increases the probability of the household by 0.116 times to be more resilient. The findings reported by Asenso-Okyere *et al.* (2013) revealed that those households with better access to labour availability were more likely to be food secured and resilient to climate-induced shocks.

Moreover, the findings revealed that a household's access to credit has an affirmative and significant relationship with the resilience of households (Table 6.23). The result implies that the more the household is likely to get credit access, the higher is the probability of the household by 0.121 times to be resilient to climate-induced shocks. Access to affordable credit is crucial for pastoralists to pass through droughts. Access to credit enables households to have bargaining power to wait for better times and receiving good prices for selling of their livestock. Access to credit also enables households to pursue non-pastoral livelihood activities such as irrigation crop farming, which allow them to purchase inputs for irrigation farming like a water pump and drought resistance seed varieties. Similar results were reported by Hassan and Nhemachena (2008) who indicated that access to credit enables households to shift their livelihood strategies in light of climate shocks and stresses. The results indicated that access to market and formal EWI were significant determinants of household resilient. The coefficient 0.237 in Table 6.23 for market access implies that a decrease in a one-hour travel from the household's residence to the market centre increases the likelihood of household resilience to recover from the climate shock by 0.237. Similarly, the coefficient 0.120 for EWI implies that the likelihood of being resilient to climate-induced shocks increases by 0.120 for those households who have access to formal EWI.

6.9 Pastoralist's Vulnerability to Climate Change and Variability in the Southern Afar Region

6.9.1 Hazards perceived by local people

According to the local respondents, the rainfall recently became more unpredictable and erratic and the instance of rainfall variability turned into frequent and prolonged droughts. The endemic diseases were also changed into epidemic diseases due to the increasing of frequent droughts and erratic rainfalls. The findings indicated that drought was the frequent hazard in the study areas as reported by 100% (n=250) of the respondents, followed by the encroachment of the rangeland by invasive species, mostly *P. juliflora,* livestock diseases, loss of dry season grazing areas and floods (Table 6.24).

Table 6.24 Hazards perceived by sample households (multiple responses were possible)

Perceived hazards	Number of respondents (N=250)	Percentage
Droughts	250	100
Rangeland encroachment by invasive species	230	92
Livestock diseases	213	85.2
Loss of dry season grazing areas	195	78
Floods	105	42

Source: Author's field survey (2016).

As indicated in Table 6.24, rangeland degradation due to rapid expansion of invasive species such as *P. juliflora,* which is discussed in detail in Chapter 7, was also the second important hazard threatening the livelihood of pastoral households. The results further showed cattle diseases such as blackleg, locally referred to as *harayti*, and trypanosomiasis, locally called *sole*, and diseases of camels such as *geramole* and *gosso,* were some of the frequent hazards threatening their cattle and camels. Contagious caprine pleuro-pneumonia, a fatal disease that mainly affect goats, and mange, a skin disease caused by parasitic mites, were also the most common diseases affecting sheep and goats in the study areas. Respondents further complained that allocation of the dry season grazing areas for commercial farmers was also another hazard curtailing livestock mobility during dry seasons, weakening pastoralist's resilience to climate change and variability.

6.9.2 Vulnerability indicators

The socio-economic and biophysical vulnerability indicators selected for this study are indicated in Table 6.25. The results showed that 76.8% of the households had more than five family members, with 32% respondents who reported more than three dependents, aged less than 15 years and 65+ years. Pastoralism is a livelihood strategy requiring more labour availability. Thus, those households with more dependents, aged less than 15 years and 65+ years, were more vulnerable to climate-related hazards. The findings further showed that 72.2% of the households were illiterate. This, in turn, decreases the household's capability to access markets, climate and EWI, making households more vulnerable to climate-induced shocks and stresses.

As shown in Table 6.25, more than 41% of the household heads were females who were more vulnerable to climate-induced shock and stresses as females had low access to assets, credits, social participation and climate information. On the other hand, 72.2% of the households had no access to extension services, indicating their increasing vulnerability to the frequently occurring climate shocks such as droughts. The results imply that the education level of the household head, access to extension services and climate information were the most important social vulnerability variables in the study area. The findings further indicated that approximately 60% of the households had no multiple livelihood opportunities and most of them were dependent on livestock production for their income sources (Table 6.25). Forty percent of the households practiced irrigation crop farming alongside livestock keeping. The results also revealed that 77.8% and 70% of the households complained that they had to travel more than 10 km to access markets and veterinary services.

Moreover, the findings showed that about 57.6% of the households practiced livestock mobility as a coping strategy against drought in the study area (Table 6.25). In addition, 85.2% of the respondents noted that they had no credit services in the study area. The results imply that low access to markets, veterinary services, credit and limited options of income sources were the most important economic vulnerability variables to climate-induced hazards such as drought and floods. The results further revealed exposure to climate shocks and stresses (Table 6.25). Ninety eight percent of the respondents indicated that they experienced decreasing rainfall, while 95% of the households experienced increasing temperature for the last three decades. Furthermore, all households experienced increasing frequency of droughts, while 42% of the households faced flood hazards two or more times in the last ten years.

Table 6.25 Selected vulnerability indicators and their effects on vulnerability

Hypothesised Vulnerability Indicators	Percentage	Effects on vulnerability*
Gender of household head: female-headed	41.2	+
Age of household head: 50+ years	46.8	+
Marital status: single	30.6	+
Household size: more than five persons	76.8	-
Dependents: >3 persons	32	+
Educational level: unable to read and write	72.2	+
Member of household sick or died associated with climate-related hazards	30.4	+
Extension services: having no extension services	72.2	+
Linkages: having social linkages	63.2	-
Distance to health service: more than 10 km	68	+
Access to EWI: no access to information	82	+
Experience: > 5 farming experience	3.6%	–
Livestock owned: having less than 2 TLU	26.8	+
Irrigation farming: having practiced irrigation farming	40	-
Non-farm income: have non-farm income sources	60	-
Mobility: ability to move freely	57.6	–
Radio owned: having a radio	18.2	–
Access to remittances: having cash transfer	30	–
Distance to market: more than 10 km	77.8	+
Distance to veterinary clinic: more than 10 km	70	+
Credit access: no credit access	85.2	+
Access to agricultural inputs	24.4	–
Households having food shortages during normal season of the year	60.6	+
Rainfall: experience decrease rainfall	98	+
Temperature: experience increasing	95	+
Households facing flood hazards two or more times in 10 years	42	+
Households experiencing increasing frequency of droughts	100	+

**Positive sign shows that the variable increases vulnerability, while a negative sign refers to that the variable decreases vulnerability. TLU refers to tropical livestock unit; 1 TLU is equivalent to 250 kg.*

Source: Author's field survey (2016).

6.9.3 Measuring vulnerability of households

In the present study, factor analysis was carried out to develop the vulnerability indices and measure the vulnerability of households quantitatively. Twenty-seven indicators of household vulnerability were studied and their factor scores are indicated in Table 6.27. The appropriateness of the data was assessed depending on the KMO and Bartlett's tests values before running the factor analysis. According to Li and Weng (2007), if the KMO value is >0.5 and the Bartlett's test value is <0.1, the factor analysis can be run.

The analysis showed that the KMO measure of sampling adequacy was 0.728, indicating that the model was fairly acceptable and the Bartlett's significance test for these data was highly significant ($p < 0.001$), suggesting the that factor analysis was suitable for integrating the socio-economic and biophysical indicators at household level (Table 6.26). Having checked the appropriateness of the data for PCA analysis, PCA analysis was carried out on the vulnerability indicators listed in Table 6.27.

Table 6.26 **Kaiser_Meyer_Olkin and Bartlett's Test**

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.728
Bartlett's Test of Sphericity	Approximate Chi-Square	1487.120
	Df	210
	Sig.	0.001

Source: Author's field survey (2016).

The results of PCA indicated that three components were extracted with eigenvalues greater than 1 explaining 77.36% of the total variation. The first principal component explained 52.33% of the variation, the second explained 14.29%, and the third explained 10.74% of the variation. The results of PCA and its relationship with the socio-economic and environmental variables are indicated in Table 6.27. The vulnerability index of each household was developed using equation xv, explained in section 4.6. Based on the developed vulnerability index, households were grouped into three vulnerability levels. Those households having a vulnerability index of +3 to 5.9 were grouped as less vulnerable and accounted 17.6% of the households (Table 6.28). Less vulnerable households are in a vulnerable state, but can still cope.

Table 6.27 Factor loadings of vulnerability indicators from principal component analysis

Vulnerability indicators	Factor score
Gender of household head	0.637
Age of household head	-0.762
Marital status	0.537
Household size	0.827
Dependant ratio	−0.504
Educational level	0.780
Member of household sick or died associated with climate-related hazards	0.542
Extension services	0.874
Social linkages	0.702
Distance to health service	0.574
Access to EWI	0.604
Farming experience	0.501
Livestock owned	0.967
Irrigation farming	-0.807
Non-farm income	0.664
Livestock mobility	0.731
Radio owned	-0.594
Access to remittances	0.569
Distance to market	0.789
Distance to veterinary clinic	0.735
Access to credits	0.813
Access to agricultural inputs	-0.819
Households having food shortage during normal season of the year	0.578
Experiencing decrease rainfall	−0.956
Experiencing increasing temperature	−0.924
Households facing flood hazards	−0.587
Households facing drought hazards	−0.834

Source: Author's field survey (2016).

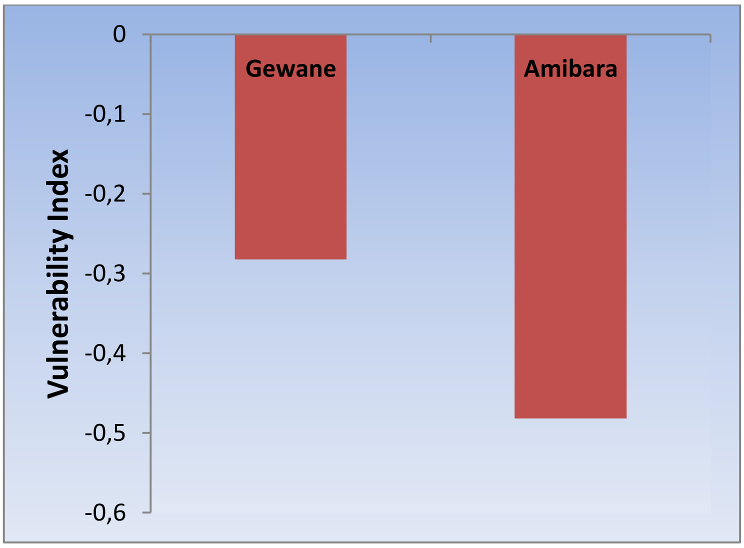
Similarly, households grouped as moderately vulnerable are those that need immediate, but short-term support during climate-induced shock and had a vulnerability index of –2.5 to +2.9 and constituted 53.6% of the sampled households. The third vulnerability groups were highly vulnerable households having a vulnerability index of –2.51 to –4.49. Highly vulnerable households are those that are at emergency level and accounted 28.8% of the sample households (Table 6.28).

Table 6.28 Vulnerability levels and situations of pastoral households

Levels of Vulnerability	Situation of households	Vulnerability index	% of households
Highly vulnerable	The most susceptible households even for slight shock and need intensive care	–2.51 to -4.49	28.80
Moderately vulnerable	Households who need temporary support to recover when they are hit by hard climate-induced shock	–2.50 to +2.59	53.60
Less vulnerable	Coping households – household in a susceptible situation, but still capable to cope	+3.00 to 5.90	17.60
Total			100.00

Source: Author's field survey (2016).

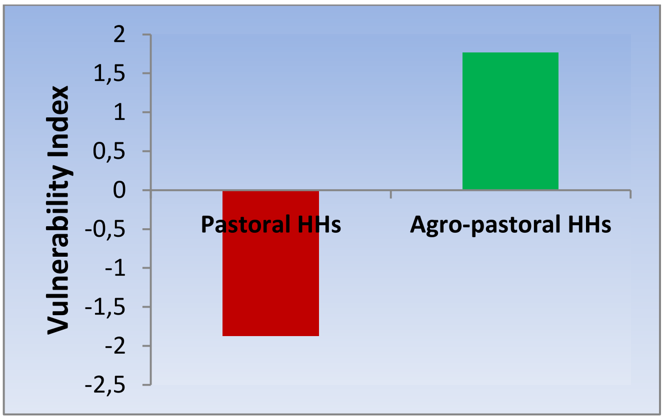
Furthermore, this study compared vulnerability of households by livelihood groups, districts and gender of the household head. Accordingly, the findings indicated that households living in the Gewane district were relatively less vulnerable than households living in the Amibara district, although significant difference was not observed between the vulnerability indexes of the two districts (Table 6.29 and Figure 6.9). This can be explained by differences in exposure to climate shocks and stresses between the two districts. The meteorological data analysis results in Chapter 5 and the local people's reports during the field survey indicated that, recently, the Amibara district was more drought prone area than the Gewane district.



Source: Author's own (2016).

Figure 6.9 Vulnerability level of households by district

The results further indicated that agro-pastoral households were significantly less vulnerable than pastoral households (Table 6.29 and Figure 6.10). This can be related to variations between the two groups with regard to livelihood diversification. Agro-pastoral households were practicing irrigation farming alongside livestock keeping, while pastoralists were solely dependent on their livestock as a source of income. Hence, agro-pastoral households had better adaptive capacity and were less vulnerable than pastoral households. This implies pastoralism is no longer accommodating the people contained in the Southern Afar region under climate-related shocks and stresses. Similar results were reported by (O'Brien et al., 2004) who indicated that those households practicing irrigation farming were more adaptable to diverse climatic conditions. The findings reported by Tsegaye et al. (2013) also indicated that even though pastoralism has been the main livelihood activity of the Afar community, those households who depended only on livestock were more vulnerable than those who combined livestock and crop farming.



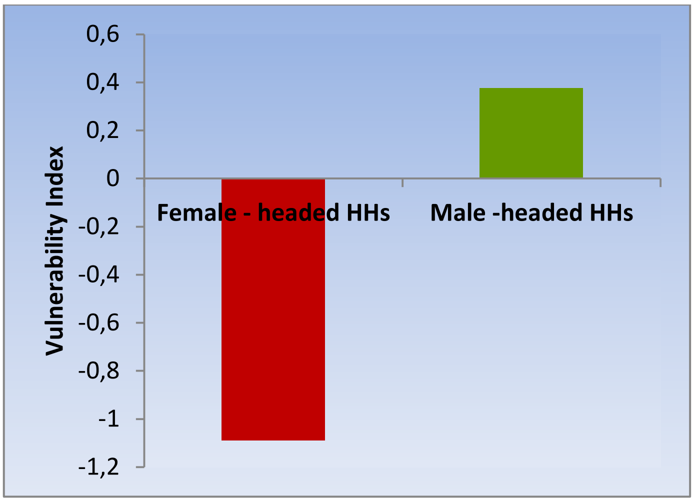
Source: Author's own (2016).

Figure 6.10 Vulnerability category of households by livelihood strategy

Table 6.29 Paired sample tests for household vulnerability index clustered by livelihood strategy, districts and gender of the household head

		Paired differences			T	Sig. (two-tailed)
		Mean	Standard deviation	Standard error mean		
Pair 1	VIPH – VIAPH	–3.593	3.114	0.3099216	–11.595	0.000
Pair 2	Gewane – Amibara district	0.418	3.797	0.3836503	1.091	0.278
Pair 3	Female- / Male-headed households	–1.249	3.469	0.3402433	–3.671	0.000

VIPH – Vulnerability index of pastoral households
VIAPH – Vulnerability index of agro-pastoral households
Source: Author's field survey (2016).



Source: Author's own (2016).

Figure 6.11 Vulnerability of households by gender

The results indicated that FHH were more vulnerable than MHH (Table 6.29 and Figure 6.11). This was due to low the adaptive capacity of FHH as a result of poor access to social participation, credits and assets and unable to combine crop farming with livestock production due to limited labour availability and low skills to crop farming activities as compared to MHH. The results of this study are supported by Ongoro and Ogara (2012) who did their studies on the vulnerability of Samburu pastoralists in Kenya and indicated that women were more vulnerable to the impacts of climate change than their men counterparts.

6.9.4. Determinants of household's vulnerability

The Tobit regression model was used to estimate the determinants of household vulnerability. As shown in Table 6.30, F-statistics are significant, implying that the explanatory variables or the independent variables jointly explain the variations in the dependent variables, namely, vulnerability levels of households. The robust estimation was also used to check for multicollinearity in the Tobit estimation of the determinants of the extent of vulnerability.

The Tobit regression result in Table 6.30 indicates that gender of the household head showed a positive and significant association with the vulnerability of the households. This implies being a FHH increases the risk of being vulnerable by 0.67 to climate change and variability as compared to MHH. This can be explained by the female's poor access to resources, credits, information and agricultural technologies due to women's marginalisation and inequality in the region. Similar findings were reported by Gebre-Michael and Kifle (2009), Mushi (2013) and Mung'ongo *et al.* (1990) in their studies conducted in Tanzania and Ethiopia which indicated that women had limited resource rights and entitlement and were more vulnerable to ever-changing, inconsistent weather in these regions. The results of the current study are also similar to the findings reported by Etim and Patrick (2010) and Geda *et al.* (2008), indicating FHH were more vulnerable to food insecurity than MHH.

Furthermore, the findings showed that the age of the household was a significantly important demographic factor in determining household vulnerability to climate shocks and stresses. Elder household heads lacked physical capacity to manage the labour-intensive livelihood activities than young household heads. That is, they were not able to move long distances in search of pastures and water during a drought season and also had labour limitations to diversify their income sources and, hence, more they were vulnerable to climate-related shock relative to young household heads. Similar findings were reported by Seid (2012) who reported that aged household heads lack physical capacity to manage their livelihoods and diversify their income sources.

Similarly, the coefficient of household size was also significant and positively associated with the vulnerability of households. Though household size is directly linked with labour availability, large family size in a household with low income level can increase their vulnerability to climate-related hazards. The results indicated that keeping constant all other variables, on average, one unit increase in family size increases vulnerability of a household by 0.463. In the Southern Afar region where the rangeland was degraded, livestock assets and productivity were declining; households with larger family sizes were more vulnerable to climate shocks and stresses due to the increased need of the household's consumption of limited resources. The results reported by Orbeta (2005) indicated that a large family size affected household welfare and reduced household savings, and increased vulnerability to poverty. Similar results were reported by Adepoju and Oyewole (2014), Awotide *et al.* (2010), Etim and Solomon (2010) and Oluwatayo (2009), who indicated that the increase in family size increases the demand for food and other consumptions which ultimately result in food insecurity and poverty. Hence, poor and food insecure households with large family size are vulnerable to climate shocks and stresses.

Table 6.30 Tobit model estimates of the determinants of vulnerability level of households

Vulnerability Indicators	Coefficient	Robust standard error	T	P>|t|
Gender of household head	0.669	0.094	7.08	0.001
Age of household head	0.060	0.005	12.97	0.025
Marital status	0.025	0.034	8.31	0.002
Household size	0.463	0.035	13.43	0.001
Dependant ratio	1.983	0.319	6.22	0.031
Educational level	–0.756	0.113	-6.70	0.001
Member of household	0.242	0.097	2.50	0.023
Extension services	–0.625	0.152	–4.10	0.001
Social linkages	–0.095	0.115	–0.826	0.223
Distance to health service	0.002	0.036	0.05	0.957
Access to EWI	0.520	0.136	3.824	0.004
Farming experience	–0.086	0.015	–5.95	0.023
Livestock owned (TLU)	–0.193	0.047	–4.11	0.001
Irrigation farming	–1.009	0.133	–7.586	0.001
Non-farm income	–1.271	0.093	–13.667	0.001
Livestock mobility	–0.764	0.064	–11.938	0.001
Radio owned	–1.487	0.094	–15.77	0.0314
Access to remittances	−0.313	0.127	–2.46	0.0162
Distance to market	0.105	0.016	6.69	0.001
Distance to veterinary clinic	1.227	0.136	9.00	0.013
Access to credits	–0.819	0.122	–6.74	0.001
Access to agricultural inputs	–0.775	0.135	–5.72	0.001
Households having food shortage during normal seasons of the year	0.164	0.025	6.47	0.001
Experiencing decrease in rainfall	−0.437	0.237	–1.843	0.345
Experience increasing	−0.098	0.058	–1.70	0.215
Households facing flood hazards from 1983–2016	0.014	0.130	0.11	0.915
Experiencing increasing frequency of droughts	−0. 256	0.165	–1.552	0.1357
_cons	−1.62979	0.358	–4.54	0.001
/sigma	0.584023	0.0178		
Number of observations	250			
F (26, 223)	265.74			
Prob > F	0.001			
Pseudo R2	0.6479			

Source: Author's field survey (2016).

The results further indicated that divorced or widowed households and households with more dependent ratio were very likely to be adversely influenced by climate-related shock. Dependency ratio refers to the ratio of family members under the age of 15 and above 65 to total household size, i.e. a measure of the number of young and old individuals that possibly need to be assisted by adult family members. The coefficient 0.025 for marital status in Table 6.30 indicated that the odds of divorced or widowed households are 0.025 times more vulnerable to climate-induced shocks than their counterparts. Similar findings were observed in a study conducted by Kakota *et al.* (2011) and Tesso *et al.* (2012) in Malawi and Ethiopia, respectively, who indicated that widowed or separated (divorced) household heads were more vulnerable as they rely on income of either the father or mother as the providers. The results further indicated that the odds of the households to be vulnerable to climate shocks and stresses would increase by 1.983 for a unit increase of dependent ratio of a household family. The results of the current study are also in line with the findings of Nkondze *et al.* (2013) who indicated that the likelihood of a household to be vulnerable to climate-induced shock such as drought increased by 1 581% for a unit increase in the number of dependents,

On the other hand, the coefficient of education level, access to extension services, credits, and agricultural inputs were negatively associated with the vulnerability of households at 1% significance level. This implies that those households that were literate and had access to extension services, affordable credits and agricultural inputs such as improved seed supply and irrigation equipment were less vulnerable to climate change and variability than their counterparts. A study conducted by Gebrehiwot and Van der Veen (2013) in the Tigray region in Ethiopia indicated that people with a low educational level were more likely dependent on climate-sensitive livelihoods and were more vulnerable to climate-related hazards. This study is also supported by the results of McCarthy *et al.* (2001) who showed that those with a low level of literacy are likely to be the most susceptible to climate-induced shock. Similar results were reported by Tesso *et al.* (2012) and Watson and Binsbergen (2008) who showed that households who have credit access, extension services and agricultural inputs are less vulnerable to climate shocks and stresses than their counterparts. The findings further indicated that the odds of a household to be vulnerable to climate shocks was significantly determined by livestock holding, irrigation farming, non-farm incomes, livestock mobility, farming experience, radio ownership, access to remittances, distance to markets and veterinary clinic, number of sick members and number of months with food shortage during the normal season of the year.

The coefficient of livestock owned in Table 6.30 indicated that a unit increase in livestock number reduces the likelihood of a household to be vulnerable to climate shocks and stresses by 0.193. More livestock assets tend to decrease the extent of poverty among pastoralists and vulnerability to the vagaries of change in climate and climate variability (Enquobarie, 2004; Woldehanna *et al.,* 2008). Furthermore, the coefficient of irrigation farming indicated that households engaged in irrigation crop farming, besides livestock keeping, were less vulnerable to the adverse influence of climate shocks and stresses by 1.01, relative to those who solely depend on livestock production. Kuyvenhoven (2012) also showed the significance of increasing irrigation activities in pastoral areas to tackle poverty and decrease their vulnerability to climate change. The results further showed radio ownership and access to remittance were negatively associated with the vulnerability of households. This implies that having a radio increases household's access to climate and market information and are less vulnerable than their counterparts. Access to remittances was also important for the poor to cope and recover from climate-induced shocks. The coefficients for access to remittance and radio ownership in Table 6.30 indicate that the odds of households to be vulnerable to climate-induced shocks decrease by 0.313 for a unit increase in access to remittance, while the likelihood of households who have radio access to be vulnerable decreases by 1.487. Similarly, a unit increase in farming experience also decreases vulnerability of households by 0.086 to climate-induced shocks and stresses. In addition, households involved in off-farm activities such as petty trading, employment and handicraft activities have a lower likelihood of being vulnerable to climate-induced shocks by 1.27, relative to those engaged only in climate-sensitive livelihood activities such as livestock production. The coefficient of livestock mobility showed a significant and negative association with household vulnerability. This implies that those households who moved their livestock freely were less vulnerable to climate-induced shocks than their counterparts.

The results further showed that the coefficients for distance to market and veterinary clinic, EWI, number of sick members and months with food shortages during normal season of the year associated positively with the vulnerability of households (Table 6.30). A unit increase in the market and veterinary clinic distance from a household's residence increases vulnerability to climate-induced shocks and stresses by 0.12 and 1.23, respectively. The results also indicated that those households who have no access to EWI are more vulnerable to climate shocks and stresses by 0.052 than their counterparts. Similarly, a unit increase in the number of sick members and months with food shortage during the normal season of the year would increase the likelihood of a household to be vulnerable to climate shocks and stresses by 0.242 and 0.164, respectively.

6.10 Summary

The findings revealed that the livelihood of the Afar communities heavily depends on natural resources, livestock and mutual support systems. Because of the unreliability and erratic nature of rainfall and recurrent droughts in the region, pasture and water availability became scarce and livestock assets and productivity were highly reduced. Consequently, the income and asset ownership of households were declining and market price of livestock were declining, while the price of food grains increased. This resulted in increased poverty and food insecurity in the region. Due to the deepening of poverty and food insecurity in the region at household and community level, the informal safety net/mutual support systems were eroded and individualism increased instead. In response to the negative impacts of droughts, the local people pursued different adaptation and coping strategies. The most important strategies deployed by the local people included (i) mixing livestock–crop production, (ii) mobility, (iii) changing herd species composition and herd splitting, (iv) reduced consumption, (v) remittance, (vi) cash-for-work, (vii) charcoal burning and firewood selling and (viii) food aid. However, there were some constraints that limited the existing opportunities of a household’s long-term and short-term strategies. These were: (i) lack of credit facilities, (ii) limited access to formal EWI, (iii) lack of access to farm inputs and equipment, (iv) limited technical skills and illiteracy.

The results further indicated that the Gewane district was more resilient than the Amibara district. This can be explained by the duration and intensity of the droughts that occurred in the last two years. In the Amibara district, there were severe and prolonged droughts for the last two years, while the Gewane district received rainfall showers in between, although the households in Gewane were also hit by the drought for a year. Hence, those households who lived in drought prone areas (Amibara) were less endowed in IFA, A, AC APS and S and, hence, less resilient. The findings also showed that pastoralists were less resilient than agro-pastoralists. This was largely due to low level of adaptive capacity and assets owned by pastoralists. The results also revealed that FHH were less resilient than MHH due to their low level of adaptive capacity and poor access to assets, public services, food and income access.

Furthermore, a multiple linear regression analysis was performed to examine the determinants that cause variations among the resilience of households in the study areas. Accordingly, (i) livestock ownership, (ii) irrigation crop farming, (iii) education level, (iv) *per capita* income, (v) mobility, (vi) herd splitting and composition change, (vii) labour, (viii) remittance, (ix) food aid, (x) access to credit, (xi) access to markets and (xii) access to formal EWI were the factors that caused variations among the household's resilience to climate shocks and stresses. Overall, if enhancing the resilience of pastoralists is the ultimate goal, the government and other partner organisations should rather focus on the long-term strategic livelihood interventions, than emergency relief interventions, by equipping the local people with the capability to manage and respond to climate-induced shock in the early stage of the crisis.

This study also identified which category of households, sectors and places were more vulnerable and which groups of households were not vulnerable, but have a great likelihood of becoming vulnerable in the future. Hence, this enables decision makers to plan for which group of households, sectors and places should they give priority in their development intervention. The results revealed that 28.8% of the pastoral households were highly vulnerable and these groups of households need an intensive care and follow-up to withdraw them from this situation. Most of the households (53.6%) were moderately vulnerable, suggesting that in the occurrence of climate induced shocks and stresses they would require some support to recover them. Only 17.6% of the pastoral households were capable to cope, despite the fact that there will be a high probability to shift from less vulnerability to moderate or high vulnerability level in the future if appropriate adaptive measures would not be taken by decision-makers. In this study, it was observed that the most important factors that determine the vulnerability of a household were gender, age and marital status of the household, household size, educational level, extension services, farming experience, livestock assets, irrigation farming, non-farm income, livestock mobility, radio ownership, access to remittance, EWI, distance to market and veterinary clinic, access to credit and agricultural inputs, dependant ratio, the number of sick members and the number of months with food shortages during the normal season of the year.

In conclusion it can be said that the natural resource base, traditional resource management and utilisation, indigenous early warning system and informal safety nets in the community were the most important components of the local people's resilience. This suggested the need to strengthen the natural resource base of the community, train and enhance the traditional resource management and utilisation of the people, empower the informal institutions and integrate the indigenous early warning system into the national and regional formal early warning system. The formal early warning system should be improved so that pastoral households could get information about the future climate related shocks and stresses to take measures and minimize the disaster risk as early as possible. This ought to be supported by legitimate climate forecast and quantitative data from meteorological stations. Along these lines, it is imperative to reinforce the meteorological station in the Southern Afar region to give solid and convenient climate data regularly. Furthermore, enhancing access of households to the market, credit and financial facilities, access to extension and education, improving the technical skills of the local people in crop farming practices, and providing farm inputs and equipment, were also important to adapt the local people to climate change and variability. This study clearly answered which groups of households and districts were less resilient and why. This has significant implications for policymakers for better interventions in pastoralist areas of the Southern Afar region.

Chapter 7
LAND-USE/LAND-COVER CHANGE, DRIVERS AND THEIR IMPACT IN THE SOUTHERN AFAR REGION

7.1 Introduction

Recently, the poor and most vulnerable pastoral communities are faced with the twin impacts of climate-induced shocks and rangeland degradation. Rangeland degradation has become the most serious problem in the twenty-first century, particularly in pastoral communities, as a result of changes in climate and anthropogenic activities (MEA, 2005; Nori & Davies, 2007). Rangeland degradation is essentially another disaster risk for the sustainability of pastoral livelihoods (Abate *et al.*, 2010). Persistent decrease of rangeland ecosystem goods and services links rangeland deterioration to loss of well-being (MEA, 2005). Shifts of rangelands to other land-use/land-cover types have been observed in pastoral communities, mainly linked to changes in climate and variability, human population growth and establishment of new invasive species (Homewood, 2004; Sala *et al.,* 2000; Vetter, 2005).

Most studies concerning with land-use/land-cover changes and its drivers were conducted in highland areas of Ethiopia, which covers nearly 40% of the total area of the country (Dessie & Kleman, 2007; Tefera, 2011) while in arid and semi-arid areas of the country limited information are available about the trends of land-use/land-cover changes and its drivers where land-use/land-cover change is believed to be a rapid process (Hurni *et al.,* 2005). Pastoralists in the Afar region depend mostly on livestock and livestock products where feed resources of livestock are mostly limited by land-use/land-cover changes (Keeley *et al*., 2014). Recently, the Afar people have also experienced recurrent droughts, population pressure, expansion from neighbouring cultivators and pastoralists (such as the Issa Somali) and invasive plants (Rede, 2014). Hence, assessing and monitoring land-use/land-cover trends and its drivers in arid and semi-arid rangelands of the Afar region are vital to understand its influence on rangeland resources and the livelihood of pastoralists. However, there is scant information concerning the land-use and land-cover changes, drivers and its impacts on Afar pastoralists. Thus, in addition to understanding the resilience of pastoralists to climate-induced shocks such as droughts and floods, the present study was also conducted to address the trends of land-use/land-cover changes, drivers, and impacts in Southern Afar pastoralists. The results of this study about land-use/land-cover trends, drivers and its impacts on pastoral communities of Southern Afar region are discussed in the following sub-topics.

7.2 Land-Use and-Land-Cover Classification

Table 7.1 and the thematic map in Figure 7.1 show the five land-cover types in the Southern Afar region. These land-cover types are shrub and bushland, cultivated land, grassland, water bodies and bare land.

Table 7.1 Land-use and land-cover types and changes in the Southern Afar region (1985–2015)

Cover type	1985		1995		2015	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Shrub and bushland	216 212.16	17.66%	347 892.03	28.40%	463 318.42	38.00%
Cultivated land	31 065.99	2.54%	27 849.49	2.27%	23 531.61	2.00%
Grassland	216 953.39	17.70%	96 306.96	7.87%	77 081.48	6.00%
Water bodies	1 553.75	0.13%	5 657.08	0.46%	2 445.35	0.20%
Bare land	758 535.09	61.96%	746 620.11	60.98%	657 953.64	54.00%
Total	1 224 320.38	100.00%	1 224 325.67	100.00%	1 224 330.50	100%

Source: Own computation from image analysis (2016).

In all three assessment periods, bare land was the dominant land cover, constituting more than 50% of the area followed by shrub and bushland (Table 7.1). The classification result revealed that shrub and bushland increased progressively from 17.66% in 1985 to 38% in 2015, with a total increase of 247 106.26 ha. It doubled its coverage in 30 years (Table 7.1). The bushes and shrubs expanded at the expense of grassland and cultivated land. However, the diminishing of grassland, cultivated land, bare land and the expansion of bush and shrub cover was clearly visible in the statistical analysis of the cover over the past 30 years. Grassland showed a dramatic decrease from 17.7% to 6%, cultivated land from 2.54% to 2% and bare land from 61.96% to 54% over the past 30 years (Table 7.1).

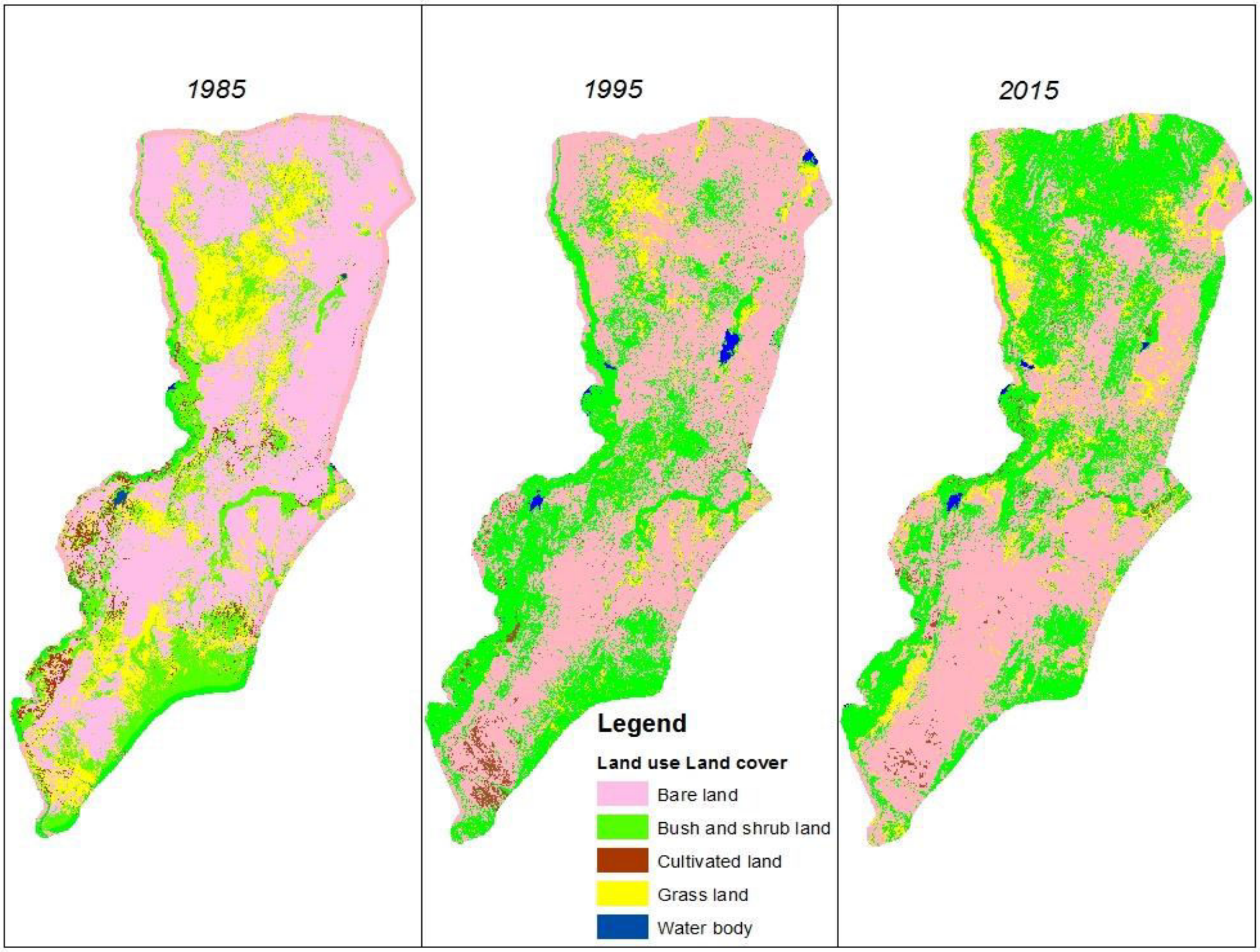


Figure 7.1 Land-use/land-cover map for the Southern Afar region for the period 1985–2015

7.3 Accuracy Assessment

Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Landsat image was geo-referenced using ground control points. Thematic Mapper Landsat images were geo-referenced using computer digitisation (digitised signatures from the image of the time). In this study, the overall accuracies achieved were 95.2%, 92.9% and 98.3% for the 1985, 1995 and 2015 images, respectively, while the kappa coefficients were 0.91, 0.87 and 0.97 for the 1985, 1995 and 2015 images, respectively.

7.4 The Magnitude and Rates of Land-use/Land-cover Changes

Analysis of the land-use/land-cover changes showed the dramatic increase of bushes and shrubs by 60.9%, 33.2%, and 114.3% at yearly rates of 6.1%, 1.7%, and 3.8% during the period 1985–1995, 1995–2015 and 1985–2015, respectively (Table 7.2). The shrub and bushland cover was largely dominated by the alien invasive species called *P. juliflora*, locally called *Dergi hara/Woyane zaf*, which is one of the globe's 100 least desirable species (Invasive Species Specialist Group [ISSG], 2004). The expansion of shrub and bushland cover was large in the period 1985–1995, compared to 1995–2015, though both time periods showed increased expansion of shrub and bushland cover. The question here is: Why did the rate of increase in shrub and bushland cover decreased in the period 1995–2015 compared to the earlier period of 1985–2015? The reduction in the rate of increase for shrub and bushland during 1995–2015 was associated with the Farm Africa project intervention, an NGO who worked in the Afar region of Ethiopia from 2001–2013 with an overall objective of controlling the spread of *P. juliflora* in the region. The Farm Africa project focused on collecting and grinding of the pods of *P. juliflora* to stop its spreading in the region by preparing it as a livestock feed source and selling to customers. Although the Farm Africa project terminated in 2013, the project at least minimised the spread of *P. juliflora* and recovered the rangeland to some extent from *P. juliflora* invasions during the period of the project. Therefore, a small rate of reduction of grassland cover (–20%) during the period 1995–2015 as compared to the rate of reduction in 1985–1995 (–55.6%) and a small rate of increment of shrub and bushland cover (33.2%) (Table 7.2) during the same period, was mostly associated with the efforts of the Farm Africa project to control the spread of *P. juliflora* in the study area.

Table 7.2 Magnitude and rates of land-use/land-cover changes in the Southern Afar region

Cover type	Area cover (ha)			Cover change between periods (%)[a]			Rate per annum (%)		
	1985	1995	2015	85–95	95–15	85–15	85–95	95–15	85–15
Shrub and bushland	216 212.16	347 892.03	463 318.42	60.9	33.2	114.3	6.1	1.7	3.8
Cultivated land	31 065.99	27 849.49	23 531.61	–10.4	–15.5	–24.3	-1.0	-0.8	–0.8
Grassland	216 953.39	96 306.96	77 081.48	–55.6	–20.0	–64.5	-5.6	–1.0	2.1
Water body	1 553.75	5 657.08	2 445.35	264.1	–56.8	57.4	26.4	–2.8	1.9
Bare land	758 535.09	746, 620.11	657 953.64	–1.6	–11.9	–13.3	–0.2	–0.6	–0.4

a-The formula employed to calculate the land-use/land-cover change was 100×(A final year–A initial year)/(A initial year) where, A refers to the land-use/land-cover type area

Overall, the shrub and bushland cover with an intensification of P. juliflora expanded by 114.3% from 1985–2015 (Table 7.2) at the expense of grasslands and cultivated lands in the Southern Afar region. On the other hand, the grassland covers dramatically decreased by 64.5%, while the cultivated land declined by 24.3% during the period 1985–2015 (Table 7.2), which was mainly associated with P. juliflora invasion and prolonged and recurrent drought in the region. According to the key informants, due to high costs to remove P. juliflora, most investors left their farmlands, especially from the Gewane district. Similar findings in pastoralist areas of Kenya were reported by Mwangi and Swallow (2005) indicating that P. juliflora was aggressively invading pastoral areas in Kenya and caused a decline of palatable grasses and browses of a rangeland, declined farmlands and associated opportunities for cultivation. Similar findings were reported by Dubale (2008), PENHA (2015) and Wakie et al. (2014), indicating that P. juliflora invasion was threatening pastoralists by encroaching their grazing areas and farmlands. From the field survey, it was observed that the government had worked on sedentarisation of pastoralists and allocating of the farmlands left by investors to pastoralists for crop farming. Hence, the number of pastoralists involved in crop farming was increasing, although P. juliflora, along with frequent and prolonged drought, would be the major challenge for the pastoral community in the Southern Afar region to practice crop farming as their livelihood strategy. Furthermore, even though cultivated land cover declined for this specific study area, the overall trend of cultivated land cover in the Afar region showed an increasing trend (Tsegaye *et al.,* 2010).

The results further indicated that the bare land cover reduced by 13.3% over the past 30 years (Table 7.2). This was mostly associated with the expansion of shrub and bushland with an intensification of *P. juliflora*. The informants stated that the major reason for the reduction of the bare land cover was associated with *P. juliflora* invasions and the enclosure of the bare land by the investors. During the field survey, it was observed that large areas of bare lands and grazing areas were enclosed by investors without any services to the investors as well as to the community, and the local people did not know for what purpose the area was enclosed. From an ecological point of view, area enclosure contributed towards restoration of the bare lands to vegetative land-cover types. The thematic map (Figure 7.1) showed that since 1995, most bare lands were covered by bush and shrub vegetation which were dominated by *P. juliflora*. Hence, *P. juliflora* contributed to afforestation of bare lands and provided other services such as construction poles, fencing poles, fuelwood and charcoal, although its cost outweighed its benefits in the Southern Afar region. The analysis is supported by Pasiecznik (1999); and Pasiecznik *et al.* (2001) who reported that *P. juliflora* was significant in the rehabilitation of arid lands, and its ability of growing under the poor soil conditions of arid lands has made *P. juliflora* especially appropriate for this purpose. The results further indicated that although the water body coverage increased twofold during 1985–1995, it was declined by 56.8% during 1995—2015 (Table 7.2). This was associated with recurrent and prolonged drought in the region. According to the key informants, many water sources, including hand-dug and shallow wells, dried up over the past 10 years due to frequent and prolonged drought.

On the other hand, the transition matrix in Table 7.3 indicated that shrub and bushland in the landscape was mainly converted into bare lands, though, at the same time, the bare land was mainly converted to shrub and bushland. Cultivated land was mainly converted into shrub and bushland while it gained mostly from bare land (Table 7.3). Grassland mainly converted into shrub and bushland and bare land while it gained mostly from bare land followed by shrub and bushland. The greatest net increase was for shrub and bushland mainly gained from grassland and bare land (Table 7.3).

Table 7.3 Transition matrix of 1985–2015 showing changes in land-use/land-cover (%) in the Southern Afar region

		2015							
	Land-cover type	Shrub and bushland	Cultivated land	Grassland	Water-body	Bare land		Total	Loss
1985	Bush &shrub land	**9.6**	0.33	1.4	0.1	6.30		17.66	8.11
1985	Cultivated land	1.8	**0.03**	0.1	0.01	0.59		2.54	2.50
1985	Grassland	8.2	0.17	**0.83**	0.01	8.49		17.77	16.89
1985	Water body	0.01	0.0001	0.01	**0.1**	----		0.13	0.02
1985	Bare land	18.3	1.39	3.9	0.02	**38.4**		61.9	23.59
	Summary						**48.9**[a]		
	Total	38	1.91	6.3	0.2	53.8			
	Gain	28.3	1.9	5.5	0.09	15.4			
	Net change[b]	20.2	-0.63	-11.4	0.07	-8.2			
	Net persistence (Np)[c]	2.1	-18.04	-13.7	0.66	0.2			

Shaded diagonal figures stand for the amount of each land-use and land-cover class that were unchanged between 1983 and 2015. The loss column and gain row shows the amount of the landscape that has undergone a gross loss and gain in each class, respectively.

All the figures in the table are shown in percentage, except net persistence, that is a ratio.

a refers to the sum of the shaded diagonal figures and indicates the total landscape which did not change, called persistent.

b Net change = gain loss.

c Np denotes the net change to persistence ratio (i.e., net change/diagonals of each class).

The results further indicated that cultivated land and grassland experienced the least persistence, while shrub and bushland was the greatest persistent land-cover type. Persistence is showed in Table 7.3 as shaded diagonal figures for each land-use/land-cover type. The net land-use/land-cover change to persistence ratio was large for cultivated land and grassland which showed negative trends in shrub and bushland, which showed positive trends, and all showed the greatest leading trends in the altering landscape. Overall, 48.9% of the total rangeland continued unchanged (Table 7.3).

7.5 Drivers of Land-use/Land-cover Change and its Impact on Livelihood of Pastoralists

In this study, four drivers which had a significant influence on land-use/land-cover changes of the Southern Afar region were identified during focus group discussions and household interviews. Rating scales were assigned for the drivers to be ranked by the respondents. The four drivers identified in this study area were (i) an invasion of *P. juliflora*, (ii) climate variability and change, (iii) government intervention and (iv) population growth (Table 7.4). Rank-based Friedman's non-parametric analysis was carried out because of the correlated sample nature of the household survey and interviewing data. The Friedman's test statistic indicated that the null hypothesis (the distribution of *P. juliflora* invasion, climate variability and change, government intervention and population growth are the same) is rejected, indicating that the drivers had a different influence on land-use/land-cover changes in the Southern Afar region.

Table 7.4 Respondents' ranking of the drivers of land-use/land-cover changes in the Southern Afar region

Ranking[a]	*P. juliflora* invasion	Climate change and variability	Government intervention	Population growth
1	0	0	0	43.6
2	0	0	0	56.4
3	4.4	11.6	84.4	0
4	95.6	88.4	15.6	0
Total responses	100.0	100.0	100.0	100.0

[a]*Rankings: (1) less influential driver, (2) = medium influential driver, (3) = influential driver and (4) =very influential driver*

7.5.1 Invasion of Prosopis juliflora

P. juliflora was introduced into the Southern Afar rangeland during the 1970s as a drought-resistant soil conservation mechanism (PENHA, 2015). During this period, the pastoral households were informed about the dual purpose uses of the plant, including as source of livestock feed, fuel wood, and restoration of the bare lands. Expecting the advantages, the pastoral communities were disposed and, hence, *P. juliflora* was established throughout the Southern Afar region by campaigns like the Food for Work Programme until 1988 (Sertse & Pasiecznik, 2005). Pastoralists' perceptions changed later when *P. juliflora* became a major reason for rangeland degradation curtailing livestock mobility, and problems associated with its sharp thorns became more pronounced**.** Although *P. juliflora* played an important role in the afforestation of the arid areas of the Southern Afar region, as well as providing fuelwood and furnishing construction materials, local communities in Afar felt unhappy about its negative impacts. According to local respondents' ranking, the major cause of land cover change in the Southern Afar region was *P. juliflora*, locally called *Dergi hara or Woyane zaf* (Table 7.4). About 95.6% (N=250) of the respondents ranked *P. juliflora* as the most influential driver of land-use/land-cover (Table 7.4). Other foreign plants that have toxic effects on livestock include *Cryptosgegia grandiflora,* locally called *Halimero*-forbs (herbaceous flowering plant) and *Wolhawula* (undesired plant) – unpalatable grass species which invade and compete with palatable grass species.

According to respondents, rangeland, the main component of pastoralist's livelihood, is currently becoming increasingly fragmented and lost partly due to an aggressive spreading of *P.juliflora*. Formerly, the main driver of rangeland productivity was rainfall. During a good rainy season after the drought, the rangeland resources such as grass and water rehabilitate and allow the pastoralists to accumulate more livestock. However, this boom and bust cycle had been broken up due to rangeland encroachment by *P. juliflora* which is a highly drought resistant shrub that spreads in large areas of rangeland during both the drought season and when the rain falls. The palatable grasses such as *Cenchrus ciliaris*, *Chrysopogon plumulous* and *Setaria acromelaena* and browses such as *Acacia tortilis*, *Acacia Senegal* and *Acacia nilotica* did not recruit. This study corroborates the findings of Kahi (2003) who reported that understory plant biomass was five times lower under the *P. juliflora* canopy and plant cover were also lower under *P. juliflora* than in the open areas. Similarly, the *Sudan Update* (1997) reported that *P. juliflora* depressed the development and persistence of indigenous vegetation around it. Consequently, *P. juliflora* has caused a massive decline in livestock numbers and productivity in the region due to loss of palatable indigenous grass and browse plants. A similar finding was reported by Pasiecznik (1999) who indicated that when *P. juliflora* grows on grazing lands, it decreases grass cover and thereby impacts livestock production. In response to the loss of grazing areas, some pastoralists with sufficient labour forces or those who can afford to pay for labour to clear *P. juliflora*, engaged themselves in crop farming as an alternative livelihood. However, for a majority of pastoralists, aggressive invasion of *P. juliflora* puts a significant threat to their farming activities. Consequently, they engaged themselves in another resource degradable and unsustainable livelihood options such as selling of firewood and charcoal. Overall, *P. juliflora* increased significantly the vulnerability of Southern Afar pastoralists to food insecurity and hunger. People in the study area were highly food insecure and dependent on food aid for their survival due to loss of grazing and farmlands associated with a prolific expansion of *P. juliflora*.

Source: Author's own field work (2016).

Figure 7.2 Prosopis juliflora

The informants further noted that *P. juliflora* had not only a direct impact on the availability of grazing pastures and farmlands, but it also had a direct negative impact on livestock health. When livestock fed on *P. juliflora* pods for an extended period of time due to prolonged droughts and lack of pasture in the invaded areas, it resulted in health problems such as constipation, disfiguration of jaws, breakdown of teeth, and loss of body condition, reduced overall productivity and death of the animal. A similar problem of livestock health associated with *P. juliflora* was reported by Mwangi and Swallow (2005) as well as Tabosa *et al.,* (2006). The respondents also complained about the negative impacts of *P. juliflora* on infrastructure, human health and predator attacks. The footpath and roads were blocked by thickets of *P. juliflora* and both human and livestock were forced to travel longer walking times to reach the desired destination. Thickets of *P. juliflora* also restricted livestock mobility in search of feed and water. Similar problems were also reported in Kenya and India (Geevan *et al.,* 2003; Mwangi & Swallow, 2005). The dense standing of *P. juliflora* provided a suitable environment for mosquito multiplication and resulted in a high incidence of malaria in the study area. Informants also complained that humans and livestock suffered from injuries as a result of pricking with the sharp, strong and poisonous thorns of the *P. juliflora*.

An elderly man in the Amibara district complained as follows:

> *Prosopis is a great disaster for Afar pastoralist as it caused loss of wet and dry season grazing land and cropland. We couldn't get the indigenous palatable grass species in areas where Prosopis grew and even the indigenous trees were also dominated by this invasive species. Lack of pasture in the invaded area forced livestock to feed on Prosopis pods for extended periods and resulted in health problems. People and livestock also suffered from sharp and poisonous Prosopis thorns* (Interview conducted on 22 February 2016).

There was a case of two men losing their eyes in the Gewane district following *P. juliflora* thorns pricking their eyes. Due to more hiding places in the dense standing of *P. juliflora*, predators such as hyena and jackal could easily attack livestock. Crop damage by wild herbivores such as warthog and bush pigs were also the most common problems reported by the respondents in the study areas. Furthermore, local respondents also complained that *P. juliflora* had eroded their reciprocity, an important aspect of pastoral persistence in the Afar region. According to the Afar customary institution, if a man/woman loses his/her livestock due to drought, diseases or other reasons, the risk will be divided among clan members and then supply them with breeding stock to start their original activity (pastoralism). However, risk sharing through reciprocity among clan members or community members was not possible anymore as all individuals lost livestock associated with the greater loss of grazing areas by the aggressively invading *P. juliflora*. Therefore, *P. juliflora* was the main driver of land-use/land-cover change in the Southern Afar regions hindering the ecosystem services to pastoralists, and negatively affecting human and livestock health and livelihood security.

7.5.2 Government interventions

According to the key informants, before the 1960s the intervention of the state to change rangelands to crop farming was limited. The informants said that they had two grazing areas: one was the dry season grazing area along the Awash River basin and the second was the wet season grazing areas. Based on customary principles, each clan managed the rangeland resources collectively in such a way that during normal rainfall seasons the clan members were informed not to use the reserved grazing areas (dry season grazing area). The reserved pasture areas were utilised after the wet season grazing areas had been exhaustively used. This was the main strategy of pastoralists in the study areas to cope with climate variability for centuries. However, the informants indicated that after 1960, especially during the 1970s, the dry season grazing areas had been allocated for state and private commercial farming and this was increasingly expanded up to the 1980s. Consequently, the mobility of pastoralists had been highly restricted, which increased their vulnerability to climate change and variability. This study corroborates the findings reported by Ali (2008), Beyene (2006), Hundle (2008) and Tsegaye *et al.* (2010) who indicated the subverting of Afar rangelands to crop farming. Similar studies showed that in the various pastoral regions of Ethiopia, expansion of crop farming from highlanders into the rangelands of pastoral communities and deforestation have drastically altered the land-use/land-cover types and has restricted pastoralist's mobility and contributed to food insecurity (Mehari, 2015; Tesfaw, 2001; Tsegaye, 1999).

Personal observation and discussion with district experts also showed that the current and past governments also established wildlife reserves in the study area such as the Awash National Park, Aledeghi Wildlife Reserve and Yangudi Rassa National Park and Mille Serdo Wildlife Reserve to increase the income of the country from the tourism sector at the expense of pastoralism. The three protected areas were established by the current government, while the Awash National Park was established during the Derg Regime in 1969. Similar studies indicated that once the protected areas are established, the pastoral communities have no access to forage and water from these protected areas throughout the year, even during the drought season when feed scarcity is serious. Moreover, the pastoralists who were the informal possessors did not get any share or advantage from the established protected areas (Abate *et al.*, 2010). Since this time, conflict and distrust between pastoralists and the government raised and throughout the 1980s and 1990s, pastoralists placed great pressure on the administration of state and investor farms by destroying mature crops in the field.

After 1990, the intervention by the government towards an expansion of commercial farms declined, while subverting of pastoralism to sedentary agriculture was the government's main agenda with the long-term objective of involving pastoralists to increase the income tax of the country. In 1991, ethnic-based federalism was introduced in Ethiopia and the Afar regional state became one of the nine regions in the country. Most state farmlands returned to pastoralists although some state and investor large-scale farming still exist in the Southern Afar region, especially in the Amibara district. According to the key informants, government authorities argued that pastoralism is no longer viable given the ecological problems, livestock mortality and population growth. Similar results were stated by Abdulahi (2003) and Getachew (2001) who reported that during the past, as well as in present state of Ethiopia, pastoralism was considered as an environmentally non-friendly livelihood strategy. Since 1991, the government has continued with the settlement of pastoralists by encouraging crop farming through the introduction of irrigation materials, farm machinery, and improved crop varieties. However, the support of the government terminated within a short time. Due to limitations regarding knowledge and physical resources for crop production, most pastoralists leased out their farmlands to investors through sharecropping. According to local respondents, the sharecropping was arranged in such a way that stakeholders pay 50% of their yearly benefit to pastoralists as rent. Since 2012, most investors left the farms, especially from the Gewane district, and moved to the Gambella regional state (one of the nine ethnic divisions of Ethiopia located in the western tip of the country) due to an expensive sharecropping arrangement in the Afar region and the high cost incurred to remove *P. juliflora* from their farmland. As a result, pastoralist's farmlands have been out of production since then and have recently been covered with *P.juliflora*. Overall, forced government intervention to change the Southern Afar rangelands into private and state-owned commercial farms and attempts to involve pastoralists into the national economy through a resettlement programme resulted in declining of the rangeland ecosystem goods and services and caused most pastoralists to be dependent on food aid throughout the year. For example, secondary data collected from the district pastoral development office indicated that in the Amibara district, out of the total of 15 360 households, 10 300 households (67%) sustain their lives through the safety net programme.

According to the informants, the government forced pastoralists to settle for the reason that it would be easier to collect taxes and give them access to public services such as education, potable water supply and health services, although none of them were achieved to the satisfaction of the local community. The informants further indicated that the areas identified for resettlement were not well-studied. Pastoralists were settled along the Awash River basin for the sake of easy access to irrigation crop production, without taking the proneness of the area towards environmental hazards such as flood risks and heat stress into account. According to the Gewane pastoral development office, in May 2016, eight settled pastoralists around the Awash River were killed by the flood, properties were damaged in the Gewane districts and local administrators were trying to resettle them again to highland areas.

A woman in Gewane district complained:

> *We left our green and shaded village and settled in the bare land where there is extreme heat stress and high flood risk area because the government promised us to give better social services such as potable water supply, school, road access and clinic. But the proposed social services had not been implemented* (Interview conducted on 18 March 2016).

Therefore, land-use/land-cover changes and settlement policy by the coercive intervention of the government adversely impacted pastoral livelihood of pastoralists in the Southern Afar region. Furthermore, the government interventions against pastoralism have also resulted in a weakening of the customary institution by replacing them with new young generations who are loyal to government interests. According to the local respondents, younger generations are not interested in sustaining local cultures. They consider traditional institutions and cultures as primitive and are more attracted to urban life. Consequently, most rangeland resources have been degraded; especially woody plants that were cut for charcoal, firewood and constructing of houses. Recently, no woody plants can be found in the Southern Afar region and the region had been encroached by bushes and shrubs since the government was not as efficient as that of the customary institution in protecting deforestation of woody plants.

An elder man in Amibara district said:

> *Formerly the rangeland resources were administered by Fimia [a rule-enforcing authority in the Afar traditional administration] and no one cut tree, no one can graze the rangeland during inappropriate times and if someone violets Fimia, his breeding female camel [the most cherished animal in Afar] will be slaughtered as punishment. Currently, the Fimia is replaced by formal laws (modern courts) and anyone can graze the rangeland at any time and cut trees* (Interview conducted on 22 February 2016).

Therefore, coercive government interventions in the Southern Afar regions brought significant land-use/land-cover change through expansion of the state and investor commercial farming and settlement of pastoralists with a consequence of restricting mobility of pastoralists, enhancing rangeland grabbing by other stockholders and degradation of rangeland resources such as overutilisation of indigenous trees and inappropriate pasture grazing due to weakening of customary institutions.

7.5.3 Climate change and variability

The perception of local communities about change in climate and climate variability in the Afar region indicated that the climate is changing, the temperature is increasing and drought was more severe than in the past as its occurrence was more prolonged and frequent. In the Southern Afar region, pastoralists reported experiencing difficulty in determining the onset of rainfall using local or indigenous knowledge as compared to 10–20 years ago when they used to receive good *Sugum* (spring) and *Karma* (summer) rainfall. However, recently the *Sugum* rainfall has disappeared and *Karma* rainfall came late and stopped earlier. As discussed in section 5.2, long-term trends of temperature and rainfall were analysed from 1983–2014 to confirm the perception of respondents. The perception of local communities was in line with the statistical analysis of 32 years rainfall and temperature data. The analysis done for this study showed the occurrence of more prolonged and frequent droughts, uneven distribution of rainfall, delayed start and early termination dates of rainfall, a decreasing trend of long-term rainfall and a significant increasing trend of monthly, seasonal and annual temperature in the Southern Afar region.

Respondents' ranking of the perceived drivers of land-use/land-cover change indicated that climate change and variability was ranked as the influential driver next to *P. juliflora* invasion. The majority of the respondents (88.4%) (N=250) ranked it as influential, while 11.6% of the respondents rated it as a very influential driver of land-use/land-cover change in the study area (Table 7.4). The respondents complained that prolonged and recurrent drought caused suppression of palatable grasses and expansion of bushes in the rangeland. The long-term rainfall data analysis indicated that, following the 1984 severe drought in the country, drought cycles have decreased in the Afar region. However, the bush encroachment has increased by 60% from 1985–1995 following the 1984 severe drought, while grassland cover decreased by 55.6% during the same period, indicating the suppression of grassland cover and stimulation of bush and shrub cover expansion following prolonged and recurrent droughts in the Southern Afar region.

Informants noted that recurrent drought caused massive loss of livestock associated with feed scarcity, disease prevalence and water scarcity. Consequently, pastoralists were forced to look for an alternative livelihood income and diversification, such as pursuing irrigation crop farming and shifting of livestock from cattle and sheep to goat- and camel-rearing as camels and goats can feed on a drought resistant bushes and shrubs. Therefore, drought was one of the significant driving factors of the region's land-use/land-cover change by aggravating the aggressively invasive nature of *P. juliflora* and suppressing the growth of grass species and promoting irrigation crop farming at the expense of the grazing areas. The results of the present study agreed with the results of Tadesse (2001) who indicated that the serious hunger and famine observed in 1973 and 1984 in Ethiopia, which was also responsible for the prevailing land-use/land-cover changes, occurred as a result of the severe drought over that period. The present study is also in agreement with Flintan (2011) and Flintan *et al.* (2011) who revealed that drought was among the major driving factors of rangeland degradation in East Africa. Variations in the intra- and inter-annual rainfall might also be associated with changing the grassland state to shrub and bushlands. Similar studies by Ellis and Swift (1988) indicated that in pastoral communities, vegetation biomass is highly determined by the spatial and temporal variability of rainfall. Other studies conducted in the Sahel region indicated that rangeland fragmentation to irreversible damage was caused by serious drought events (Herrmann *et al.,* 2005). Furthermore, the increasing dry spells in the Afar region were also exacerbated by a significant increasing trend of temperature. The increasing temperature trend in the region might be associated with higher evaporation of soil moisture and made the palatable grasses and browses more water stressed and suppressed. This is supported by Cho *et al.* (2011), Farrar *et al.* (1994) and Gonsalez *et al.* (2012) who reported that although variation of soil moisture in semi-arid and arid regions is considerably determined by rainfall amount, temperature may be also taken as an additional climatic variable in the alteration of soil moisture content since soil can lose water by evaporation, in which temperature contributes a significant role in rainfall, causing land cover change.

In general, climate shocks and stresses in terms of prolonged and recurrent drought, rainfall variability and increasing trend of temperature were identified as a major driver of land-use/land-cover changes in the Southern Afar region with a consequence of reducing feed supply for livestock, rangeland degradation and increasing food insecurity of pastoralists.

7.5.4 Population growth

The human population of the Amibara and Gewane district is indicated in Table 7.5. The results revealed that the population of the Amibara and Gewane district together grew at 43.67% between 1994 and 2007 at a rate of 3.35% annually, while the population grew at 39.28% between 2007 and 2015 at a rate of 4.9% annually. Overall, the population of the study area grew twofold (100%) between 1994 and 2015 at a rate of 4.77% annually (Table 7.5). Since polygamy was a common practice in the Afar region, the rapid growth of the population of the area might be associated with the culture of polygamy. For example, Hayase and Liaw (1997) showed that the culture of polygamy played a great role to the increasing population growth in African countries, such as Ghana, Kenya, Senegal, and Zimbabwe.

Table 7.5 Population growth of the Amibara and Gewane districts: 1994–2015

Variable	Amibara district			*Gewane district*		
	Census year			Census year		
	1994	2007	2015	1994	2007	2015
Population (thousands)	18,136	27,443	36,822	9,782	12,666	19,076
	1994-2007	2007-2015	1994-2015	1994-2007	2007-2015	1994-2015
(Population growth (%)	51.34	34.20	103.03	29.50	50.60	95.01
Annual growth rate (%)	3.90	4.30	4.90	2.30	6.30	4.50

Source: For 1994-2007, CSA, 2007. For 2007-2015, district statistical office

In the present study, even though the population was growing rapidly, the households did not see it as an important influential factor in driving the land-use/land-cover change which was against the findings reported by Gashaw *et al.* (2014) who indicated that population growth was the major driver of land-use/land-cover changes in northwest Ethiopia. Similarly, the findings of the present study did not agree with the previous findings in other parts of the country which reported population pressure as main driving factor of land-use/land-cover changes (Bewket, 2002; Hurni *et al.,* 2005; Kidane *et al.,* 2012). Furthermore, studies in other parts of East African savannah indicated that population growth was among the major driving forces of land use change. However, population growth was found to be the least influential factor in the land-use/land-cover change in the study area.

However, the households ranked population growth as least influential factor in driving the land-use/land-cover change in the study area; however, its contribution for land-use/land-cover change was still important. Secondary data from the district pastoralism development office indicated that during normal seasons of the year, more than 60% of the pastoralists in the study area were dependent on safety net programmes throughout the year, indicating that pastoralism was not enough to feed the growing population. This might be associated with the rapid growth of the population, increasing trend of rangeland resource degradation and declining of livestock assets. In order to support the rising population, people shifted to non-pastoral activities such as selling of firewood, charcoal and expansion of cultivation, which put severe pressure on the existing rangeland resources and brought substantial land-use/land cover changes.

7.6 Summary

This study identified the land-use/land-cover changes in the Southern Afar region in the period 1985–2015 and the trend showed a substantial loss of grassland and farmland and a dramatic increase of shrub and bushland, cover with an intensification of the alien shrub *P. juliflora*, the dominant invader threatening Afar pastoralists. This study further concluded that although *P. juliflora* was important in the reclamation of bare lands and afforestation of the arid areas of Afar region, its unchecked expansion on the grazing areas and farmlands of pastoralists threatened their livelihoods. Consequently, although the benefits of *P. juliflora* were being far outweighed by its disadvantages, the pastoralists were vigorously pushing the local and regional authorities for its eradication from the region since *P. juliflora* was beyond pastoralist's capacity to eradicate or even to control it.

Furthermore, this study identified the driver of land-use/land-cover changes and their impacts on livelihood and food security of pastoralists and the results showed that coercive government intervention in terms of expansion of commercial farms on dry season grazing areas, forcing pastoralists to practice sedentary crop cultivation and weakening of customary institution, aggressive expansion of *P. juliflora*; climate-related factors such as prolonged and recurrent droughts, intra- and inter-annual rainfall variability and increased temperature and rapid growth of population, were the driving forces of land-use/land-cover changes in the Southern Afar region. Consequently, access to rangeland resources and farmlands for pastoralists was highly restricted putting the pastoral production system under increasing threat.

The present trend may lead to more rangeland degradation and weakening of pastoralist resilience to the increasingly climate variability in the region if control measures will not be taken to restore the rangeland ecology. The study recommends government interventions to establish a policy for controlling *P. juliflora* and keeping the land open for access to grazing and strengthening of the customary institution for effective management of rangeland resources.

Chapter 8
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary of the Research Findings

Climate change and climate extremes are increasingly being identified as a serious challenge to pastoral production systems. The anticipated climate situations are projected to exacerbate some of the prevailing vulnerabilities in pastoral communities, and that was predicted to compel new risks beyond the range of present experiences. A clear understanding of household vulnerability and resilience to climate-related shock is therefore important for developing appropriate resilience interventions in pastoral communities and strengthening existing pastoralists' resilience strategies against the climate-induced shocks and stresses.

This study led to a better understanding of resilience and vulnerability of pastoralists to climate change and variability in a changing rangeland environment in the Southern Afar region. It attempted to determine the trends of climate change and variability in the study area. Accordingly, to achieve this objective, ten-day satellite recorded rainfall, and minimum and maximum temperature time series data were taken from the Ethiopian NMA for the period 1983–2013 for rainfall, and 1983–2014 for temperature. Moreover, the study identified the perception of local people on change in climate and climate variability, the livelihood resource and well-being trends, influences of climate variability and extremes on livelihood of pastoralists. Furthermore, this study also determined resilience and vulnerability of pastoral households and their adaptation and coping mechanisms to climate-induced shocks and stresses. To achieve these objectives, data was collected from 250 randomly selected households using a semi-structured questionnaire with open-ended, multiple-response and dichotomous questions. Household's resilience to climate-induced shock and stresses was determined using the multi-stage modelling approach suggested by Alinovi *et al.* (2010). The approach was depending on the premise that the alternatives accessible to a household to make a living determine the household's resilience at a given point in time. The vulnerability of pastoral households to climate-induced shock was assessed using the integrated vulnerability assessment approach based on social, economic and biophysical indicators of vulnerability. Following the IPCC (2012), the different socio-economic and biophysical indicators had categorised into adaptive capacity, sensitivity and exposure. PCA was employed to assign weights to selected indicators to develop vulnerability indices. Furthermore, attempts have been made to determine the trend of the land-use/land-cover changes, its drivers and impacts on the livelihood of pastoralists using Landsat images, field observations and household interviews.

As indicated in Chapter 1, the first question was designed related to the trends of climate change and variability. Accordingly, the results indicated a significant increasing trend of monthly, seasonal and annual temperatures, including mean, maximum and minimum temperatures, and the significant declining trend of *Sugum* rainfall, which occurred from March to May and the significant increasing trend of *Karma* rainfall, which occurred from June to September. The results further showed the shrinkage of the long rainy season in the Southern Afar region worsening the region's water and pasture availability. The research further indicated the significant increasing trend of temperature in the study areas and agreed with the recent trends of global warming as reported by IPCC (2013). However, the long-term rainfall trend from 1983–2013 indicated a non-significant declining trend. Overall, it can be concluded that there is adequate confirmation to recommend that there have been climate change over the Southern Afar region. Scarcity of water was a fact of life turning the lives of pastoralists in the study area from bad to worse because of the great temporal rainfall variations. It can be said that the rainfall in the region is normal if there is a regular distribution of the rainfall and when the rainfall starts and ends during the normal rainfall seasons. However, the analysis showed an uneven distribution of rainfall, late onset and early cessation dates of rainfall in the study areas. Sometimes the rain stops early, or it falls in higher intensity but for limited months. That is what has made the recorded rainfall intensity stay without significant declining for a long time. The increasing temperature trend in the region, which will result in higher evaporation of water bodies and soil moisture and significant decreasing of *Sugum* rainfall, will have disastrous effects on the seasonal availability of pasture and water for livestock which may impact the resilience of pastoral communities in the Southern Afar region. The prolonged and recurrent droughts and the increasingly changing bimodal rainfall regime have become the number one risk for the Southern Afar region.

The second question dealt with the local people's perception on the region's climate change and variability and its impacts and their adaptation/coping mechanisms as well as livelihood resources and well-being trends. This study showed that the socio-economic characteristics of the Southern Afar region revealed a high illiteracy and dependency ratio, low income and poor asset ownership and poor access to basic services such as access to markets, extension services, credit and EWI. The findings further revealed that the livelihood of the Afar communities heavily depended on natural resources, livestock and mutual support system. Recently, because of the unreliable and erratic nature of rainfall and recurrent droughts in the region, pasture and water availability became scarce and livestock assets and productivity became highly reduced. Consequently, the income and asset ownership of households was declining and market price of livestock was decreasing, while the price of food grains has been increasing in the local market, resulting to mounting of poverty and food insecurity in the region. Due to deepening of poverty and food insecurity in the region at household and community level, the informal safety net/mutual support system was eroded and individualism was increasing instead. In response to the adverse influence of climate shocks and stresses, the local people pursued different adaptation and coping strategies. The most important strategies deployed by the local people included mixed livestock–crop production, mobility, changing herd species composition and herd splitting, reduced consumption, remittance, cash-for-work, charcoal burning, firewood selling and food aid. The indigenous early warning system and mutual support among the extended families, neighbours and community were still significant in building the resilience of the community, though the indigenous early warning system was not integrated into the formal early warning system and the informal safety nets have been becoming eroded and replaced by formal safety net programmes. The results further revealed that although the local people employed different strategies to adapt and cope with the adverse influence of climate-induced shocks and stresses, there were constraints that limited the existing opportunities of a household's long- and short-term strategies. For example, lack of credit facilities, limited access to formal EWI, lack of access to farm inputs and equipment and limited technical skills and illiteracy were the constraints reported by the local people during the study period.

As shown in Chapter 1, the third question deals with the resilience status of pastoralists to climate change and variability. Accordingly, the resilience of households to climate variability and change was determined by clustering households into livelihood groups (pastoralists versus agro-pastoralists), districts and gender (MHH versus FHH). The results indicate that Gewane was more resilient than the Amibara district. This can be explained by duration and intensity of drought occurred over the last two years. In the Amibara district, there was severe and prolonged drought for the last two years while Gewane received rainfall showers in between, although households in Gewane were also hit by the drought for a year. Hence, those households lived in drought prone areas. Amibara was less endowed in IFA, A, AC, APS and S and, hence, less resilient. The findings also showed that pastoralists were less resilient than agro-pastoralists. This was largely due to low level of adaptive capacity and assets owned by pastoralists. The main consequences of recurrent droughts were declining of livestock assets and productivity, with increasing food prices. Hence, pastoralists who bought but did not produce food were less resilient to climate-related shocks as they remained anchored to pastoralism, while agro-pastoralists who started both herding and crop farming were less impacted by the increasing food price during droughts as they had their own food stock and, hence, were more resilient to climate-induced shock. Furthermore, most agro-pastoralists had settled in one area, were relatively stable and had better access to education, health and other public services than pastoralists. Therefore, households with a higher number of income sources and who had better access to public services were better off in terms of resilience. On the other hand, recurrent droughts negatively impacted pastoralist's terms of trade as they had poor access to markets and inadequate transport infrastructures. Pastoral households had travelled long distances to sell their livestock and buy food grains for own consumption. However, livestock reached the market centre with poor body conditions due to sacristy of feed and long distance travelling. Hence, pastoralists did not have bargaining power and forced to sell their livestock at a low price, while the price of food grains had been increased. Therefore, recurrent droughts negatively affected the price of outputs and inputs of the pastoral people, resulting in the weakening of their resilience to climate-induced shock. The results also revealed that FHH were less resilient than MHH due to their low level of adaptive capacity and poor access to assets, public services, food and income access. Therefore, this study clearly answered which groups of households, sectors and districts were less resilient and why. This has significant implications for policymakers for better interventions in pastoralist areas of the Southern Afar region. Furthermore, a multiple linear regression analysis was employed to identify the determinant factors that caused variations among the resilience of households in the study areas. Accordingly, (i) irrigation crop farming, (ii) livestock ownership, (iii) education level, (iv) *per capita* income, (v) mobility and herd splitting, (vi) herd composition change, (vii) labour, (viii) remittance, (ix) food aid, (x) access to credit, (xi) access to market, and (xii) access to formal EWI were found to be significantly correlated in explaining the variations among the household's resilience to climate change and variability.

As explained in Chapter 1, the fourth question deal with the vulnerability of pastoral households to climate change and variability. Understanding of vulnerability of households to climate change and variability is indispensable for decision makers to establish adaptation strategies for long-term resilience of pastoral households. This study identified which category of households, sectors and places were more vulnerable and which groups of households were not vulnerable, but have a great likelihood of becoming vulnerable in the future. Hence, this would enable decision makers which group of households, sectors and places should be given priority in their development intervention. Accordingly, the results revealed that 28.8% of the pastoral households were highly vulnerable and these groups of households would need intensive care and follow-up to disengage them from this situation. Most of the households (53.6%) were moderately vulnerable, suggesting that in the case of climate-induced shock they would need some support to recover. Only 17.6% of the households were capable to cope even though there would be a high probability to move from less vulnerable to a moderate or high vulnerability level in the future if no appropriate adaptive measures would be taken by decision makers. In this study, it is observed that the most important factors that determined the vulnerability of the households were: (i) gender, (ii) age, (iii) marital status of the household, (iv) household size, (v) education level, (vi) extension services, (vii) farming experience, (viii) livestock asset, (ix) irrigation farming, (x) non-farm income, (xi) livestock mobility, (xii) radio ownership, (xiii) access to formal EWI, (xiv) distance to market and (xv) access to veterinary clinic, (xvi) access to credit and (xvii) agricultural inputs, (xviii) the number of sick members, (xix) the number of months with food shortage during the normal season of the year, and (xx) number of dependants in the household.

The fifth question of this study dealt with the trends of land-use/land-cover changes, its drives and impacts on the livelihood of Southern Afar pastoralists. Accordingly, this study identified the land-use/land-cover changes in the Southern Afar region in the period 1985−2015 and the trend showed a substantial loss of grassland and farmlands and a dramatic increase of shrub and bushland covers, with an intensification of the alien shrub *P. juliflora*, the dominant invader threatening Afar pastoralists. This study further identified that although *P.juliflora* was important in reclamation of bare land and afforestation of the arid areas of the Afar region, its unchecked expansion on the grazing areas and farmlands of pastoralists threatened their livelihoods. Consequently, the benefits of *P. juliflora* were being far outweighed by its disadvantages, and the pastoralists were vigorously pushing the local and regional authorities for its eradication from the region since *P. juliflora* was beyond pastoralist's capacity to eradicate or even to control. Furthermore, this study identified the drivers of land-use/land-cover changes and their impacts on livelihood and food security of pastoralists. The results showed that coercive government intervention in terms of expansion of commercial farms on the dry season grazing areas, forcing pastoralists to practice sedentary crop cultivation and weakening of customary institution; aggressively expansion of *P. juliflora*; climate-related factors such as prolonged and recurrent droughts, intra- and inter-annual rainfall variability and increased temperature and rapid growth of population, were the driving forces of land-use/land-cover changes in the Southern Afar region. Consequently, access to rangeland resources and farmlands for pastoralists was highly restricted, putting the pastoral production system under increasing threat.

8.2 Conclusion and Recommendations

In the Southern Afar region, climate variability is increasing and becomes a great risk for the sustainability of pastoralism which is the major livelihood strategy for pastoral communities in this region. Therefore, the policymakers should develop an adaptation strategy to the increasingly becoming climate variability; the government and NGOs should develop workable strategies to anticipate and reduce the impacts associated with climate-induced hazards such as droughts and floods. The natural resource base, traditional resource management and utilisation, indigenous early warning system and informal safety nets in the community were the most important components of the local people's resilience. This suggested the need to strengthen the natural resource base of the community, train and enhance the traditional resource management and utilisation of the people to empower the informal institutions. Moreover, the indigenous early warning of the local people should be integrated to formal early warning and intervention strategies for effective preparedness and prevention against disasters. On the other hand, the present land-use/land-cover trend may lead to more rangeland degradation and weakening of pastoralist resilience to the increasingly becoming climate change and variability in the region if control measures would not be taken to restore rangeland ecology. Hence, the government should develop a policy for controlling

P. juliflora and keeping the rangeland open for grazing and strengthening of the customary institution for effective management of rangeland resources.

The results indicated that having more numbers of livestock enhanced the resilience of pastoral communities. This indicated the need to increase livestock assets and productivity by improving the availability of pasture and water to animals and improving animal health care. Policy and strategies should be developed for the provision and management of communal rangelands and water points to provide resources needed by pastoralists and boost the livestock assets and productivity in the area. This study also indicated that those households who practiced irrigation farming were more resilient than those households solely dependent on livestock production. Therefore, the government should enhance household's capacity in terms of finance through provision of affordable credit access, and provide training to enhance their technical skills on crop farming. To enhance the contribution of irrigation crop farming to increasing household resilient, households should be provided with improved agricultural technologies such as a water pump for irrigation, and improved seed varieties with short growing periods and resistant to diseases. It was also observed that mobility was the key strategy for households to cope with droughts. Hence, it is crucial to avoid risks associated with mobility such as avoiding conflicts with neighbouring ethnic groups and enhancing peace among them. Dry season grazing areas which were allocated to investors for commercial farming should be free to pastoralists to make pastoralism a viable way of life and sustainable livelihood strategy in the Southern Afar region.

In the Southern Afar region, it was identified that lack of access to nearby markets adversely affected the resilience of pastoral households. Therefore, interventions should be introduced to improve access to markets if pastoralists need to be more resilient. Pastoralists can get the best value for their products and become more resilient if the government improves market access and develops marketing opportunities for pastoral households through establishment of the nearby market centres, road access, provision of water access along stock routes and providing security along market routes. The present study also showed that lack of access to formal EWI adversely affected resilience of pastoralists in the Southern Afar region. Therefore, early warning and early response (interventions) should be regarded as of great concern by government and should be included in the pastoral development policy for enhancing resilience of pastoralists to climate-related disasters. The formal early warning system should be improved so that pastoral households could get information about the future climate related shocks and stresses to take measures and minimize the disaster risk as early as possible. This ought to be supported by legitimate climate forecast and quantitative data from meteorological stations. Along these lines, it is imperative to reinforce the meteorological station in the Southern Afar region to give solid and convenient climate data regularly.

Overall, for long-term resilience of pastoral households in the Afar region, it is better to focus on livestock intervention strategies such as enhancing the ability of pastoral households to de-stock their livestock with a fair price before and during drought season by improving market access and infrastructure, increasing the productivity of livestock through better access to pasture and water and improving veterinary services. On the other hand, water-related interventions are also paramount to enhance the resilience of pastoral households, such as creating and rehabilitating water wells and boreholes and subsidised provision of water pump and fuel for irrigation activities. This would also assist the local people to diversify their livelihood activities into crop farming and develop forages and improve water access for livestock and human consumption. If enhancing the resilience of pastoralists is the ultimate goal, the government and other partner organisations should focus on long-term strategic livelihood interventions than emergency relief interventions by equipping the local people with the capacity to manage and respond to climate-induced shocks in the early stage of the crisis. Furthermore, policies with emphasis on women empowerment such as improving their access to and control over resources through a better institutional set-up, improving irrigation facilities (physical assets) and skills, and expanding the participation of pastoral households on irrigation farming, creating opportunities for non-farm income and access to affordable credits, improving and scaling up extension services, supporting livestock mobility, increasing access to markets, health and veterinary services, are likely to improve resilience of pastoral households.

8.3 Areas for Further Research

Further research is essential to enhance the basis of intervention and develop more evidence to policymakers and improve understanding on climate change and variability, climate extremes, resilience of pastoral households, and improve livelihood of pastoral households in the Afar region. The areas for further research involve, but are not limited to, the following:

i) There is a need to understand the dynamics of pastoralist's resilience to climate-induced shocks and stresses. The present study determined the current status of the resilience of Afar pastoralists to climate-induced shocks based on cross-sectional data. However, due to lack of suitable panel data sets, the present study did not analyse the dynamics of pastoral household resilience to climate variability and change.

ii) There is also a need to differentiate among climate-induced land-use/land-cover changes and other human-made factors in the Afar region.

iii) An in-depth study to understand the basic causes that influence climate of Afar region is also essential.

iv) Further research to understand the driving factors of seasonal and annual variability of rainfall is also paramount.

REFERENCES

A

Abate, T., Ebro, A. and Nigatu, L. 2010. Traditional rangeland resource utilisation practices and pastoralists' perceptions on land degradation in south-east Ethiopia. *Tropical Grasslands*, *44*:202-212.

Abdulahi, M. 2003. December. Pastoral developments strategies and policies in Ethiopia: A Critical analysis and evaluation. *Third National Conference on Pastoralism and Pastoral Development*. Addi Ababa, Ethiopia.

Abdulahi, M. 2004. December. Pastoral developments strategies and policies in Ethiopia: A Critical analysis and evaluation. In: Admassu, Y. (Ed.), *Pastoral Development in Ethiopia.* Addis Ababa, Ethiopia: Pastoralist Forum Ethiopia, pp. 37-72.

Abiyot, B. & Getachew, T. 2006. Regeneration of indigenous woody species in the understorey of exotic tree species plantations in southwestern Ethiopia. *Ethiopian Journal of Biological Sciences*, *5*(1):31-43.

ACCRA (Africa Climate Change Resilience Alliance). 2012. *Climate trends in Ethiopia*: *Summary of ACCRA research in three sites*. Available from http://community.accraconsortium.org/.5a3ed4ef/ACCRA_Policy_Brief_Ethiopia_Climate_Trends.pdf

Adams, W.M. 2006. The future of sustainability: Re-thinking environment and development in the twenty-first century. In *Report of the IUCN renowned thinkers meeting*, 29-31 January 2006. IUCN, The World Conservation Union. Available from http://cmsdata.iucn.org/downloads/iucn_future_of_sustanability.pdf

Adepoju, A.O. & Oyewole, O.O. 2014. Rural livelihood diversification and income inequality in local government area Akinyele, Ibadan, Oyo state, Nigeria. *Journal of Agricultural Sciences*, *59*(2):175-186.

Adger, W.N., Brooks, N., Bentham, G., Agnew, M. & Eriksen, S.H. 2004. *New indicators of vulnerability and adaptive capacity* (Technical Report 7). Norwich: Tyndall Centre for Climate Change Research.

Adger, W.N., Brown, K. & Tompkins, E.L. 2005. The political economy of cross-scale networks in resource co-management. *Ecology and Society*, *10*(2):9. http://www.ecologyandsociety.org/vol10/iss2/art9/

Adger, W.N., Huq, S., Brown, K., Conway, D. & Hulme, M. 2003. Adaptation to climate change in the developing world. *Progress in Development Studies*, *3*(3):179-195.

Agrawal, A. 2010. Local institutions and adaptation to climate change. In: Mearns, R. & Norton, A. (Eds.), *Social dimensions of climate change: Equity and vulnerability in a warming world*. Washington, DC: World Bank Publications, pp. 173-198.

Alinovi, L., D'Errico, M., Mane, E. & Romano, D. 2010. Livelihoods strategies and household resilience to food insecurity: An empirical analysis to Kenya. Paper prepared for the Conference on *Promoting resilience through social protection in sub-Saharan Africa*, Dakar, Senegal, 28-30 June 2010. Available from http://erd.eui.eu/media/BackgroundPapers/Alinovi-Romano-D%27Errico-Mane.pdf

Alinovi, L., Mane, E. and Romano, D. 2008. *Towards the measurement of household resilience to food insecurity: applying a model to Palestinian household data. Deriving food security information from national household budget surveys.* Experiences, Achievement, Challenges. FAO. Rome, pp. 137-52.

Amsalu, A. & Adem, A. 2009. *Assessment of climate change-induced hazards, impacts and responses in the southern lowlands of Ethiopia*. Addis Ababa Forum for Social Studies/Cordaid.

Anderson, S., Morton, J. & Toulmin, C. 2010. Climate change for Agrarian societies in drylands: Implications and future pathways. In: Mearns, R. & Norton, A. (Eds.), *Social dimensions of climate change: Equity and vulnerability in a warming world*. Washington, DC: World Bank Publications, pp. 199-230.

Andreu, J., Pérez, M.A., Ferrer, J., Villalobos, A. & Paredes, J. 2007. Drought management decision support system by means of risk analysis models. In Rossi, G., Vega, T & Bonaccorso, B. (Eds.), *Methods and tools for drought analysis and management.* Netherlands: Springer, pp. 195-216.

ANRS (Afar National Regional State). 2010. *Programme of plan on adaptation of climate change.* Semera, Ethiopia. Available from https://www.academia.edu/18627729/Afar_National_Regional_State_Climate_Change_Adaptation_prog

Anyah, R.O. & Semazzi, F.H. 2007. Variability of East African rainfall based on multiyear RegCM3 simulations. *International Journal of Climatology*, *27*(3):357-371.

ARS (Afar Regional State). 2004. *A strategic plan for the sustainable development, conservation, and management of the woody biomass resources*. Final report. Ethiopia, Addis Ababa. Available from http://www.eap.gov.et/sites/default/files/AFAR_STRAT_PLAN.pdf

Asenso-Okyere, K., Mekonnen, D.A. & Zerfu, E. 2013. Determinants of food security in selected agro-pastoral communities of Somali and Oromia regions, Ethiopia. *Journal of Food Science and Engineering*, *3*(9):453.

Asner, G.P., Elmore, A.J., Olander, L.P., Martin, R.E. & Harris, A.T. 2004. Grazing systems, ecosystem responses, and global change. *Annual Review of Environment and Resources*, *29*:261-299. https://doi.org/10.1146/annurev.energy.29.062403.102142

Augustine, D.J. & McNaughton, S.J. 2006. Interactive effects of ungulate herbivores, soil fertility, and variable rainfall on ecosystem processes in a semi-arid savanna. *Ecosystems*, *9*(8):1242-1256.

Awotide, O.D., Kehinde, A.L. & Agbola, P.O. 2010. Poverty and rural livelihood diversification among farming households in southwest Nigeria. *Journal of Food, Agriculture & Environment*, *8*(1):367-371.

Awuor, C. 2009. Increasing drought in arid and semi-arid Kenya. In: Ensor, J. & Berger, R. (Eds.), *Understanding climate change adaptation: Lessons from community-based approaches*. Taylor & Francis, pp. 101-114.

Ayalew, D., Tesfaye, K., Mamo, G., Yitaferu, B. and Bayu, W., 2012. Variability of rainfall and its current trend in Amhara region, Ethiopia. African Journal of Agricultural Research, 7(10): 1475-1486.

Ayalew, G. 2004. The effects of development projects on the Karrayu in Metahara Area. In: Alula, P. and Piguet, F. (Eds.), *People, space and the state: Migration, resettlement and displacement in Ethiopia.* Proceedings of the Workshop held by the Ethiopian Society of Sociologists, Social Workers and Anthropologists and the United Nations Emergencies Unit for Ethiopia, 28-3 January 2003. Addis Ababa: Ethiopian Society of Sociologists, Social Workers and Anthropologists, pp. 28-30.

B

Babar, S.F. & Ramesh, H. 2013. Analysis of south west monsoon rainfall trend using statistical techniques over Nethravathi basin. *International Journal of Advanced Technology in Civil Engineering, 2*(1):130-136.

Baigorria, G.A., Jones, J.W. & O'Brien, J.J. 2007. Understanding rainfall spatial variability in southeast USA at different timescales. International journal of climatology, 27(6): 749-760.

Barros, A.P. & Bowden, G.J. 2008. Toward long-lead operational forecasts of drought: An experimental study in the Murray-Darling River Basin. *Journal of Hydrology*, *357*(3):349-367.

Barros, V.R., Field, C.B., Dokke, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C. & Girma, B. 2014. *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Bates, B.C., Kundzewicz, Z.W., Wu, S. & Palutikof, J.P. 2008. *Climate change and water*. Technical Paper of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat. Available from https://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

Baylis, M. & Githeko, A.K. 2006. The effects of climate change on infectious diseases of animals. *Report for the Foresight Project on Detection of Infectious Diseases,* Department of Trade and Industry, UK Government, 35.

Behnke Jr, R.H. 2008. The drivers of fragmentation in arid and semi-arid landscapes. In: Galvin, A., Reid, R.S., Behnke Jr, R.H. & Hobs, N.T., *Fragmentation in semi-arid and arid landscapes: Consequences for human and natural systems*. Netherlands: Springer, pp. 305-340.

Bekele, A. & Amsalu, A. 2012. Household responses to drought in Fentale Pastoral Woreda of Oromia Regional State, Ethiopia. *International Journal of Economic Development Research and Investment,3*(2):36-52.

Bekele, E. 2008. Status of extreme poverty and hunger in pastoral areas of Ethiopia: Looking forward and inward. In *Millennium Development goals and pastoral development: Opportunities & challenges in the new Ethiopian millennium.* Proceedings of the Fourth National Conference on Pastoral Development in Ethiopia, pp. 92-108.

Ben Mohamed, A., Van Duivenbooden, N. & Abdoussallam, S. 2002. Impact of climate change on agricultural production in the Sahel— part 1. Methodological approach and case study for millet in Niger. *Climate Change*, *54*(3):327-348. DOI: 10.1023/A:1016189605188

Berhanu, W., Colman, D. & Fayissa, B. 2007. Diversification and livelihood sustainability in a semi-arid environment: A case study from southern Ethiopia. *Journal of Development Studies*, *43*(5):871-889.

Berkele, Y. 2002. Magnitude of famine for the pastoral areas: Past and present. *Proceedings of the Roundtable on Drought and Famine in the Pastoral Regions of Ethiopia,* Global Hotel, Addis Ababa.

Berkes, F. & Jolly, D. 2002. Adapting to climate change: Social-ecological resilience in a Canadian Western Arctic community. *Conservation Ecology*, *5*(2): Art. 18. http://www.consecol.org/vol5/iss2/art18/

Berlow, E.L., D'Antonio, C.M. & Swartz, H. 2003. Response of herbs to shrub removal across natural and experimental variation in soil moisture. *Ecological Applications*, *13*(5):1375-1387.

Beruk, Y. 2003. *Food security situation in the pastoral areas of Ethiopia*. UK: Oxfam.

Bewket, W. & Conway, D. 2007. A note on the temporal and spatial variability of rainfall in the drought- prone Amhara region of Ethiopia. *International Journal of Climatology*, *27*(11):1467-1477

Bewket, W. 2002. Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile Basin, Ethiopia. *Mountain Research and Development*, *22*(3):263-269.

Beyene, F. & Korf, B. 2008. *Unmaking the commons: Collective action, property rights, and resource appropriation in Somali region, Ethiopia*. CAPRi Working Paper 88. Washington, DC: International Food Policy Research Institute.

Beyene, F. 2006. Informal institutions and access to grazing resources: Practices and challenges among pastoralists of Eastern Ethiopia. In: *11th Biennial Conference of International Association for the Study of Common Property Resources on Survival of the Commons: Mounting Challenges and New Realities, Bali*.

Bhavani, R., Vordzorgbe, S., Owor, M. & Bousquet, F. 2008. *Status of disaster risk reduction in the sub-Saharan Africa region*. Washington, DC: The World Bank.

Birch, I. & Grahn, R. 2007. Pastoralism: Managing multiple stressors and the threat of climate variability and change. *UNDP Human Development Report Office Occasional Paper.* UNDP: New York.

Birkmann, J. 2010. Measuring vulnerability to natural hazards: Towards disaster resilient societies. *The Journal of Risk and Insurance*, 77(4):959-961. (Book review. Reviewed by M. Pompella. American Risk and Insurance Association).

Blaikie, P., Cannon, T., Davis, I. & Wisner, B. 1994. *At risk: Natural hazards, people's vulnerability and disasters.* New York: Routledge

Bollen, K.A. 1989. *Structural equations with latent variables*. New York: John Wiley & Sons.

Bonte, P., Guillaume, H. & Zecchin, F. 1996. Nomads: Changing societies and environments. *Nature Resources, 32*(1):2-10.

Boone, R.B. 2007. Effects of fragmentation on cattle in African savannas under variable precipitation. *Landscape Ecology*, *22*(9):1355-1369.

Boone, R.B., Galvin, K.A., Thornton, P.K., Swift, D.M. & Coughenour, M.B. 2006. Cultivation and conservation in Ngorongoro conservation area, Tanzania. *Human Ecology*, *34*(6):809-828.

Brooks, N. & Adger, W.N. 2003. *Country level risk measures of climate-related natural disasters and implications for adaptation to climate change*. Norwich: Tyndall Centre for Climate Change Research.

Brooks, N., Adger, W.N. & Kelly, P.M. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, *15*(2):151-163.

Brown, D.G., Pijanowski, B.C. & Duh, J.D. 2000. Modeling the relationships between land use and land cover on private lands in the Upper Midwest, USA. *Journal of Environmental Management*, *59*(4):247-263.

Brown, M.E. & Funk, C.C. 2008. Food security under climate change. *Science*, 319(5863):580-581. DOI: 10.1126/science.1154102

Bruhn, D. 2002. *Plant respiration and climate change effects*. Doctoral thesis, Botanical Institute, University of Copenhagen.

Bryan, E., Deressa, T.T., Gbetibouo, G.A. & Ringler, C. 2009. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. *Environmental Science & Policy*, *12*(4):413-426.

Burke, I.C., Lauenroth, W.K. & Coffin, D.P. 1995. Soil organic matter recovery in semiarid grasslands: Implications for the conservation reserve program. *Ecological Applications*, *5*(3):793-801.

Burke, I.C., Yonker, C.M., Parton, W.J., Cole, C.V., Flach, K. & Schimel, D.S. 1989. Texture, climate, and cultivation effects on soil organic matter content in U.S. grassland soils. *Soil Science Society of America Journal*, *53*(3):800-805.

Burnsilver, S. 2008. Grassland/rangeland intensification vs intensification debate. In: *People and policy in rangeland management – A glossary of key concepts*. Prepared for the 2008 International Grasslands and Rangelands Congress, Hohhot, Inner Mongolia, June 29-July 5. Beijing, China: Science in China Press.

Burton, I., Huq, S., Lim, B., Pilifosova, O. & Schipper, E.L. 2002. From impacts assessment to adaptation priorities: The shaping of adaptation policy. *Climate Policy*, *2*(2-3):145-159.

Butterfield, R. 2011. *Climate changes in east Africa*. weADAPT. [Online]. Available at https://www.weadapt.org/knowledge-base/national-adaptation-planning/climate-changes-in-east-africa (Accessed 20/08/2016)

C

Callaway, R.M., Brooker, R.W., Choler, P., Kikvidze, Z., Lortie, C.J., Michalet, R., Paolini, L., Pugnaire, F.I., Newingham, B., Aschehoug, E.T. & Armas, C. 2002. Positive interactions among alpine plants increase with stress. *Nature*, *417*(6891):844-848.

Campbell, D.J. 1999. Response to drought among farmers and herders in southern Kajiado District, Kenya: A comparison of 1972-1976 and 1994-1995. *Human Ecology*, *27*(3):377-416.

Campbell, D.J., Gichohi, H., Mwangi, A. & Chege, L. 2000. Land use conflict in Kajiado district, Kenya. *Land Use Policy*, *17*(4):337-348.

Cancelliere, A., Di Mauro, G., Bonaccorso, B. & Rossi, G. 2007. Stochastic forecasting of drought indices. In Rossi, G., Vega, T. & Bonaccorso, B. (Eds.), *Methods and tools for drought analysis and management.* Netherlands: Springer, pp. 83-100).

Carney, D. 1999. Approaches to sustainable livelihoods for the rural poor. *ODI Poverty Briefing 2,* January. Brighton, UK: Overseas Development Institute (ODI). Available from https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/3093.pdf

Carter, M.R., Little, P.D., Mogues, T. & Negatu, W. 2006. Shocks, sensitivity and resilience: Tracking the economic impacts of environmental disaster on assets in Ethiopia and Honduras. *BASIS Research Program on Poverty, Inequality and Development.* Washington, DC: US Agency for International Development.

Case, M. 2006. *Climate change impacts on East Africa: A review of the scientific literature*. Switzerland: WWF-World Wide Fund for Nature Available from file:///C:/Users/Dora/Downloads/east_africa_climate_change_impacts_final_2.pdf

Central Statistical Agency. 2007. *Ethiopia – Population and housing census of 2007*. Ethiopia: Ministry of Finance and Economic Development.

Challinor, A., Wheeler, T., Garforth, C., Craufurd, P. & Kassam, A. 2007. Assessing the vulnerability of food crop systems in Africa to climate change. *Climatic change*, *83*(3):381-399.

Chapin F.S. III, Folke, C. & Kofinas, G.P. 2009. A framework for understanding change. In Chapin III, F.S., Kofinas, G.P. & Folke, C. (Eds.) 2009. *Principles of ecosystem stewardship: Resilience-based natural resource management in a changing world*. New York: Springer Science & Business Media, pp. 3-28.

Chauvin, N.D., Mulangu, F. & Porto, G. 2012. *Food production and consumption trends in sub-Saharan Africa: Prospects for the transformation of the agricultural sector*. Working Paper. United Nations Development Programme (UNDP), Africa.

Chen, H., Githeko, A.K., Zhou, G., Githure, J.I. & Yan, G. 2006. New records of *Anopheles arabiensis* breeding on the Mount Kenya highlands indicate indigenous malaria transmission. *Malaria Journal*, *5*(1):1.

Cheung, W.H., Senay, G.B. & Singh, A. 2008. Trends and spatial distribution of annual and seasonal rainfall in Ethiopia. *International Journal of Climatology*, *28*(13):1723-1734.

Cho, J., Komatsu, H., Pokhrel, Y., Yeh, P.J.F., Oki, T. & Kanae, S. 2011. The effects of annual precipitation and mean air temperature on annual runoff in global forest regions. *Climatic change*, *108*(1-2):401-410.

Christy, J.R., Norris, W.B. & McNider, R.T. 2009. Surface temperature variations in East Africa and possible causes. *Journal of Climate*, *22*(12):3342-3356.

Clerici, N., Bodini, A. & Ferrarini, A. 2004. Sustainability at the local scale: Defining highly aggregated indices for assessing environmental performance. The Province of Reggio Emilia (Italy) as a case study. *Environmental Management*, *34*(4):590-608.

Codjoe, S.N.A. & Owusu, G. 2011. Climate change/variability and food systems: Evidence from the Afram Plains, Ghana. *Regional Environmental Change*, *11*(4):753-765.

Collins, M., Knutti, R., Arblaster, J., Dufresne, J.L., Fichefet, T., Friedlingstein, P., Gao, X., Gutowski, W.J., Johns, T., Krinner, G. & Shongwe, M. 2013. Long-term climate change: Projections, commitments and irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. United Kingdom: Cambridge University Press. Available from http://www.climatechange2013.org/images/report/WG1AR5_Chapter12_FINAL.pdf

Collins, S.L., Knapp, A.K., Briggs, J.M., Blair, J.M. & Steinauer, E.M. 1998. Modulation of diversity by grazing and mowing in native tallgrass prairie. *Science*, *280*(5364):745-747.

Conway, D. & Schipper, E.L.F. 2011. Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change*, *21*(1):227-237.

Conway, D. 2000. Some aspects of climate variability in the north east Ethiopian Highlands-Wollo and Tigray. *Sinet: Ethiopian Journal of Science*, *23*(2):139-161.

Conway, D., Hanson, C.E., Doherty, R. & Persechino, A. 2007. GCM simulations of the Indian Ocean dipole influence on East African rainfall: Present and future. *Geophysical research letters*, *34*(3).

Conway, D., Mould, C. & Bewket, W. 2004. Over one century of rainfall and temperature observations in Addis Ababa, Ethiopia. *International Journal of Climatology*, *24*(1):77

Cooper, P.J.M. & Coe, R. 2011. Assessing and addressing climate-induced risk in sub-Saharan rain fed agriculture. *Experimental Agriculture*, *47*(02):179-184.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B. & Twomlow, S. 2008. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems & Environment*, *126*(1):24-35.

Coppola, D.P. 2011. *Introduction to international disaster management*. Burlington, MA: Elsevier.

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M. & Lee, M. 2009. Managing the health effects of climate change. *The Lancet*, *373*(9676):1693-1733.

Coughenour, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching, and native ungulate ecosystems. *Journal of Range Management*, *44*(6):530-542.

Coughenour, M.B. 2008. Causes and consequences of herbivore movement in landscape ecosystems. In Galvin, K.A., Reid, R.S., Behnke, R.H. & Hobbs Jr, N. (Eds.), *Fragmentation in semi-arid and arid landscapes.* Netherlands: Springer, pp. 45-91.

Craine, J.M., Nippert, J.B., Elmore, A.J., Skibbe, A.M., Hutchinson, S.L. & Brunsell, N.A. 2012. Timing of climate variability and grassland productivity. *Proceedings of the National Academy of Sciences*, *109*(9):3401-3405.

Craufurd, P.Q. & Wheeler, T.R. 2009. Climate change and the flowering time of annual crops. *Journal of Experimental Botany*, *60*(9):2529-2539.

Crespo, O., Hachigonta, S. & Tadross, M. 2011. Sensitivity of southern African maize yields to the definition of sowing dekad in a changing climate. *Climatic Change*, *106*(2):267-283.

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E. & Webb, J. 2008. A place-based model for understanding community resilience to natural disasters. *Global environmental change*, *18*(4):598-606.

Cutter, S.L., Boruff, B.J. & Shirley, W.L. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2):242-261.

D

Daron, J.D. 2014. *Regional climate messages for West Africa*. Scientific report from the CARIAA Adaptation at Scale in Semi-Arid Regions (ASSAR) Project, December 2014.

Davies, J. & Bennett, R. 2007. Livelihood adaptation to risk: Constraints and opportunities for pastoral development in Ethiopia's Afar region. *The Journal of Development Studies*, *43*(3):490-511.

Davies, J. 2008. Pastoralism & pastoralists. In: *People and Policy in Rangeland Management – A glossary of key concepts*. Prepared for the 2008 International Grasslands and Rangelands Congress, Hohhot, Inner Mongolia, June 29-July 5. Beijing, China: Science in China Press: 64–74.

Davies, M., Guenther, B., Leavy, J., Mitchell, T. & Tanner, T. 2009. Climate change adaptation, disaster risk reduction and social protection: complementary roles in agriculture and rural growth? *IDS Working Papers*, *2009*(320):01-37.

Davis, D.K. 2005. Indigenous knowledge and the desertification debate: problematising expert knowledge in North Africa. *Geoforum*, *36*(4):509-524.

Demeke, A.B., Keil, A. & Zeller, M. 2011. Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia. *Climatic change*, *108*(1-2):185-206.

Demeke, M. & Tefera, N. 2010. *Household resilience to food insecurity in Ethiopia: Panel data evidence*.

Dercon, S. & Krishnan, P. 2000. Vulnerability, seasonality and poverty in Ethiopia. *The Journal of Development Studies*, *36*(6):25-53.

Dercon, S. 2004. Growth and shocks: Evidence from rural Ethiopia. *Journal of Development Economics*, *74*(2):309-329.

Deressa, T., Hassan, R.M. & Ringler, C. 2008. *Measuring Ethiopian farmers' vulnerability to climate change across regional states.* IFPRI Discussion Paper 00806. Ethiopia: International Food Policy Research Institute.

Deressa, T.T. & Hassan, R.M. 2009. Economic impact of climate change on crop production in Ethiopia: Evidence from cross-section measures. *Journal of African Economies*, 18(4):529-554.

Dessie, G. & Kleman, J. 2007. Pattern and magnitude of deforestation in the South Central Rift Valley Region of Ethiopia. *Mountain Research and Development*, 27(2):162-168.

Devereux, S. & Edwards, J. 2004. Climate change and food security. *IDS Bulletin*, *35*(3):22-30.

DFID (Department for International Development, UK Government). 2011. *Defining disaster resilience: A DFID Approach Paper.* Department for International Development, London. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/186874/defining-disaster-resilience-approach-paper.pdf

DFID (Department of International Development, UK Government). 2009. *Climate change facts: Ethiopia*. Department for International Development, London.

Dinku, T., Asefa, K., Hilemariam, K., Grimes, D. and Connor, S., 2011. Improving availability, access and use of climate information. Bulletin of the World Meteorological Organization, 60(2): 80.

Dinku, T., Hailemariam, K., Maidment, R., Tarnavsky, E. & Connor, S., 2014. Combined use of satellite estimates and rain gauge observations to generate high- quality historical rainfall time series over Ethiopia. *International Journal of Climatology*, *34*(7); 2489-2504.

Douglas, E.M., Vogel, R.M. and Kroll, C.N., 2000. Trends in floods and low flows in the United States: impact of spatial correlation. Journal of hydrology, 240(1): 90-105

DPPC (Disaster Preparedness and Prevention Commission). 2005. *Ethiopia national information on disaster reduction*. Report for the World Conference on Disaster Reduction, Kobe-Hyogo, Japan, 18-22 January. Ethiopia, Addis Ababa.

Dubale, A. 2008. *Invasive plants and food security: The case of Prosopis juliflora in the Afar region of Ethiopia*. IUCN/FARM-Africa. Available from http://cmsdata.iucn.org/downloads/invasive_plants_and_food_security___final.pdf

Dugdale, G., McDougall, V.D. & Milford, J.R., 1991. Rainfall estimates in the Sahel from cold cloud statistics: accuracy and limitations of operational systems. In *The International Workshop on Soil Water Balance in the Sudano-Sahelian Zone, Niamey, Niger, 02/18-23/91* (pp. 65-74).

Durbin, J. & Watson, G.S. 1971. Testing for serial correlation in least squares regression. III. *Biometrika*, *58*(1):1-19.

E

Easterling, W., Aggarwal, P., Batima, P., Brander, K., Bruinsma, J., Erda, L., Howden, M., Tubiello, F., Antle, J., Baethgen, W. & Barlow, C. 2007. Food, fibre, and forest products. *Climate Change 2006: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson (Eds.)]. United Kingdom: Cambridge University Press.

Edwards, D.C., 1997. *Characteristics of 20th century drought in the United States at multiple time scales* (No.AFIT-97-051). AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH.

Eischeid, J.K., Bruce Baker, C., Karl, T.R. & Diaz, H.F., 1995. The quality control of long-term climatological data using objective data analysis. *Journal of Applied Meteorology*, *34*(12): pp.2787-2795.

Ellis, F. 2000. *Rural livelihoods and diversity in developing countries*. United Kingdom: Oxford University Press.

Ellis, J. & Galvin, K.A. 1994. Climate patterns and land-use practices in the dry zones of Africa. *BioScience*, *44*(5):340-349.

Ellis, J. & Swift, D.M.1988. Stability of African pastoral ecosystems: Alternate paradigms and implications for development. *Journal of Range Management Archives*, *41*(6):450-459.

Ellis, J. 1995. Climate variability and complex ecosystem dynamics: Implications for pastoral development. In: Scoones, I. (Ed.) 1995. *Living with uncertainty: New directions in pastoral development in Africa.* London: Intermediate Technology Publications.

Enquobahrie, A. 2004. *Understanding poverty: The Ethiopian context.* Paper presented at The Gambia AAPAM Roundtable Conference, Banjul, The Gambia, 19-23 April. Available from http://unpan1.un.org/intradoc/groups/public/documents/aapam/unpan025674.pdf

Ericksen, P., De Leeuw, J., Thornton, P., Said, M., Herrero, M. & Notenbaert, A. 2013. Climate change in sub-Saharan Africa: What consequences for pastoralism? In: Catley, A., Lind, J. & Schoones, I. (Eds.), *Pathways to sustainability. Pastoralism and development in Africa: Dynamic change at the margins*. New York: Routledge, pp. 71-82.

Eriksen, S.E., Klein, R.J., Ulsrud, K., Næss, L.O. & O'Brien, K. 2007. *Climate change adaptation and poverty reduction: Key interactions and critical measures*. Report prepared for the Norwegian Agency for Development Cooperation (Norad). GECHS Report 2007:1. University of Oslo. Available from https://www.norad.no/globalassets/import-2162015-80434-am/www.norad.no-ny/filarkiv/vedlegg-til-publikasjoner/gechs-report-2007-1.pdf

Eriksen, S.H., Brown, K. & Kelly, P.M. 2005. The dynamics of vulnerability: Locating coping strategies in Kenya and Tanzania. *The Geographical Journal*, *171*(4):287-305.

Etim, N.A.A. & Patrick, I.V. 2010. Estimating the determinants of poverty among fishing households in Akwa Ibom State, Nigeria. *Journal of Agriculture and Social Sciences*, *6*(3):61-63.

Etim, N.A.A. & Solomon, V.A. 2010. Determinants of rural poverty among broiler farmers in Uyo, Nigeria: Implications for rural household food security. *Journal of Agriculture and Social Sciences*, *6*(2):24-28.

F

FAO (Food and Agriculture Organisation). 2001. *Pastoralism in the New Millennium* (*FAO Animal Production & Health Paper).* Paper 150, Rome, Italy.

FAO (Food and Agriculture Organisation). 2008. *Climate change and food security: A Framework Document. Summary.* Food and Agriculture Organisation of the United Nations: Rome, Italy. Available from ftp://ftp.fao.org/docrep/fao/010/i0145e/i0145e00.pdf

Farrar, T.J., Nicholson, S.E. & Lare, A.R. 1994. The influence of soil type on the relationships between NDVI, rainfall, and soil moisture in semiarid Botswana. II. NDVI response to soil moisture. *Remote sensing of Environment*, *50*(2):121-133.

FDRE (Federal Democratic Republic of Ethiopia). 1995. *Disaster prevention and preparedness commission establishment proclamation*. Proclamation No. 10/1995. Federal Negarit Gazeta. Addis Ababa, Ethiopia.

FDRE (Federal Democratic Republic of Ethiopia). 2000. *The revised family code*. Proclamation No. 213/2000, Federal Negarit Gazeta, Extraordinary Issue, 6th year, No. 1. Addis Ababa, Ethiopia.

FDRE (Federal Democratic Republic of Ethiopia). 2002. *Rural development policies, strategies and instruments.* Addis Ababa, Ethiopia.

Feleke, S., Kilmer, R.L. & Gladwin, C. 2003. *Determinants of food security in southern Ethiopia*. Paper presented at the 2003 American Agricultural Economics Association Meetings in Montreal, Canada. Available from http://ageconsearch.umn.edu/bitstream/22010/1/sp03fe02.pdf

Fernandez- Gimenez, M.E. & Allen- Diaz, B. 1999. Testing a non- equilibrium model of rangeland vegetation dynamics in Mongolia. *Journal of Applied Ecology*, *36*(6):871-885.

Fernandez-Gimenez, M.E. & Le Febre, S. 2006. Mobility in pastoral systems: Dynamic flux or downward trend? *The International Journal of Sustainable Development and World Ecology*, *13*(5):341-362.

Fernández-Giménez, M.E. & Swift, D.M. 2003. Strategies for sustainable grazing management in the developing world. In: Allsopp, N. *et al*. (Eds.), *Proceedings of the VIIth International Rangelands Congress,* 26 July–1 August 2003, Durban, South Africa. Grassland Society of South Africa, pp. 821-831.

Ferris-Morris, M. 2003. Planning for the next drought: Ethiopia case study: An assessment of the drought response 1999-2000 and current preparedness. Washington: USAID. Available from: http://pdf.usaid.gov/pdf_docs/Pnact133.pdf

Few, R. 2007. Health and climatic hazards: Framing social research on vulnerability, response and adaptation. *Global Environmental Change*, 17(2):281-295.

FEWS-NET (Famine Early Warning System Network). 2002. *Emerging food crisis in the Afar region and East Shewa Zone, Ethiopia.* Food security warning, 8 July 2002. Addis Ababa, Ethiopia.

Filho, L.W. & Mannke, F. 2014. Managing the impacts of climate change in Latin America: The need for technology transfer. In: Filho, W.L., Alves, F., Caeiro, S. & Azeiteiro, U.M. (Eds), *International perspectives on climate change: Latin America and beyond*. Netherlands: Springer, pp. 95-106.

Filmer, D. & Pritchett, L.H., 2001. Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. Demography, 38(1):115-132.

Finan, T.J., West, C.T., Austin, D. & McGuire, T. 2002. Processes of adaptation to climate variability: A case study from the US Southwest. *Climate Research*, *21*(3):299-310.

Fischer, G., Shah, M.M. & Van Velthuisen, H. 2002. *Climate change and agricultural vulnerability*. Special report prepared by the International Institute for Applied Systems Analysis (IIASA). Available from http://indiaenvironmentportal.org.in/files/climate%20change%20agri%20vulnerability%20JB-Report.pdf

Flintan, F. 2011. *Broken lands: Broken lives? Causes, processes and impacts of land fragmentation in the rangelands of Ethiopia, Kenya and Uganda*. A report for REGLAP (Regional Learning and Advocacy Programme), Nairobi. Available from http://landportal.info/sites/default/files/blbl_1introductionsummary_copy.pdf

Flintan, F., Tache, B. & Eid, A. 2011. Rangeland fragmentation in traditional grazing areas and its impact on drought resilience of pastoral communities: Lessons from Borana, Oromia and Harshin, Somali Regional States, Ethiopia. Regional Learning Advocacy Programme for Vulnerable Dryland Communities. Available from http://reliefweb.int/sites/reliefweb.int/files/resources/Ethiopia%20Land%20Fragmentation%20Report_FINAL%207%20feb%202012.pdf

Folke, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyzes. *Global Environmental Change*, *16*(3):253-267.

Frankenberger, T., Spangler, T., Nelson, S., Campbell, J. & Langworthy, M. 2012. *Enhancing resilience to food security shocks in Africa.* Discussion paper. Tucson: Tango International. Available from http://www.fsnnetwork.org/sites/default/files/discussion_paper_usaid_dfid_wb_nov._8_2012.pdf

Fraser, E.D. 2007. Travelling in antique lands: Using past famines to develop an adaptability/resilience framework to identify food systems vulnerable to climate change. *Climatic Change*, *83*(4):495-514.

Fratkin, E. 2001. East African pastoralism in transition: Maasai, Boran, and Rendille cases. *African Studies Review*, 1-25.

Fratkin, E. & Roth, E.A. 2005. Pastoral sedentarisation in Marsabit District, Northen Kenya. In: Fratkin, E. & Roth, E.A. (Eds.), *As pastoralists settle: Social, health and economic consequences of pastoral sedentarisation in Marsabit district, Kenya*. New York: Kluwer Academic.

Funk, C., Dettinger, M.D., Michaelsen, J.C., Verdin, J.P., Brown, M.E., Barlow, M. & Hoell, A. 2008. Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proceedings of the National Academy of Sciences*, *105*(32):11081-11086.

Funk, C., Eilerts, G., Davenport, F. & Michaelsen, J. 2010. A climate trend analysis of Kenya—August 2010. *US Geological Survey Fact Sheet*, *3074*.

Funk, C., Senay, G., Asfaw, A., Verdin, J., Rowland, J., Michaelson, J., Eilerts, G., Korecha, D. & Choularton, R. 2005. *Recent drought tendencies in Ethiopia and equatorial-*

subtropical eastern Africa. Famine Early Warning System Network, USAID, Washington, DC.

Füssel, H.M. 2007. Vulnerability: a generally applicable conceptual framework for climate change research. *Global environmental change*, *17*(2):155-167.

G

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

Gashaw, T., Bantider, A. & Mahari, A. 2014. Population dynamics and land-use/land cover changes in Dera district, Ethiopia. *Global Journal of Biology Agriculture & Health Sciences*, *3*:137-140.

Gbetibouo, G. A. & Ringler, C. 2009. *Mapping South African farming sector vulnerability to climate change and variability. A subnational assessment*. IFPRI Discussion Paper 00885. Washington, DC: International Food Policy Research Institute (IFPRI).

Gbetibouo, G.A., Ringler, C. & Hassan, R. 2010, August. Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural Resources Forum*, 34(3):175-187.

Gebrehiwot, T. & Van der Veen, A. 2013. Climate change vulnerability in Ethiopia: Disaggregation of Tigray Region. J*ournal of Eastern African Studies*, *7*(4):607-629.

Gebre-Michael, Y. & Kifle, M. 2009. *Local innovation in climate-change adaptation by Ethiopian pastoralists.* Prolinnova-Ethiopia and Pastoral Forum for Environment.

Geda, A., Shimeles, A. & Zerfu, D. 2008. Finance and poverty in Ethiopia: A Household-level analysis. In: Guha-Khasnobis, B. & Mavrotas, G. (Eds.), *Financial development, institutions, growth and poverty reduction*. Palgrave Macmillan UK, pp. 61-86.

Geevan, C.P., Dixit, A.M. & Silori, C.S. 2003. *Ecological economic analysis of grassland systems: Resource dynamics and management challenges–Kachchh District (Gujarat).* Gujarat Institute of Desert Ecology.

Getachew, K.N. 2001. *Among the pastoral Afar in Ethiopia: Tradition, continuity and socio-economic change*. Utrecht, Netherlands: International Books.

Ghosh, S., Luniya, V., and Gupta, A., 2009. Trend analysis of Indian summer monsoon rainfall at different spatial scales. Atmospheric Science Letters, 10, 285–290.

Giertz, S., Diekkrüger, B., Jaeger, A. & Schopp, M. 2006. An interdisciplinary scenario analysis to assess the water availability and water consumption in the Upper Ouémé catchment in Benin. *Advances in Geosciences*, *9*:3-13.

GoK (Government of Kenya). 2007. *National Policy for the Sustainable Development of Arid and Semi-Arid Lands of Kenya*. Nairobi.

GoK (Government of Kenya). 2010. *Kenya: Millennium Development Goals Report*. Government of Kenya, Nairobi.

Gonsalez, P., Tucker, C.J. & Sy, H. 2012. Tree density and species decline in the African Sahel attributable to climate. *Journal of Arid Environments*, *78*:55-64.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. & Wiltshire, A. 2010. Implications of climate change for agricultural productivity in the early twenty-first century. *Philosophical Transactions of the Royal Society: Biological Sciences*, *365*(1554):2973-2989. DOI: 10.1098/rstb.2010.0158

Grahn, R. 2008. *The paradox of pastoral vulnerability*. Background paper for the development of 'From Poverty to Power. How Active Citizens and Effective States Can Change the World' (Green, D. & Fried, M.). Oxford: Oxfam GB.

Grau, H.R. & Aide, M. 2008. Globalisation and land-use transitions in Latin America. *Ecology and Society*, *13*(2):16.

Grimes, D.I.F., Pardo-Iguzquiza, E. and Bonifacio, R., 1999. Optimal areal rainfall estimation using raingauges and satellite data. *Journal of Hydrology*, *222*(1), pp.93-108.

Gunderson, L.H. & Holling, C.S. (Eds.) 2002. *Panarchy: Understanding transformations in systems of human and natural systems*. Washington DC: *Island Press*.

Gunderson, L.H., Holling, C.S. & Light, S.S. (Eds.) 1995. *Barriers and bridges to the renewal of ecosystems and institutions*. New York: Columbia University Press.

H

Hadgu, G., Tesfaye, K., Mamo, G. & Kassa, B., 2013. Trend and variability of rainfall in Tigray, northern Ethiopia: analysis of meteorological data and farmers' perception. Academia Journal of Agricultural Research, 1(6): 88-100

Hagmann, T. 2005. Beyond clannishness and colonialism: Understanding political disorder in Ethiopia's Somali Region, 1991-2004. *Journal of Modern African Studies*, *43*(4):509.

Haile, K., Alemu, Z.G. & Kundhlande, G. 2005. Causes of household food insecurity in Koredegaga peasant association, Oromiya zone, Ethiopia. *Agrekon*, *44*(4):543-560.

Haile, M. 2005. Weather patterns, food security and humanitarian response in sub-Saharan Africa. *Philosophical transactions of the Royal Society B: Biological Sciences*, *360*(1463):2169-2182.

Haines, A., Kovats, R.S., Campbell-Lendrum, D. & Corvalán, C. 2006. Climate change and human health: Impacts, vulnerability and public health. *Public Health*, *120*(7):585-596.

Hamed, K.H. 2008. Trend detection in hydrologic data: The Mann–Kendall trend test under the scaling hypothesis. *Journal of Hydrology*, *349*(3):350-363.

Haque, M.A., Yamamoto, S.S., Malik, A.A. & Sauerborn, R. 2012. Households' perception of climate change and human health risks: A community perspective. *Environmental Health*, *11*(1):1.

Hare, F.K., 1983. Climate and Desertification. Revised analysis (WMO-UNDP) WCP-44 pp 5-20. Geneva, Switzerland

Hassan, R. & Nhemachena, C. 2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(1):83-104.

Hassan, R.M. 2010. Implications of climate change for agricultural sector performance in Africa: Policy challenges and research agenda. *Journal of African Economies*, *19*(suppl 2):ii77-ii105.

Hassen, A.H. 2008. *Vulnerability to drought risk and famine: Local responses and external interventions among the Afar of Ethiopia, A study on the Aghini pastoral community*. Doctoral thesis, Department of Social Geography, University of Bayreuth, Germany. Available from https://epub.uni-bayreuth.de/616/1/Ali_Hassen_ web_low_version.pdf

Havstad, K.M., Peters, D.P., Skaggs, R., Brown, J., Bestelmeyer, B., Fredrickson, E., Herrick, J. and Wright, J. 2007. Ecological services to and from rangelands of the United States. *Ecological Economics*, *64*(2):261-268.

Hawinkel, P., Thiery, W., Lhermitte, S., Swinnen, E., Verbist, B., Van Orshoven, J. & Muys, B. 2016. Vegetation response to precipitation variability in East Africa controlled by biogeographical factors. *Journal of Geophysical Research: Biogeosciences*, 121(9):2422-2444.

Hay, S.I., Cox, J., Rogers, D.J., Randolph, S.E., Stern, D.I., Shanks, G.D., Myers, M.F. & Snow, R.W. 2002. Climate change and the resurgence of malaria in the East African highlands. *Nature*, *415*(6874):905-909.

Hayase, Y. & Liaw, K.L. 1997. Factors on polygamy in Sub- Saharan Africa: Findings based on the demographic and health surveys. *The Developing Economies*, *35*(3):293-327.

Hayes, M.J., Svodoba, M.D., Wilhite, D.A. & Vanyarkho, O.V. 1999. Monitoring the 1996 drought using the standardised precipitation index. *Bulletin of the American Meteorological Society*, *80*(3):429.

Hazell, P., Oram, P. & Chaherli, N. 2003. Managing livestock in drought-prone areas of the Middle East and North Africa: Policy issues. In: *Food, Agriculture and Economic Policy in the Middle East and North Africa (Research in Middle East Economics, Volume 5).* Emerald Group Publishing Limited, pp. 79-104.-

Hebb, A. & Mortsch, L. 2007. Floods: Mapping vulnerability in the Upper Thames watershed under a changing climate. CFCAS Project: Assessment of water resources risk and vulnerability to changing climatic conditions, Project Report XI. Available from https://pdfs.semanticscholar.org/4740/7fe199eaf440a0a21d8f8e95f7fb5be8a966.pdf

Heisler- White, J.L., Blair, J.M., Kelly, E.F., Harmoney, K. & Knapp, A.K. 2009. Contingent productivity responses to more extreme rainfall regimes across a grassland biome. *Global Change Biology*, *15*(12):2894-2904.

Helland, J. 2006. Pastoral land tenure in Ethiopia. In contribution to ‘Colloque international “Les frontières de la question foncière–At the frontier of land issues”, Montpellier, France.
https://www.mpl.ird.fr/colloque_foncier/Communications/PDF/Helland.pdf

Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Msangi, S., Freeman, H.A., Bossio, D., Dixon, J., Peters, M., Van de Steeg, J. & Lynam, J. 2010. Smart investments in sustainable food production: Revisiting mixed crop-livestock systems. *Science*, *327*(5967):822-825.

Herrmann, S.M., Anyamba, A. & Tucker, C.J. 2005. Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environmental Change*, *15*(4):394-404.

Hesse, C. & MacGregor, J. 2006. *Pastoralism: Drylands' invisible asset?* Drylands Programme, International Institute for Environment and Development.

Hesse, C. & Odhiambo, M.O. 2006. Strengthening pastoralists' voice in shaping policies for sustainable poverty reduction in ASAL regions of East Africa. In: *Conference on Pastoralism and Poverty Reduction in East Africa*, 27-28 June 2006, Nairobi, Kenya.

Hession, S.L. & Moore, N. 2011. A spatial regression analysis of the influence of topography on monthly rainfall in East Africa. *International Journal of Climatology*, *31*(10):1440-1456.

Hirsch, Robert M., and James R. Slack. 1984. "A nonparametric trend test for seasonal data with serial dependence." Water Resources Research 20, no. 6:727-732.

Hlavinka, P., Trnka, M., Semeradova, D., Dubrovský, M., Žalud, Z. & Možný, M. 2009. Effect of drought on yield variability of key crops in Czech Republic. *Agricultural and Forest Meteorology*, *149*(3):431-442.

Hobbs, N.T., Galvin, K.A., Stokes, C.J., Lackett, J.M., Ash, A.J., Boone, R.B., Reid, R.S. & Thornton, P.K. 2008. Fragmentation of rangelands: Implications for humans, animals, and landscapes. *Global Environmental Change*, *18*(4):776-785.

Hoddinott, J.F.F. & Quisumbing, A.R. 2008. *Methods for microeconometric risk and vulnerability assessments.* Social Protection Discussion Paper. International Food Policy Research Institute (IFPRI).

Holling, C.S. & Meffe, G.K. 1996. Command and control and the pathology of natural resource management. *Conservation Biology*, *10*(2):328-337.

Holling, C.S. 1986. Resilience of terrestrial ecosystems: Local surprise and global change: 292-317. In Clark, W.C. & Munn, R.E. (Eds.), *Sustainable Development of the Biosphere*. Cambridge, UK: Cambridge University Press.

Holling, C.S. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems*, 4(5):390-405.

Homewood, K.M. 2004. Policy, environment and development in African rangelands. *Environmental Science & Policy*, *7*(3):125-143.

Hulme, M. 1990. The changing rainfall resources of Sudan. *Transactions of the Institute of British Geographers*, 15(1):21-34.

Hulme, M., Doherty, R., Ngara, T., New, M. & Lister, D. 2001. African climate change: 1900-2100. *Climate Research*, 17:145–168.

Hundle, B. 2008. *Pastoralism, institutions and social interaction: Explaining the coexistence of conflict and cooperation in pastoral Afar, Ethiopia*. ICAR (Institutional Change in Agriculture and Natural Resources). Germany: Shaker Verlag.

Hurkman, W.J., Vensel, W.H., Tanaka, C.K., Whitehand, L. & Altenbach, S.B. 2009. Effect of high temperature on albumin and globulin accumulation in the endosperm proteome of the developing wheat grain. *Journal of Cereal Science*, *49*(1):12-23.

Hurni, H., Tato, K. & Zeleke, G. 2005. The implications of changes in population, land use, and land management for surface runoff in the upper Nile basin area of Ethiopia. *Mountain Research and Development*, *25*(2):147-154.

I

ILCA (International Livestock Centre for Africa). 1990. *ILCA Annual Report*. Addis Ababa, Ethiopia.

Illius, A.W. & O'Connor, T.G. 2000. Resource heterogeneity and ungulate population dynamics. Oikos, 89:283-294. Available from http://archive.bio.ed.ac.uk/illius/kr.pdf

IPCC (Intergovernmental Panel in Climate Change). 2007a. *Climate change 2007: Impacts, adaptation, and vulnerability. Contribution of working group II to the fouth assessment report of the intergovernmental panel on climate change*. [M. Parry, O. Canziani, J. Palutikof, P. Van der Linden & C. Hanson (Eds.)]. United Kingdom: Cambridge University Press. Available from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf

IPCC (Intergovernmental Panel in Climate Change). 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation. Special report of the Intergovernmental Panel on Climate Change*. [Field, C.B., Barros V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, A.K., Tignor, M. & Midgley, P.M. (Eds.)]. Cambridge: Cambridge University Press.

IPCC (Intergovernmental Panel in Climate Change). 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment*

Report of the Intergovernmental Panel on Climate Change. [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. United Kingdom. Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2001. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovermental Panel on Climate Change*. United Kingdom: Cambridge University Press. [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)] United Kingdom: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2007b. *Climate change 2007: Synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team Pachauri, R.K. & Reisiner, A. (Eds.)]. IPCC, Geneva, Switzerland. Available from https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

IPCC (Intergovernmental Panel on Climate Change). 2014a. *Climate Change 2014: Impacts, adaptation, and vulnerability: Regional Aspects. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. United Kingdom: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2014b. Africa. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)].Cambridge: Cambridge University Press.

ISSG (Invasive Species Specialist Group), IUCN 2004

J

Jones, R., Boer, R., Magezi, S. & Mearns, L. 2004. Assessing current climate risks. In: Burton, I., Malone, E. & Huq, S. (authors) and Lim, I. & Spanger-Siegfried, E.

(Eds.), *Adaptation policy frameworks for climate change: Developing strategies, policies and measures*. Cambridge: Cambridge University Press, pp. 91-117.

Jung, H.S., Choi, Y., Oh, J.H. & Lim, G.H. 2002. Recent trends in temperature and precipitation over South Korea. *International Journal of Climatology*, *22*(11):1327-1337.

Jury, M.R. & Funk, C. 2013. Climatic trends over Ethiopia: Regional signals and drivers. *International Journal of Climatology*, *33*(8):1924-1935.

K

Kahi, H. 2003. *The effects of Prosopis juliflora and Acacia tortilis trees on understory plant species and soil properties on Njemps flats, Baringo District, Kenya*. MSc thesis. Department of Range Management, Faculty of Agriculture, University of Nairobi.

Kakota, T, Nyariki, D., Mkwambisi, D. & Kogi-Makau, W. 2011. Gender vulnerability to climate variability and household food insecurity. *Climate and Development,* 3(4):298-309.

Kartiki, K. 2011. Climate change and migration: A case study from rural Bangladesh. *Gender & Development*, *19*(1):23-38.

Kassie, B.T., 2014. Climate variability and change in Ethiopia: exploring impacts and adaptation options for cereal production. Wageningen University.

Kassie, B.T., Rötter, R.P., Hengsdijk, H., Asseng, S., Van Ittersum, M.K., Kahiluoto, H. & Van Keulen, H. 2013. Climate variability and change in the Central Rift Valley of Ethiopia: Challenges for rainfed crop production. *The Journal of Agricultural Science*, *152(1)*:58-74.

Kebede, D. & Adane, H. 2011. *Climate change adaptations and induced farming livelihoods*. DCG Report no. 64. Dryland Coordination Group. Available from http://drylands-group.org/assets/documents/Publications/1059-dcg_report_no._64.pdf

Keeley, J., Seide, W.M., Eid, A. & Kidewa, A.L.2014. *Large-scale land deals in Ethiopia: Scale, trends, features and outcomes to date*. London: IDRC and IIED.

Kidane, Y., Stahlmann, R. & Beierkuhnlein, C. 2012. Vegetation dynamics, and land use and land cover change in the Bale Mountains, Ethiopia. *Environmental Monitoring and Assessment*, *184*(12):7473-7489.

Kirkbride, M. & Grahn, R. 2008. Survival of the fittest: pastoralism and climate change in East Africa. *Oxfam Policy and Practice: Agriculture, Food and Land*, *8*(3):174-220.

Kirtman, B., Power, S.B., Adedoyin, J.A., Boer, G.J., Bojariu, R., Camilloni, I., Doblas-Reyes, F.J., Fiore, A.M., Kimoto, M., Meehl, G.A. & Prather, M. 2013. Near-term climate change: Projections and predictability. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge: Cambridge University Press.

Klein, J.A., Harte, J. and Zhao, X.Q. 2007. Experimental warming, not grazing, decreases rangeland quality on the Tibetan Plateau. *Ecological Applications*, *17*(2):541-557.

Klein, J.A., Yeh, E., Bump, J., Nyima, Y. & Hopping, K. 2011. Coordinating environmental protection and climate change adaptation policy in resource-dependent communities: A case study from the Tibetan Plateau. In: Ford, J.D. & Berrang-Ford, L. (Eds.), *Climate change adaptation in developed nations: From theory to practice.* Advances in Global Change Research 42. Netherlands: Springer, pp. 423-438.

Krejcie, R.V. & Morgan, D.W. 1970. Determining sample size for research activities. *Educational and Psychological Measurement*, 30:607-310.

Kristjanson, P., Radeny, M., Nkedianye, D, Kruska, R., Reid, R., Gichohi, H., ATieno, F. & Sanford, R. 2002. *Valuing alternative land-use options in the Kitengela wildlife dispersal area of Kenya.* A joint International Livestock Research Institute (ILRI) and African Conservation Centre (ACC) report undertaken for the Kitengela community. ILRI Impact Assessment Series 10. Available from https://KitengelaImpactAssessment.pdf

Kruger, A.C. & Shongwe, S. 2004. Temperature trends in South Africa: 1960–2003. *International Journal of Climatology*, *24*(15):1929-1945.

Kuyvenhoven, A. 2012. Book review: International Food Policy Research Institute (2012): 2011 Global Food Policy Report. *Food Security*, 4:679-681. Available from http://groupedebruges.eu/sites/default/files/publications/downloads/global_food_policy_report_2011_ifpri-_full_version_.pdf

L

Lambin, E.F., Geist, H.J. & Lepers, E. 2003. Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources*, *28*(1):205-241.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C. & George, P. 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*, 11(4):261-269.

Lautze, S., Aklilu, Y., Raven-Roberts, A., Young, H., Kebede, G. & Leaning, J. 2003. *Risk and vulnerability in Ethiopia: Learning from the past, responding to the present, preparing for the future.* Report for the U.S. Agency for International Development. Boston: Feinstein International Famine Center, Inter-University Initiative on Humanitarian Studies and Field Practice. Available from http://fic.tufts.edu/assets/risk_ethiopia.pdf

Le Houerou, H.N. 1984. Rain use efficiency: a unifying concept in arid-land ecology. *Journal of Arid Environments*, *7*(3):213-247.

Lemma, Y.A.R.E.D., Beyene, F. & Hundie, B. 2013. Climate change and variability: Implications for household food security in Agro-pastoral areas of Jijiga district, Eastern Ethiopia. *Ethiopian Journal of Economics*, 22(1):71-106.

Levin, I.P., Schneider, S.L. & Gaeth, G.J. 1998. All frames are not created equal: A typology and critical analysis of framing effects. *Organisational Behavior and Human Decision Processes*, *76*(2):149-188.

Li, G. & Weng, Q. 2007. Measuring the quality of life in city of Indianapolis by integration of remote sensing and census data. *International Journal of Remote Sensing*, *28*(2):249-267.

Liebmann, B., Hoerling, M.P., Funk, C., Bladé, I., Dole, R.M., Allured, D., Quan, X., Pegion, P. & Eischeid, J.K. 2014. Understanding recent Eastern Horn of Africa rainfall variability and change. *Journal of Climate*, 27(23):8630-8645.

Little, P.D. 2013. Reflections on the future of pastoralism in the Horn of Africa. In: Catley, A., Lind, J. & Scoones, I. (Eds.), *Pastoralism and development in Africa: Dynamic change at the margins.* London: Routledge, pp. 243-249.

Little P.D., Smith, K., Cellarius, B., Coppock, D.L. & Barrett, C.B. 2001. Avoiding disaster: Diversification and risk management among East African herders. *Development and Change,* 32:401-433.

Lloret, F., Escudero, A., Iriondo, J.M., Martínez- Vilalta, J. & Valladares, F. 2012. Extreme climatic events and vegetation: The role of stabilizing processes. *Global Change Biology*, *18*(3):797-805.

Lloyd, S.J., Kovats, R.S. and Chalabi, Z. 2011. Climate change, crop yields, and undernutrition: Development of a model to quantify the impact of climate scenarios on child undernutrition. *Environmental Health Perspectives*, 119(12):1817-1823.

Lobell, D.B., Bänziger, M., Magorokosho, C. & Vivek, B. 2011. Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change*, *1*(1):42-45.

Long, H., Tang, G., Li, X. and Heilig, G.K., 2007. Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China. Journal of Environmental management, 83(3), pp.351-364.

Longley, K. & Wekesa, M. 2008. *An analysis of Kenya's drought response: Lessons from the 2005–06 drought response in pastoral areas*.

Luers, A.L., Lobell, D.B., Sklar, L.S., Addams, C.L. & Matson, P.A. 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change*, *13*(4):255-267.

Lyon, B. & DeWitt, D.G. 2012. A recent and abrupt decline in the East African long rains. *Geophysical Research Letters*, *39*(2). DOI: 10.1029/2011GL050337

M

Maddison, D.J. 2007. The perception of and adaptation to climate change in Africa. *World Bank Policy Research Working Paper 4308*. The World Bank, Development Research Group and Sustainable Rural and Urban Development Team.

Madu, I.A. 2012. *Spatial vulnerability of rural households to climate change in Nigeria: Implication for internal security.* Working paper No. 2. The Robert S. Strauss Center for International Security and Law. Avalable from https://www.files.ethz.ch/isn/152916/working%20paper%20no%202_final.pdf

Mair, A. and Fares, A., 2009. Assessing rainfall data homogeneity and estimating missing records in Mākaha valley, O ʻahu, Hawai ʻi. Journal of Hydrologic Engineering, 15(1):.61-66.

Markakis, J. 2004. *Pastoralism on the margin*. London: Minority Rights Group International. Available from http://minorityrights.org/wp-content/uploads/old-site-downloads/download-149-Pastoralism-on-the-Margin.pdf

Martin, V., Chevalier, V., Ceccato, P., Anyamba, A., De Simone, L., Lubroth, J., De la Rocque, S. & Domenech, J. 2008. The impact of climate change on the epidemiology and control of Rift Valley fever. *Revue scientifique et technique (International Office of Epizootics)*, *27*(2):413-426.

McCabe, J.T. 1990. Turkana pastoralism: A case against the tragedy of the commons. *Human Ecology*, *18*(1):81-103.

McCabe, J.T. 2006. Cattle bring us to our enemies. Turkana ecology, politics, and raiding in a disequilibrium system. *Human Ecology*, 34(1):147–149.

McCabe, J.T., Leslie, P.W. and DeLuca, L., 2010. Adopting cultivation to remain pastoralists: The diversification of Maasai livelihoods in northern Tanzania. *Human Ecology*, 38(3):321-334.

McCarthy, J.J., Canziani, O.F, Leary, N.A., Dokken, D.J. & White, K.S. (Eds.) 2001. *Climate Change 2001: Impacts, adaptation, and vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

McGahey, D., Davies, J. and Barrow, E., 2008. Pastoralism as conservation in the Horn of Africa: effective policies for conservation outcomes in the drylands of Eastern Africa. Annals of Arid Zones, 46(2):353-377.

McKee, T.B., Doesken, N.J. & Kleist, J. 1993: The relationship of drought frequency and duration of time scales. *Proceedings of the Eighth Conference on Applied Climatology*, Anaheim, California, 17-22 January 1993. American Meteorological Society, pp. 179-186.

McKee, T.B., Doesken, N.J. & Kleist, J. 1995. Drought monitoring with multiple time scales. In: *Proceedings of the Ninth Conference on Applied Climatology* Dallas, Boston, MA: American Meteorological Society, pp. 233-236.

McMichael, A.J. & Kovats, R.S. 2000. Climate change and climate variability: Adaptations to reduce adverse health impacts. *Environmental Monitoring and Assessment*, *61*(1):49-64.

McPeak, J. & Little, P.D. 2005. Cursed if you do, cursed if you don't: The contradictory processes of pastoral sedentarisation in Northern Kenya. In: Fratkin, E. & Roth

E.A. (Eds.), *As pastoralists settle: Social, health, and economic consequences of the pastoral sedentarisation in Marsabit district, Kenya (Studies in human ecology and adaptation)*. New York: Kluwer Academic Publishers, pp. 87-104.

McSweeney, C., Lizcano, G., New, M. & Lu, X. 2010. The UNDP climate change country profiles: Improving the accessibility of observed and projected climate information for studies of climate change in developing countries. *Bulletin of the American Meteorological Society*, *91*(2):157-166.

McSweeney, C., New, M. & Lizcano, G. 2009. UNDP climate change country profiles: Kenya. Available from http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Kenya/Kenya.lowres.report.pdf

MEA (Millennium Ecosystem Assessment). 2005. Ecosystems and human well-being: *Desertification synthesis*. Washington, DC: World Resources Institute.

Mehari, Z.H. 2015. The invasion of *Prosopis juliflora* and Afar pastoral livelihoods in the Middle Awash area of Ethiopia. *Ecological Processes*, *4*(1), p.1.

Meikle, A. 2010. *Ethiopia country level literature review*. Africa Climate Change Resilience Alliance (ACCRA).

Mekasha, A., Tesfaye, K. & Duncan, A.J. 2014. Trends in daily observed temperature and precipitation extremes over three Ethiopian eco- environments. *International Journal of Climatology*, *34*(6):1990-1999.

Mengistu, D., Bewket, W. & Lal, R. 2014. Recent spatiotemporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia. *International Journal of Climatology*, *34*(7):2278-2292.

MENR (Ministry of Environment and Natural Resources. Republic of Kenya). 2002. First national communication of Kenya to the Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC). National Environment Secretariat, Ministry of Environment and Natural Resources, Nairobi.

Merasha, E. 1999. Annual rainfall and potential evapotranspiration in Ethiopia. *Ethiopian Journal of Natural Resources,* 1:137-154.

Mesfin, W-M. 1999. *The Horn of Africa: Conflict and poverty*. Commercial Printing Press.

Meze-Hausken, E. 2004. Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. *Climate Research*, 27:19-31. Available from http://www.int-res.com/articles/cr2004/27/c027p019.pdf

Migosi, J.A., Nanok, D., Ombuki, C.N. & Metet, J. 2012. Hindrances to pupil's access and participation in primary school eduction in Kakuma and Lokichoggio divisions, Turkana county. *Journal of Education and General Studies*, 1(10):308-315.

Milford, J.R., McDougall, V.D. and Dugdale, G., 1994, December. Rainfall estimation from cold cloud duration: Experience of the TAMSAT group in West Africa. In *Validation Problems of Rainfall Estimation by Satellite in Intertropical Africa, Guillot B., edt., Proc. Niamey workshop* (pp. 1-3).

Ministry of Federal Affairs. Ethopia. 2003. *Project implementation manual*. Pastoral Community Development Project (PCDP). Pastoral Development Department. Ethiopia, Addis Ababa.

Mohammed, A. 2003. Pastoral developments strategies and policies in Ethiopia: A critical analysis and evaluation. In: *Proceedings of the Third National Conference on Pastoral Development in Ethiopia*.

Mohammed, A.R. & Tarpley, L. 2009. High nighttime temperatures affect rice productivity through altered pollen germination and spikelet fertility. *Agricultural and Forest Meteorology*, *149*(6):999-1008.

Mohammed, Y. 2004. Pastoral land tenure issues and development in the Middle Awash Valley: Case study on Amibara and Gewane Woredas, Master of Arts in Regional and Local Development Studies, Addis Ababa University, Ethiopia. Available from http://etd.aau.edu.et/bitstream/123456789/1786/3/YASIN%20MOHAMMED.pdf

Mondal, A., Kundu, S. & Mukhopadhyay, A. 2012. Rainfall trend analysis by Mann-Kendall test: A case study of north-eastern part of Cuttack district, Orissa. *International Journal of Geology, Earth and Environmental* Sciences, 2(1):70-78.

Mortimore, M., Anderson, S., Cotula, L., Faccer, K., Hesse, C., Mwangi, A., Nyangena, W. & Skinner, J. 2008. *Drylands– An economic asset for rural livelihoods and economic growth.* Draft Challenge Paper. Global Drylands Imperative (GDI). Available from http://cmsdata.iucn.org/downloads/draft_drylands_challenge_paper_29sept08.pdf

Morton, J. & Meadows, N. 2000. Pastoralism and sustainable livelihoods: An emerging agenda. Policy Series 11. England: Natural Resources Institute, University of Greenwich.

Morton, J. 2008. *DFID's current and potential engagement with pastoralism: A scoping study*. Natural Resources Institute: University of Greenwich.

Müller, C., Cramer, W., Hare, W.L. & Lotze-Campen, H. 2011. Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences*, *108*(11):4313-4315.

Müller-Mahn, D., Rettberg, S. & Getachew, G. 2010. Pathways and dead ends of pastoral development among the Afar and Karrayu in Ethiopia. *The European Journal of Development Research*, 22(5):660-677.

Mulubrhan B. & Tafere, K. 2013. Gendered impacts and adaptation mechanisms to climate change among Afar pastoralists in North eastern Ethiopia. In: Mulinge, M.M. & Getu, M. (Eds.), *Impacts of Climate Change and Variability on Pastoralist Women in sub-Saharan Africa*. Organisation for Social Science Research in Eastern and Southern Africa (OSSREA). Kampala: Fountain Publishers, pp. 83-120.

Mung'ongo, C.G., Kwasila, H.L. & Madulu, N.F. 1990. *A socio-economic assessment of north eastern parts of Tanzania. IRA, University of Dar-es-Salaam.*

Mushi, V.A. 2013. Women pastoralists and climate change impacts in Kilosa District, Tanzania. In: Getu, M. & Mulinge, M.M. (Eds.), *Impacts of climate change and variability on pastoralists women in sub-Saharan Africa*. Organisation for Social Science Research in Easter and Southern Africa (OSSREA). Kampala: Fountain Publishers. pp. 155-186.

Mwangi, E. & Swallow, B. 2005. *Invasion of prosopis juliflora and local livelihoods: Case study from the Lake Baringo area of Kenya*. Working Paper: Eastern and Central Africa. Nairobi, Kenya: World Agroforestry Centre. Available from http://www.worldagroforestry.org/downloads/Publications/PDFS/wp03mwangi.pdf

N

Nasrallah, H.A., Nieplova, E. & Ramadan, E. 2004. Warm season extreme temperature events in Kuwait. *Journal of Arid Environments*, *56*(2):357-371.

Nassef, M., Anderson, S. & Hesse, C. 2009. *Synthesis Paper. Pastoralism and climate change: Enabling adaptive capacity*. Humanitarian Policy Group and Regional Pastoral Livelihoods Advocacy Project. London: Overseas Development Institute (ODI). Available from http://www.fao.org/fileadmin/user_upload/drought/docs/Climate%20Change.pdf

Nelson, R., Kokic, P., Crimp, S., Martin, P., Meinke, H., Howden, S. M., De Voil, P. & Nidumolu, U. 2010. The vulnerability of Australian rural communities to climate variability and change: Part II – Integrating impacts with adaptive capacity. *Environmental Science & Policy*, 13(1):18-27.

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M. Valmonte0Santos, R., Ewing, M & Lee, D. 2009. *Food Policy Report. Climate change: Impact on agriculture and costs of adaptation* (Vol. 21). Washington DC: International Food Policy Research Institute (IFPRI). Available from http://www.fao.org/fileadmin/user_upload/rome2007/ docs/Impact_on_Agriculture_and_Costs_of_Adaptation.pdf

Neumann, R.P. 1998. *Imposing wilderness: Struggles over livelihood and nature preservation in Africa*. Berkeley: University of California Press.

Niamir-Fuller, M. & Turner, M.D. 1999. A review of recent literature on pastoralism and transhumance in Africa. In: Niamir-Fuller, M. & Turner, M.D. (Eds,), *Managing mobility in African rangelands: The Legitimisation of Transhumance*. England: Practical Action Publishing, pp. 18-46.

Nkondze, M.S., Masuku, M.B. & Manyatsi, A. 2013. Factors affecting households vulnerability to climate change in Swaziland: A case of Mpolonjeni area development programme (ADP). *Journal of Agricultural Science*, *5*(10):108.

NMSA (National Meteorological Services Agency, Ethiopia). 2001. *Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC).* Addis Ababa, Ethiopia: Federal Democratic Republic of Ethiopia. Ministry of Water Resources.

Nori, M. & Davies, J. 2007. *Change of wind or wind of change? Climate Change, adaptation and pastoralism.* Prepared for the World Initiative for Sustainable Pastoralism. IUCN, Nairobi. Available from https://cmsdata.iucn.org/downloads/c__documents _and_settings_hps_local_settings_application_data_mozilla_firefox_profile.pdf

Norris, F.H., Stevens, S.P., Pfefferbaum, B., Wyche, K.F. & Pfefferbaum, R.L. 2008. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology*, *41*(1-2):127-150.

Notenbaert, A.M., Davies, J., De Leeuw, J., Said, M., Herrero, M., Mansano, P., Waithaka, M., Aboud, A. & Omondi, S. 2012. Policies in support of pastoralism and biodiversity in the heterogeneous drylands of East Africa. *Pastoralism: Research, Policy and Practice*, *2*(1), p.14.

Ntale, H.K. & Gan, T.Y. 2003. Drought indices and their application to East Africa. *International Journal of Climatology*, *23*(11):1335-1357.

Nyong, A., Adesina, F. & Elasha, B.O. 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for global Change*, *12*(5):787-797.

O

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L. & West, J. 2004. Mapping vulnerability to multiple stressors: climate change and globalisation in India. *Global Environmental Change*, *14*(4):303-313.

O'Brien, R.M. 2007. A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity*, *41*(5):673-690.

Oba, G. 2009. *Harnessing pastoralist's indigenous range management knowledge for drought-resilient livelihood systems in the Horn of Africa.* World Initiative for Sustainable Pastoralism (WISP) and IUCN. Available from http://cmsdata.iucn.org/ downloads/harnessing_pastoralists_indigenous_knowledge_review_2009_1.pdf

O'Brien, K., Sygna, L. & Haugen, J.E. 2004. Vulnerable or resilient? A multi-scale assessment of climate impacts and vulnerability in Norway. *Climatic Change*, *64*(1-2):193-225.

Oechel, W.C., Vourlitis, G.L., Hastings, S.J., Ault, R.P. Jr. & Bryant, P. 1998. The effects of water table manipulation and elevated temperature on the net CO_2 flux of wet sedge tundra ecosystems. *Global Change Biology*, *4*(1):77-90.

Ojima, D.S., Valentine, D.W., Mosier, A.R., Parton, W.J. & Schimel, D.S. 1993. Effect of land use change on methane oxidation in temperate forest and grassland soils. *Chemosphere*, *26*(1):675-685.

Oliver, J.E. 1980. Monthly precipitation distribution: a comparative index. *The Professional Geographer*, *32*(3):300-309.

Oluwatayo, I.B. 2009, April. Poverty and income diversification among households in rural Nigeria: A gender analysis of livelihood patterns. In: *The 2nd Instituto de*

EstudosSociais e Económicos (IESE) Conference on 'Dynamics of Poverty and Patterns of Economic Accumulation in Mosambique, pp. 22-23.

Omamo, S.W., Gentilini, U. and Sandström, S. 2010. *Revolution: From food aid to food assistance. Innovations in overcoming hunger.* Rome: World Food Programme.

Omondi, P.A.O., Awange, J.L., Forootan, E., Ogallo, L.A., Barakisa, R., Girmaw, G.B., Fesseha, I., Kululetera, V., Kilembe, C., Mbati, M.M. & Kilavi, M. 2014. Changes in temperature and precipitation extremes over the greater Horn of Africa region from 1961 to 2010. *International Journal of Climatology*, *34*(4):1262-1277.

Omotesho, O.A., Adewumi, M.O., Muhammad-Lawal, A. & Ayinde, O.E. 2006. Determinants of food security among the rural farming households in Kwara State, Nigeria. *African Journal of General Agriculture, 2*(1).

Omumbo, J.A., Lyon, B., Waweru, S.M., Connor, S.J. & Thomson, M.C. 2011. Raised temperatures over the Kericho tea estates: revisiting the climate in the East African highlands malaria debate. *Malaria Journal*, *10*(1):1.

Ongoro, E.B. & Ogara, W. 2012. Impact of climate change and gender roles in community adaptation: A case study of pastoralists in Samburu East District, Kenya, *International Journal of Biodiversity and Conservation*, 42(2):78-79.

Opiyo, F.E., Ngugi, R.K. & Mureithi, S.M., 2011. The influence of water availability on pastoralist's resource use in Mwingi and Kitui districts in Kenya. *Journal of Human Ecology*, 35(1):43-52.

Orbeta A.C. Jr. 2005. Poverty, vulnerability and family size: Evidence from the Philippines. ADB Institute Research Paper Series No. 68. Asian Development Bank Institute. Available from https://www.adb.org/sites/default/files/publication/157217/adbi-rp68.pdf

Osbahr, H., Twyman, C., Adger, W.N. & Thomas, D.S. 2008. Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mosambique. *Geoforum*, *39*(6):1951-1964.

Osman, M. & Sauerborn, P. 2002. A preliminary assessment of characteristics and long term variability of rainfall in Ethiopia – Basis for sustainable land use and resource management. Conference on International Agricultural Research for Development. Deutscher Tropentag, Witzenhausen, October 9-11. Available from http://www.tropentag.de/2002/abstracts/full/11.pdf.

Owen-Smith, N. 2004. Functional heterogeneity in resources within landscapes and herbivore population dynamics. *Landscape Ecology*, *19*(7):761-771.

P

Pantuliano, S. & Wekesa, M. 2008. *Improving drought response in pastoral regions of Ethiopia. Somali and Afar regions and Borena Zone in Oromiya region.* Humanitarian Policy Group an Overseas Development Institute, London. Available from http://www.fao.org/fileadmin/user_upload/drought/docs/HPG%20Drought%20Response.pdf

Parkins, J.R. & MacKendrick, N.A. 2007. Assessing community vulnerability: A study of the mountain pine beetle outbreak in British Columbia, Canada. *Global Environmental Change*, *17*(3):460-471.

Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M. and Fischer, G. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14(1):53-67.

Parton, W.J., Scurlock, J.M.O., Ojima, D.S., Gilmanov, T.G., Scholes, R.J., Schimel, D.S., Kirchner, T., Menaut, J.C., Seastedt, T., Garcia Moya, E. & Kamnalrut, A. 1993. Observations and modeling of biomass and soil organic matter dynamics for the grassland biome worldwide. *Global Biogeochemical Cycles*, *7*(4):785-809.

Pasiecznik, N. 1999. Prosopis: Pest or providence, weed or wonder tree? European Tropical Forest Research Network Newsletter, 28:12-14.

Pasiecznik, N.M., Felker, P., Harris, P.J., Harsh, L., Cruz, G., Tewari, J.C., Cadoret, K. & Maldonado, L.J. 2001. *The Prosopis Juliflora – Prosopis Pallida Complex: A monograph*. Coventry, UK: HDRA.

PENHA (Pastoral and Environmental Network in the Horn of Africa) in partnership with The International Fund for Agricultural Development (IFAD), the Ethiopian Agro-pastoralist Development Association and University College London (UCL). 2015. *Exploring Prosopis management and policy options in the greater Horn of Africa.* In: Tsegay, B.T., Livingstone, J. & Fre, Z. (Eds.), Proceedings of a regional conference, 26-27 November 2014, Addis Ababa, Ethiopia. Available from http://www.penhanetwork.org/sites/default/files/uploads/manual/documents/PENHA%20Prosopis%20Regional%20Conference%20Proceedings%20Feb%202015.compressed.pdf.

Pavanello, S. 2009. *Pastoralists' vulnerability in the Horn of Africa: Exploring political marginalisation, donors' policies and cross-border issues: Literature review*. Humanitarian Policy Group (HPG) and Overseas Development Institute. London, UK. Available from http://www.fao.org/fileadmin/user_upload/drought/docs/Literature_Review_RREAD.pdf

Pedersen, J.& Benjaminsen, T.A. 2008. One leg or two? Food security and pastoralism in the Northern Sahel. *Human Ecology*, 36(1):43-57.

PFE, IIRR & DF. 2010. *Pastoralism and land: Land tenure, administration and use in pastoral areas of Ethiopia*. Kenya: Pastoralist Forum Ethiopia; International Institute of Rural Reconstruction; The Development Fund.

Population Census Commission. Ethiopia. 2008. *Summary and statistical report of the 2007 Population and Housing Census: Population size by age and sex*. Addis Ababa, Ethiopia: Federal Democratic Republic of Ethiopia, Population Census Commission.

Porter, J.R. & Semenov, M.A. 2005. Crop responses to climatic variation. Philosophical Transactions of the Royal Society B. *Biological Sciences*, *360*(1463):2021-2035.

Pratt, D.J., Greenway, P.J. & Gwynne, M.D. 1966. A classification of East African rangeland, with an appendix on terminology. *Journal of Applied Ecology*, 3(2):369-382.

R

Radeny, M., Nkedianye, D., Kristjanson, P. & Herrero, M. 2006. Livelihood choices and returns among agro-pastoralists in southern Kenya. Paper presented at an international conference, *Pastoralism and Poverty Reduction in East Africa: A Policy Research Conference*, International Livestock Research Institute, 27-28 June 2006, Nairobi. Available from http://www.saga.cornell.edu/saga/ilri0606/30radeny.pdf

Rajeevan, M., Bhate, J., Kale, J.D. and Lal, B., 2006. High resolution daily gridded rainfall data for the Indian region: Analysis of break and active. Current Science, 91(3).

Rass, N. 2006. *Policies and strategies to address the vulnerability of pastoralists in sub-Saharan Africa*. Pro-poor Livestock Policy Initiative (PPLPI) Working Paper No. 37. Available from http://www.eldis.org/vfile/upload/1/document/0708/DOC22899.pdf

Ravallion, M. 2012. Benchmarking global poverty reduction. World Bank Policy Research Working Paper 6205. The World Bank, Development Economics Vice Presidency, Office of the Chief Economist. Available from http://documents.worldbank.org/curated/en/317521468158374029/pdf/wps6205.pdf

Reda, K.T. 2012. Pastoralism at crossroads: Changing features of climate, livelihood and social organisation in East Africa. *Global Journal of Human Social Science*, *12*(9-C).

Reda, K.T. 2014. Formal and informal land tenure systems in the Afar region, Ethiopia: Perceptions, attitudes and implications for land use disputes. *African Journal on Conflict Resolution*, *14*(2):41-62.

REGLAP (Regional Learning and Advocacy Programme for Vulnerable Dryland Communities). 2012. *Key statistics on the drylands of Kenya, Uganda and Ethiopia.* REGLAP Secretariat. Regional Learning & Advocacy Programme for Vulnerable Dryland Communities. Available from http://reliefweb.int/sites/reliefweb.int/files/resources/Annex%2B1%2BKey%2BStatistics%2Bon%2Bdrylands%2Bof%2Bthe%2BHorn%2Bof%2BAfrica_October_%2B2012.pdf

Reich, P.B., Tilman, D., Craine, J., Ellsworth, D., Tjoelker, M.G., Knops, J., Wedin, D., Naeem, S., Bahauddin, D., Goth, J. & Bengtson, W. 2001. Do species and functional groups differ in acquisition and use of C, N and water under varying atmospheric CO_2 and N availability regimes? A field test with 16 grassland species. *New Phytologist*, 150(2):435-448.

Reid, R.S., Galvin, K.A. & Kruska, R.S. 2008. Global significance of extensive grazing lands and pastoral societies: An introduction. In: Galvin, K.A., Reid, R.S., Behnke Jr, R.H. & Hobbs, N.T. (Eds.), *Fragmentation in semi-arid and arid landscapes: Consequences for human and natural systems*. The Netherlands: Springer, pp. 1-24.

Reilly, J., Baethgen, W., Chege, F.E., Van de Geijn, S.C., Erda, L., Iglesias, A., Kenny, G., Patterson, D., Rogasik, J., Rötter, R., Rosenzweig, C. Sombroek, W. & Westbrook, J. 1996. *Agriculture in a changing climate: Impacts and adaptation.* Chapter 13, pp. 427-467.

Rettberg, S. 2006. *Local risk discourses in Afar: Socio-ecological challenges to pastoral livelihood security*. In: Presentation at workshop held by the CGIAR Systemwide Program on Collective Action Property Rights (CAPRi).

Reynolds, J.F., Smith, D.M.S., Lambin, E.F., Turner, B.L., Mortimore, M., Batterbury, S.P., Downing, T.E., Dowlatabadi, H., Fernández, R.J., Herrick, J.E. & Huber-Sannwald, E. 2007. Global desertification: Building a science for dryland development. S*cience*, *316*(5826):847-851.

Rose, A. 2009. Economic resilience to disasters. CARRI Research Report 8. Community & Regional Resilience Institute. Available from http://www.resilientus.org/wp-content/uploads/2013/03/Research_Report_8_Rose_1258138606.pdf

Rosell, S. & Holmer, B. 2007. Rainfall change and its implications for Belg harvest in South Wollo, Ethiopia. *Geografiska Annaler: Series A, Physical Geography*, *89*(4):287-299.

Rosell, S. 2011. Regional perspective on rainfall change and variability in the central highlands of Ethiopia, 1978-2007. *Applied Geography*, *31*(1):329-338.

Roselle, L., Launchbaugh, K., Jones, T., Babcock, L., Ambrosek, R., Stebleton, A., Brewer, T., Sanders, K., Mink, J., Haley, J. & Hyde, G. 2011. Rangelands: An introduction to wild open spaces. Idaho: University of Idaho Rangeland Centre and Idaho Rangeland Resource Commission. Available from http://www.envirothon.org/files/Rangeland_Ecology.pdf

Rota, A. 2010. *Livestock: Thematic papers. Tools for project design*. Rome, Italy: International Fund for Agricultural Development (IFAD). Available from http://www.fao.org/fileadmin/templates/agphome/images/iclsd/documents/wk3_c5_rota.pdf

Rowhani, P., Lobell, D.B., Linderman, M. & Ramankutty, N. 2011. Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology*, *151*(4):449-460.

S

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A. & Leemans, R. 2000. Global biodiversity scenarios for the year 2100. *Science*, *287*(5459):1770-1774.

Sala, O.E., Lauenroth, W.K. & Parton, W.J. 1992. Long- term soil water dynamics in the shortgrass steppe. *Ecology*, *73*(4):1175-1181.

Sala, O.E., Parton, W.J., Joyce, L.A. & Lauenroth, W.K. 1988. Primary production of the central grassland region of the United States. *Ecology*, *69*(1):40-45.

Sanford, S. & Habtu, Y. 2000. Emergency response interventions in pastoral areas of Ethiopia. London: Department for International Development.

Sarr, B. 2012. Present and future climate change in the semi- arid region of West Africa: A crucial input for practical adaptation in agriculture. *Atmospheric Science Letters*, *13*(2):108-112.

Schilling, J., Opiyo, F.E.O. & Scheffran, J. 2012. Raiding pastoral livelihoods: motives and effects of violent conflict in north-western Kenya. *Pastoralism: Research, Policy and Practice*, *2*:25.

Schindler, K. 2010. Credit for what? Informal credit as a coping strategy of market women in Northern Ghana. *The Journal of Development Studies*, *46*(2):234-253.

Schlesinger, W.H., Reynolds, J.F., Cunningham, G.L., Huenneke, L.F., Jarrell, W.M., Virginia, R.A. & Whitford, W.G. 1990. Biological feedbacks in global desertification. *Science*, *247*(4946):1043-1048.

Scholes, R.J. 1993. Nutrient cycling in semi-arid grasslands and savannas: Its influence on pattern, productivity and stability. In *Proceedings of the XII International Grassland Congress*. Palmerston North: International Grasslands Society, pp. 1331-1334.

Schreck, C.J. and Semazzi, F.H. 2004. Variability of the recent climate of eastern Africa. *International Journal of Climatology*, 24(6):681-701.

Scoones, I. 2004. Climate change and the challenge of non-equilibrium thinking. *IDS Bulletin,* 35(3):114-119. DOI: 10.1111/j.1759-5436.2004.tb00144.x

Scoones, I. 2007. Climate change and the challenge of non-equilibrium thinking. *IDS Bulletin*, 35(3):114-119

Seid, M.J. 2012. Household perception about *Prosopis juliflora* and its effect on pastoral livelihood diversification strategy: The case of Gewane district in the Afar regional state, Ethiopia. *International Journal of Advances in Scientific Research*, *2*(3):21-51.

Seleshi, Y. & Camberlin, P. 2006. Recent changes in dry spell and extreme rainfall events in Ethiopia. *Theoretical and Applied Climatology*, *83*(1-4):181-191.

Seleshi, Y. & Zanke, U. 2004. Recent changes in rainfall and rainy days in Ethiopia. *International Journal of Climatology*, *24*(8):973-983.

Sen, P.K., 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*, *63*(324), pp.1379-1389.

Sertse, D. & Pasiecznik, N.M. 2005. *Controlling the spread of prosopis in Ethiopia by its utilisation*. Henry Doubleday Research Association (HADRA). Coventry, UK. Available from http://www.spate-irrigation.org/wordpress/wp-content/uploads/2011/06/EthiopiaProsopisBrief.pdf

Shaw, M.R., Savaleta, E.S., Chiariello, N.R., Cleland, E.E., Mooney, H.A. & Field, C.B. 2002. Grassland responses to global environmental changes suppressed by elevated CO_2. S*cience*, *298*(5600):1987-1990.

Simenew, K., Dejen, T., Tesfaye, S., Fekadu, R., Tesfu, K. & Fufa, D. 2013. Characterisation of camel production system in Afar pastoralists, North East Ethiopia. *Asian Journal of Agricultural Sciences*, 5(2):16-24.

Smit, B. & Pilifosova, O. 2003. Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9):9.

Smit, B., Burton, I., Klein, R.J. & Wandel, J. 2000. An anatomy of adaptation to climate change and variability. *Climatic Change*, *45*(1):223-251.

Smith, L., Frankenberger, T., Langworthy, B., Martin, S., Spangler, T., Nelson, S. & Downen, J. 2014. Ethiopia Pastoralist Areas Resilience Improvement and Market Expansion (PRIME) Project impact evaluation: Baseline survey report. *Feed the Future FEEDBACK project report for USAID*.

Songok, C.K., Kipkorir, E.C., Mugalavai, E.M., Kwonyike, A.C. & Ng'weno, C. 2011. Improving the participation of agro-pastoralists in climate change adaptation and disaster risk reduction policy formulation: A case study from Keiyo district, Kenya. In Filho, W.L. (Ed.), *Experiences of climate change adaptation in Africa*. Berlin, Heidelberg: Springer, pp. 55-68.

Sonneveld, B.G.J.S., Keyzer, M.A., Georgis, K., Pande, S., Ali, A.S. & Takele, A. 2009. Following the Afar: Using remote tracking systems to analyze pastoralists' trekking routes. *Journal of Arid Environments*, *73*(11):1046-1050.

Stafford-Smith, D.M., McKeon, GM., Stone, G.S., Syktus, J.I., Carter, J.O., Flood, N.R., Ahrens, D.G., Bruget, D.N., Chilcott, C.R., Cobon, D.H., Cowlwy, R.A., Crimp, S.J., Fraser, G.W., Howden, S.M., Johnston, P.W., Ryan, J.G. & Day, D.A. 2009. Climate change impacts on northern Australian rangeland livestock carrying capacity: A review of issues. *Rangeland Journal*, 31:1-29.

Stephenson, N.L. 1990. Climatic control of vegetation distribution: The role of the water balance. *American Naturalist,* 135(5):649-670.

Sudan Update. 1997. Desert tree is a victim of its own success. *Sudan Update*, *8*(22):11.

Swift, D.M., Coughenour, M.B. & Atsedu, M. 1996. In: McClanahan, T.R. & Young, T.P. (Eds.) 1996. *East African ecosystems and their conservation*. Oxford: Oxford University Press.

Swift, J. 1988. *Major issues in pastoral development, with special emphasis on selected African countries*. Rome: Food and Agriculture Organisation of the United Nations.

T

Tabosa, I.M., Riet-Correa, F. Barros, S.S., Summers, B.A., Simões, S.V.D., Medeiros, R.M.T. & Nobre, V.M.T. 2006. Neurohistologic and ultrastructural lesions in cattle experimentally intoxicated with the plant Prosopis juliflora. *Veterinary Pathology Online*, *43*(5):695-701.

Tache, B. & Oba, G. 2008. Linkages between land use changes, drought impacts and pastoralists' livelihood responses in Borana, southern Ethiopia. In Boku Tache, *Pastoralism under stress: Resources, institutions and poverty among the Borana Oromo in Southern Ethiopia* (appendices). Doctoral thesis, Norwegian University of Life Sciences.

Tadege, A. (Ed.) 2007. *Climate change national adaptation program of action (NAPA) of Ethiopia*. Federal Democratic Republic of Ethiopia, Ministry of Water Resources, National Meteorological Agency. Addis Ababa, Ethiopia.

Tadege, A. 2008. Climate change and development adaptation measures. *Economic Focus*, *11*(1):15-24. Addis Ababa, Ethiopia: Ethiopian Economics Association.

Tadesse, G. 2001. Land degradation: A challenge to Ethiopia. *Environmental Management*, *27*(6):815-824.

Tarnavsky, E., Grimes, D., Maidment, R., Black, E., Allan, R.P., Stringer, M., Chadwick, R. and Kayitakire, F., 2014. Extension of the TAMSAT satellite-based rainfall monitoring over Africa and from 1983 to present. *Journal of Applied Meteorology and Climatology*, *53*(12), pp.2805-2822.

Tazalika, L., 2004. Satellite derived rainfall over tropical Africa: its pattern variability and calibration (Doctoral dissertation).

Tefera, M.M. 2011. Land-use/land-cover dynamics in Nonno District, Central Ethiopia. *Journal of Sustainable Development in Africa*, 13(1):123-141.

Tesfaw, W. 2015. *Challenges and opportunities of livelihood diversification: The case of pastoral communities in Yabelo Woreda, Borana Zone, Ethiopia*. Master's dissertation, Indira Gandi National Open University School of Continuing Education, Addis Ababa, Ethiopia. Available from http://repository.smuc.edu.et/bitstream/123456789/1946/1/WONDWOSEN%20TESFAW.pdf

Tesso, G., Emana, B. & Ketema, M. 2012. Analysis of vulnerability and resilience to climate change induced shocks in North Shewa, Ethiopia. *Agricultural Sciences*, *3*(06):871.

Thomas, D.S. & Twyman, C. 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change*, 15(2):115-124.

Thornton, P.K. & Cramer, L. (Eds.) 2012. *Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate*. Working Paper No. 23. CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS).

Thornton, P.K. & Gerber, P.J. 2010. Climate change and the growth of the livestock sector in developing countries. *Mitigation and Adaptation Strategies for Global Change*, *15*(2):169-184.

Thornton, P.K. 2010. Livestock production: Recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554):2853-2867.

Thornton, P.K., Ericksen, P.J., Herrero, M. & Challinor, A.J. 2014. Climate variability and vulnerability to climate change: A review. *Global Change Biology*, *20*(11):3313-3328.

Tierney, J.E., Ummenhofer, C.C. & deMenoal, P.B. 2015. Past and future rainfall in the Horn of Africa. *Science Advances*, 1(9):e1500682.

Tirado, M.C., Crahay, P., Hunnes, D. & Cohen, M. 2010. Climate change and nutrition in Africa with a focus on sub-Saharan Africa. Paper prepared a background for the Sunray Project, a Coordination and Support Action under the EU FP7 AFRICA call. Available from https://www.globalcube.net/clients/ntw/content/medias/download/SUNRAY_Climate_change_and_nutrition.pdf

Tolera, A. 2000. Problems of sustainable resource use among pastoralist societies: The influence of state intervention on the pastoral life of the Karrayyu. In Manger, L. & Ahmed, A.G.M. (Eds.), *Pastoralists and environment: Experiences from the greater Horn of Africa,* Proceedings of the Regional Workshops on African Drylands. Addis Ababa/Jinja, November 1997/March 1998. Addis Ababa: Organisation for Social Science Research in Eastern & Southern Africa (OSREA).

Trench, P., Rowley, J., Diarra, M., Sano, F. & Keita, B. 2007. *Beyond any drought: Root causes of chronic vulnerability in the Sahel*. The Sahel Working Group. Available from http://pubs.iied.org/pdfs/G02317.pdf

Tschakert, P., Huber-Sannwald, E., Ojima, D.S., Raupach, M.R. & Schienke, E. 2008. Holistic, adaptive management of the terrestrial carbon cycle at local and regional scales. *Global Environmental Change*, *18*(1):128-141.

Tsegaye, D. 1999. Land use and vegetation changes in the semi-arid area of Aba'ala district, northeastern Ethiopia: Arial photo analysis and field survey. *Proceedings of the National Workshop on Challenges and Opportunities for Research and Development in Pastoral and Agro-pastoral Areas of Ethiopia.* Dryland husbandry project (DHP). Mekele University College. May 1999

Tsegaye, D., Vedeld, P. & Moe, S.R. 2013. Pastoralists and livelihoods: A case study from northern Afar, Ethiopia. *Journal of Arid Environments*, *91*:138-146.

Tsegaye, D.T., Moe, S.R., Vedeld, P. & Aynekulu, E. 2010. Land-use/cover dynamics in Northern Afar rangelands, Ethiopia. *Agriculture, Ecosystems & Environment*, *139*(1-2):174-180.

Türke∏, M. & Sümer, U.M. 2004. Spatial and temporal patterns of trends and variability in diurnal temperature ranges of Turkey. *Theoretical and Applied Climatology*, *77*(3):195-227.

U

UNDP (United Nations Development Programme). 2008. *Climate Change and human development in Africa: Assessing the risks and vulnerability of climate change in Kenya, Malawi and Ethiopia*. Human Development Report 2007-08. United Nations Development Programme (UNDP), Intergovernmental Authority on Development and the Climate Prediction and Applications Centre.

UNDP (United Nations Development Programme). 2012. *One planet to share: Sustaining human progress in a changing climate*. New Delhi: UNDP Asia–Pacific Regional Center. Routledge.

UNFCCC (United Nations Framework Convention on Climate Change). 2007. Climate Change: Impacts, vulnerabilities and adaptation in developing countries. Germany: Climate Change Secretariat. Available from https://unfccc.int/resource/docs/publications/impacts.pdf

UN-EUE (United Nations Emergencies Unit for Ethiopia). 2002. *Afar: Insecurity and delayed rains threaten livestock and people.* Assessment Mission Report, 29 May–8 June 2002. Addis Ababa, Ethiopia.

UN OCHA (United Nations Office for the Coordination of Humanitarian Affairs). 2008. *21st century pastoralism. Strategies and ideas for pastoralism in the future*. Ethiopia: The UN OCHA Pastoralist Communication Initiative. Available from http://www.pastoralists.org/wp-content/uploads/2012/02/21CPastoralism.pdf

V

Van de Steeg, J.A., Herrero, M., Kinyangi, J., Thornton, P.K., Rao, K.P.C., Stern, R. & Cooper, P. 2009. *The influence of climate variability and climate change on the agricultural sector in East and Central Africa – Sensitizing the ASARECA strategic plan to climate change*. Nairobi, Kenya: International Livestock Research Institute.

Verdin, J., Funk, C., Senay, G. & Choularton, R. 2005. Climate science and famine early warning. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *360*(1463):2155-2168.

Vetter, S. 2005. Rangelands at equilibrium and non-equilibrium: Recent developments in the debate. *Journal of Arid Environments*, *62*(2):321-341.

Vincent, K. 2004. *Creating an index of social vulnerability to climate change for Africa*. Working Paper 56. Tyndall Centre for Climate Change Research. University of East Anglia, Norwich, UK. Available from https://www.researchgate.net/profile/Katharine_Vincent/publication/228809913_Creating_an_Index_of_Social_Vulnerability_to_Climate_Change_in_Africa/links/546478a50cf2c0c6aec52194/Creating-an-Index-of-Social-Vulnerability-to-Climate-Change-in-Africa.pdf

Viste, E., Korecha, D. & Sorteberg, A. 2013. Recent drought and precipitation tendencies in Ethiopia. *Theoretical and Applied Climatology*, *112*(3-4):535-551.

Vose, R.S., Easterling, D.R. & Gleason, B. 2005. Maximum and minimum temperature trends for the globe: An update through 2004. *Geophysical Research Letters*, *32*(23).

W

Wagesho, N., Goel, N.K. and Jain, M.K., 2013. Temporal and spatial variability of annual and seasonal rainfall over Ethiopia. Hydrological Sciences Journal, 58(2), pp.354-373.

Wakie, T.T., Evangelista, P.H., Jarnevich, C.S. & Laituri, M. 2014. Mapping current and potential distribution of non-native *Prosopis juliflora* in the Afar region of Ethiopia. PloS ONE, 9(11): e112854. https://doi.org/10.1371/journal.pone.0112854

Walker, B. & Salt, D. 2012. *Resilience thinking: Sustaining ecosystems and people in a changing world*. E-book format. Washington DC: Island Press.

Walker, B., Holling, C.S., Carpenter, S.R. & Kinzig, A. 2004. Resilience, adaptability and ztransformability in social–ecological systems. *Ecology and Society*, *9*(2):5.

Walter, O., Edgardo, V. & Patrica, L. 2010. Climate change and links to animal diseases and animal production. *Compendium of technical items presented to the OIE World Assembly of Delegates and to OIE Regional Commissions*:169-186.

Wan, S., Xia, J., Liu, W. & Niu, S. 2009. Photosynthetic overcompensation under nocturnal warming enhances grassland carbon sequestration. *Ecology*, *90*(10):2700-2710.

Watson, D.J. & Binsbergen, J.V. 2008. *Livestock market access and opportunities in Turkana, Kenya*. ILRI.

Webb, P. & Braun, J.V. 1994. *Famine and food security in Ethiopia: Lessons for Africa*. Chichester (UK): John Wiley and Sons.

Webb, W.L., Lauenroth, W.K., Szarek, S.R. & Kinerson, R.S. 1983. Primary production and abiotic controls in forests, grasslands, and desert ecosystems in the United States. *Ecology*, *64*(1):134-151.

Weldegebriel, Z.B. & Prowse, M. 2013. Climate- change adaptation in Ethiopia: To what extent does social protection influence livelihood diversification? *Development Policy Review*, *31*(s2):o35-o56.

Weng, Q. 2002. Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modelling. *Journal of Environmental Management*, *64*(3):273-284.

Wheeler, T. & Von Braun, J. 2013. Climate change impacts on global food security. *Science*, *341*(6145):508-513.

Williams, A.P. & Funk, C. 2011. A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. *Climate Dynamics*, *37*(11-12):2417-2435.

Williams, A.P., Funk, C., Michaelsen, J., Rauscher, S.A., Robertson, I., Wils, T.H., Koprowski, M., Eshetu, Z. & Loader, N.J. 2012. Recent summer precipitation trends in the Greater Horn of Africa and the emerging role of Indian Ocean sea surface temperature. *Climate Dynamics*, *39*(9-10):2307-2328.

Wilson, G.A. 2012. *Community resilience and environmental transitions*. New York: Routledge.

WISP (World Initiative for Sustainable Pastoralism). 2007. Pastoralists' species and ecosystems knowledge as the basis for land management. *WISP Policy Brief*, 5:1-4.

WISP (World Initiative for Sustainable Pastoralism). 2008. *Policies that work for pastoral environments. A six-country review of positive policy impacts on pastoral environments.* A project of the Global Environment Facility. Nairobi. Available from https://cmsdata.iucn.org/downloads/goa_uicn_wisp_policies_and_pastoral_environments_en.pdf

Woldeamlak, B. & Conway, D. 2007. A note on temporal and spatial variability of rainfall in drought prone Amhara regions of Ethiopia. *International Journal of Climatology,* 27:1467-1477.

Woldehanna, T., Hoddinott, J., Ellis, F. & Dercon, S. 2008. Dynamics of growth and poverty reduction in Ethiopia:(1995/96-2004/05). *A report for Development Planning and Research Department, The Ministry of Finance and Economic Development* (MoFED).

Woldetsadik, M. & Hailu, M. 2011. Climate change and variability, its impact on rural livelihoods, local coping and adaptation strategies in Woreilu Woreda, North Eastern Ethiopia. *Ethiopian Journal of Development Research*, *32*(2).

Y

Yamin, F., Rahman, A. & Huq, S. 2005. Vulnerability, adaptation and climate disasters: A conceptual overview. *IDS Bulletin*, *36*(4):1-14.

Yanda, P.Z. & Mubaya, C.P. 2011. *Managing a changing climate in Africa: Local level vulnerabilities and adaptation experiences*. African Books Collective.

Yesuf, M., Di Falco, S., Deressa, T., Ringler, C. & Kohlin, G. 2008. *The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin, Ethiopia*. International Food Policy Research Institute and Ethiopia Development Research Institute. Washington, DC. Available from http://www.fao.org/fileadmin/user_upload/rome2007/docs/ifpri_Adaptation_Food Production_Ethiopia.pdf

Z

Zerga, B. 2015. Degradation of rangelands and rehabilitation efforts in Ethiopia. The case of Afar rangelands. *Journal of Mechanical and Industrial Engineering Research*, *4*(2):45.

Appendix 1

QUESTIONNAIRES FOR LIVELIHOOD VULNERABILITY/RESILIENCE ASSESSMENTS

I. Social capital

A) Demographic characteristics

1. Household head name ____
2. Household head age _________________
3. Household head gender
   3.1 Female
   3.2 Male
4. Marital status of the household head:
   4.1 Married
   4.2 Single
   4.3 Divorced
5. How many spouses/wives do you have? __________________
6. Write number of household members:
   6.1 Below 18 years old_________
   6.2 Above 65 years old____________
   6.3 Between 18 and 65 years old_________
7. Settlement pattern:
   7.1 Sedentary
   7.2 Transhumance
   7.3 Others

B) Network and Relationship

8. Did you receive any kind of support and help from neighbors in the last 12 months?
   8.1 Yes
   8.2 No
9. If yes, what was it?
   9.1 Livestock
   9.2 Cash
   9.3 Gun
   9.4 Others (Specify) ____
10. In the most recent 12 months has your family unit gotten any of the accompanying types of help from anybody outside the family unit?

Item		From whom	Why	Where do they live
10.1.	10.2.	10.3.	10.4.	10.5.
Lending Milking animal	Yes 1 No2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Livestock	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Cash	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Cash loan	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Food or grain	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Free labour	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Free use of oxen	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Free use of camel	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
Other	1 2	1 2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
		Code: 1=relatives/kin 2= own clan Members 3=other clan Members 4= non-Afar friends 5= other specify	Code: 1= food shortage 2= to buy consumer goods 3=for marriage ceremony 4= funeral ceremony 5= loss of stock 6= other(specify)	Code: 1= same Village 2 =Somalia 3= Oromiya zone 4 =Dubti 5 =Asayita 6 =Djibouti 7 = other (specify)

11. Did you receive any kind of assistance from local government or aid?
    11.1 Yes
    11.2 No

12. If yes, what was it?
    12.1 Livestock
    12.2 Cash
    12.3 Food or grain
    12.3 Other (Specify): ____

13. Do you think the assistant from the government or aid is important?
    13.1 Yes
    14.2 No

14. If yes, what are their importances? ______________________________________

15. What is the reason that your household was the beneficiary of above assistance?
    15.1 Severe food shortage
    15.3 Loss of livestock
    15.4 It is a free distribution?

15.4 Other (specify) ____

16. Do the community members support each other during bad and good times?
    16.1 Yes
    16.2 No

II. Human capital

A. Knowledge and skills

17. Level of education of the household head: ____

18. Do you send your children to school?
    18.1 Yes
    18.2 No

19. If no, why? (Provide the most relevant reason to your household)
    19.1 They have to keep cattle
    19.2 Inaccessibility of schools
    19.3 Other (specify) ____

20. Did you attend training in the last five years?
    20.1 Yes
    20.2 No

21. If yes, what kind of training did you attend?
    21.1 In relation to livestock and rangeland management
    21.2 In relation to marketing
    21.3 In relation to water harvesting and irrigation
    21.4 Other (specify) ____

B) Food security and consumption

22. Did your household endure any deficiency of food?
    22.1 Yes
    22.2 No

23. If yes, in which months was food shortage most acute for your household? __________________

24. During that worst month, how frequently a day did the adults and children in your family unit eat?

	Mealtimes every day
A. Adults	0 1 2 3
School-age and working children	0 1 2 3 4
	Code: 0=Occasionally passed an entire day without eating anything

25. In your household, how many months did the food shortage last?
Write the number of months: _______

C) Health

26. How long (hours) it takes to access healthcare from your resident? __________________

27. Is your household able to afford health care prices?
    27.1 No
    27.2 Yes
    27.3 Partially
    27.4 Others (specify) ____

28. Have you observed diseases that have impacted your household during climatic extremes (low rainfall, high rainfall and high temperature from the normal range)?

____
____

29. If yes, list the type of diseases that occurred during climatic extremes
____
____

30. What is the impact of the aforementioned diseases in production?
____
____

31. How do you rate interventions done to prevent the above diseases by the government or other agencies?
    31.1 Bad
    31.2 Worse
    31.3 Worst
    31.4 Good
    31.5 Better
    31.6 Best

III. Natural Capital

A) Land

32. Does your household own farming plot?
    32.1 Yes
    32.2 No

33. If yes, how large is your farm land (ha) ------------

Plot type	When did you start having your plot? (Year)	Plot size (Owned)	Types of crop planted: 1=maize 2=pepper 3=vegetables 4 =onion or potato 5 = fruits 6=other	How the land is cultivated: 1= women 2 = men 3= renting out 4=sharecropping 5= support from friend 6= hiring labour 7 = other
Irrigated land			1 2 3 4 5 6	1 2 3 4 5 5 6 7
Rain fed located near the homestead			1 2 3 4 5 6	1 2 3 4 5 5 6 7
Bush field far from home			1 2 3 4 5 6	1 2 3 4 5 5 6 7
Other			1 2 3 4 5 6	1 2 3 4 5 6 7

34. Why have you started cultivation? Multiple response is possible, but give priority
    - 34.1 For additional sources of food or income
    - 34.2 Since animal rearing alone has been less viable
    - 34.3 Since I saw my village fellows
    - 34.4 Since I saw neighbouring Oromo groups
    - 35.5 Other (specify) ____

35. If you use sharecropping to work your farmland, how do you share the produce?
    - 35.1 Sharing the produce equally
    - 35.2 I give 25% of the produce to sharecropper
    - 35.3 Other arrangement (specify) ______________________________________

36. If you use hired labour, how much money did you pay? ________________Birr per day

37. What is the source of money for hiring labour?
    - 37.1 Sale of livestock
    - 37.2 Sale of crop
    - 37.3 Sale of milk
    - 37.4 Other (specify) ____

38. Why did you use sharecropping arrangement or hiring labour to carry out cultivation? Multiple response is possible
    - 38.1 Lack of skill to carry out cultivation
    - 38.2 Shortage of labour
    - 38.3 Lack of tool
    - 38.4 Lack of traction power
    - 38.5 Other (specify) ____

39. Do you have your own land which is registered or certified?
    39.1 Yes
    39.2 No

40. If no, what is the land tenure system in your area?
    ____

B) **Grazing land and herd movement**

41. Have you lost your traditional grazing land/dry season grazing area?
    41.1 Yes
    41.2 No

42. If yes, why? Multiple response is possible, but give priority
    42.1 Grazing land is taken by investors or government for commercial farms
    42.2 Conflict with neighbouring groups
    42.3 Agricultural expansion from highland areas
    42.4 Rangeland is invaded by invasive species
    42.5 Mining
    42.6 Other (specify) ______________________________

43. What happened to your household when you lost grazing land?
    43.1 I lost my livestock
    43.2 I started crop cultivation
    43.3 I had to move my livestock to distant places
    43.4 I had to confine livestock close to my village
    43.5 Other (specify)………………………………

44. Did you move livestock as you did it before 20 to 30 years?
    44.1 Yes
    44.2 No

45. If no, list the factors that have led to further reduction of livestock mobility?
    ____
    ____

46. Which of the following factors are causes of decline for pasture availability (multiple response is possible)? Give priority for each factor from 1-5, 1 being the main factor, 5 being the least factor.

Perceived factors for decline of pasture availability	Yes	Priority
46.1 Recurring drought		
46.2 Invasive species		
46.3 Encroachment of agricultural frontiers		
46.4 Expansion of large-scale irrigated farms in the dry season grazing area		
46.5 Change in land tenure from communal to privatization		
46.6 Others (specify)		

47. What extension services did you get to improve livestock productivity for the last five 5 years?

____

48. What extension services did you get to improve rangeland productivity for the last five 5 years?

____

49. Who is responsible for the management of the grazing land?
    49.1 Government
    49.2 NGOs
    49.3 User communities
    49.4 Traditional rangeland management committee (if any)
    49.5 Others Specify) ____

50. What problems do you have in relation to range/pasture/browse land?
    50.1 Management problem
    50.2 Too many livestock
    50.3 Distance from homestead
    50.4 Grazing/pasture land shortage
    50.5 Bush encroachment and un-palatable and toxic plants
    50.6 Low forage and browse yield
    50.7 Others (Specify) ____

51. What do you think the mitigation strategies of issues at 47 above? Multiple response is possible
    51.1 Bush clearing
    51.2 Improved fodder production
    51.3 Encouraging communal land management
    51.4 Providing trainings for community at large and committees in particular
    51.5 Strengthen and train/ capacitate traditional rangeland management system
    51.6 Promote/increased area enclosure for range land
    51.7 Promoting environmental protection
    51.8 Others: ____

B) Livestock holdings and access

52. Currently, how many livestock do you own as a HH?
    52.1 Cattle _______________
    52.2 Sheep _______________
    52.3 Donkey _______________
    52.4 Camel _______________
    52.5 Goat _______________
    52.6 Others: ____

53. If you lost your livestock due to diseases and drought before a year, how many livestock did you own before the occurrence of drought and diseases?
    53.1 Cattle _______________
    53.2 Sheep _______________

53.3 Donkey ______________

53.4 Camel ______________

53.5 Goat ______________

53.6 Others: ____

54. Currently, if you don't have any livestock, from where do you get livestock to start the previous activity?

    ____

55. If you will not go to the previous livelihood activity (livestock production), what will be your option as livelihood strategy?

    ____

56. What are the sources of fodder in the wet season?
    56.1 Grazing
    56.2 Trees and leaves
    56.3 Crop residues
    56.4 Other (specify) ____

57. What are the sources of fodder in dry season?
    57.1 Grazing
    56.2 Trees and leaves
    56.3 Cut and carry
    56.4 Hay
    56.5 Other (specify) ____

58. Did you have extension contact in relation to livestock marketing?
    58.1 Yes
    58.2 NO

59. Do you get a marketing information preceding sale?
    59.1 Yes
    59.2 NO

60. If yes, what is /are your source(s) of marketing information?
    60.1 Radio/TV
    60.2 VEWs
    60.3 Cooperatives
    60.4 Broker
    60.5 Means of local information exchange (*Dagu*)
    60.6 Others (specify) ____

61. If you don't get marketing information, might you want to have a normal source in the future?
    61.1 Yes
    61.2 No

62. How often would you like to receive?
    62.1 Daily
    62.2 Weekly
    62.3 Monthly

63. Do you have access to livestock market?
    63.1 Yes
    63.2 No

64. Distance from the peasant Association (PA) to the nearest market center _________ walking time (in an hour or day).

65. What do you think about the current livestock numbers and species composition as compared to the last 10/20 years? What are the reasons for these changes?

Livestock numbers and species composition status	Yes	Reasons for changes in livestock numbers and composition	
		Reasons for changes in number of livestock	Reasons for changes in spp. Composition
64.1 Livestock asset holding has been declining in recent years			
64.1 In recent years there is a shift from cattle and sheep to goats and camels			

66 Which factors do affect your animal husbandry? (Multiple responses are possible). Give priority from 1-6, 1 being the main factor and 6 being the least

Factors	Priority
Loss of grazing due to bush encroachment	
Recurrent severe drought	
Livestock diseases	
Scarcity of water	
Loss of dry season grazing areas for commercial farms	
Other (specify)	

67. Was the livestock production adequate to provide food for your family before 10 years?
    67.1 Yes
    67.2 No

68. Is current livestock production less viable?
    68.1 Yes
    68.2 No

69. If yes, why is the traditional livelihood strategy (livestock production) less viable now?
    69.1 Degradation of pasture
    69.2 Prolonged drought or severe recurrent drought
    69.3 Population increase
    69.4 Animal epidemics
    49.5 Other (specify) ____

C) **Water**

70. What are the primary sources of water for human utilization?
    70.1 Ponds
    70.2 Traditional well
    70.3 Protected spring
    70.4 Unprotected spring
    70.5 Cisterns
    70.6 Deep well
    70.7 Others (Specify) ____

71. Does your family make use of irrigation to produce crops/vegetables/fruits?
    71.1 Yes
    72.1 No

72. If Yes, from which source? ____
    And who irrigates it? ____

73. If No, why?
    73.1 No water resources for irrigation purpose in our village
    73.2 There are irrigable water resources, but we do not have technical and financial capacity to irrigate
    73.3 There are irrigated water resources, but as a HH, we do not want to make use of irrigation water for crops/vegetables/fruit production
    73.4 Other reasons (if any) ____

74. How much time do you spend for fetching/collecting water for human consumption every day?
    ____

75. What are the main sources of water for livestock consumption?
    75.1 Ponds
    75.2 Traditional well
    75.3 Protected spring
    75.4 Unprotected spring
    75.5 Cisterns

75.6 Deep well
75.7 Rivers
75.8 Others (Specify) ____

76. Is it within the village?
    76.1 Yes
    76.2 No

77. If not within the village, name the name of the village, distance from the residential area and hours of walk from the residence?
    77.1 Name of the village ____
    77.2 Distance ____
    77.3 Hours ____

D) Forest

78. What is the major source of energy for cooking/heating purpose in your house?
    78.1 Firewood
    78.2 Petroleum
    78.3 Others ____

79. How much time does it take to fetch firewood for your family? ________________

80. What is the situation of availability of firewood in comparison to 30 years back?
    80.1 Increased
    80.2 Decreased
    80.3 Same as before

E) Finance

81. What are the sources of income for your household?
    81.1 Livestock and livestock products sale
    81.2 Crops sale
    81.3 Cash for work program
    81.4 Rent (house, land, livestock)
    81.5 Vegetable sales
    81.6 Natural resources (gum, incense, salt)
    81.7 Remittance
    81.8 Firewood/charcoal sells
    81.9 Employment
    81.10 Others(specify) ____

82. Contribution of each income source to the total annual income of the household

Source of income	Annual income (in Birr)	Rank
Livestock		
Crops		
Employment		
Rent (house, land, livestock		
Charcoal or firewood sale		
Remittance		
Cash for work program		
Natural resources (gum, incense, salt		
Others (specify)		

83. Which kind of stock do you sell in times of financial need?
    83.1 Sheep and goat
    83.2 Cattle
    83.3 Camel
    83.4 Others (specify) ____

84. When (season of the year) did you like to sell livestock? __________________________
    and why do you prefer the season? ____

85. What do you say about the price you receive for your livestock in the market?
    85.1 Reasonable/fair
    85.2 Not fair

86. If no, what do you think are the reasons?
    ____

IV. Physical capital

87. How long (hours) it takes from your resident to the nearest market? ___________

88. How reliable is the road network where you live?

Please expound____

____

____

Description of types of road infrastructure

____

____

____

V. Early warning system

89. Do you have access to early warning information regarding climate change and variability?
    89.1 Yes
    89.2 No
90. From where do you get?
    ____

91. Description of Early Warning information availability
____
____
____

Appendix 2

QUESTIONNAIRES TO UNDERSTAND PERCEPTION OF HOUSEHOLDS ON CLIMATE AND LAND USE CHANGES

1. What is the present amount of precipitation during a rainy season in contrast to the last 10/20 years?
   1.1 Very low
   1.2 Low
   1.3 Normal
   1.4 High
   1.5 Very high

2. Since how many years have you noticed this change?
   2.1 10
   2.2 20
   2.3 30
   2.4 40
   2.5 50

3. What is the present amount of temperature in contrast to the last 10/20 years?
   3.1 Very low
   3.2 Low
   3.3 Normal
   3.4 High
   3.5 Very high

4. Frequency of drought in your area:
   4.1 Increased
   4.2 Decreased
   4.3 Constant
   4.4 Unsure

5. How many times your area has passed from drought condition since 1983?
   5.1 One
   5.2 Two
   5.3 Three
   5.4 Four
   5.5 Above five
6. When was the last time there was a severe drought in your area? _________

7. Frequency of drying rivers:
   7.1 Increased
   7.2 Decreased

7.3 Constant
7.4 Unsure

8. What can you say about the frequency of hunger in your area:
   8.1 Increased
   8.2 Decreased
   8.3 Constant

9. Has the drought affected the livestock life in your area?
   9.1 Yes
   9.2 No

10. References question no 5, what kind of effects you observed in livestock lives?
    10.1 Deaths
    10.2 Decrease in market price
    10.3 Increase in animal diseases
    10.4 All
    10.5 Any other: ____

11. What do you think about the impacts of change in rainfall on livestock?
    11.1 Lack of fodder
    11.2 Livestock deaths

12. What problems do you observe due to changes in the intensity of temperature?

12.1 Thermal stress on livestock & caused production loss	
12.2 Growth and yield of crops have decreased and caused production loss	
12.3 Can't go outside of the house because of extreme heat and caused working loss	
12.4 Need to work hard for irrigation and caused extra work	
12.5 Burning sensation	
12.6 Feel tired	
12.7 Can't rest around evening time because of extreme heat and sweating	
12.8 Tin top of house turns out to be excessively hot	
12.9 Others……………………………………………………………………….	

13. Select "yes" or "no" for the following questions?

Variables	Yes	No
13.1 Does precipitation happen routinely during rainy season?		
13.2 Are the water points full during rainy season?		
13.3 Does flooding happen during the rainy season?		
13,4 Can you harvest your crops utilizing precipitation water?		
13.5 Does rainfall occur early from the normal season?		
13.6 Does the rainfall occur late from the normal season?		

14. What do you think about the current incidence of human diseases as compared to the last 10/20 years?
    14.1 Increased

14.2 Decreased
14.3 Constant
14.4 Unsure

15. What do you think about the impacts of change in rainfall on humans?
    15.1 Food insecurity
    15.2 Hunger
    15.3 Loss of livelihood
    15.4 All

16. Currently, what do you think of the following land use/ covers? Give priority

No	Variables	Increased	Decreased	Priority	Cause
16.1	Percentage of open grassland				
16.3	Percentage of shrub land				
16.4	Percentage of woodland				
16.5	Percentage of bare land				
16.6	Percentage of Agricultural land				
16.7	Percentage of water bodies				
16.8	Others (specify)				

17. Do you think that there are invasive species in your area?
    17.1 Yes
    17.2 No

    If yes, name their local names:

____

18. What are the impacts of these invasive species in your livelihood?

    ____

    ____

19. What should be done to avoid these invasive species?

    ____

Appendix 3

CAPACITY ANALYSIS: COPING AND ADAPTATION MECHANISMS

1. What are the adaptive strategies to cope with the ecological/environmental stress and livelihood insecurity? Give priority 1-9, 1 being the main strategy and 9 the least strategy.

Coping / adaptation strategies	Yes	Priority
1.1. Combining herding with non-pastoral activities (trading, cultivation)		
1.2. Changing the composition of herds		
1.3. Herd splitting and mobility to areas where fodder can be available		
1.4. Leaving livestock under the care of bond-friend/kin		
1.5. Gotten food aid		
1.6. Sold charcoal and firewood		
1.7. Movement/looked for business somewhere else		
1.8. Lent from relatives and others		
1.9. Sold our cattle, camel, sheep and goat		
1.10. Others(specify)		

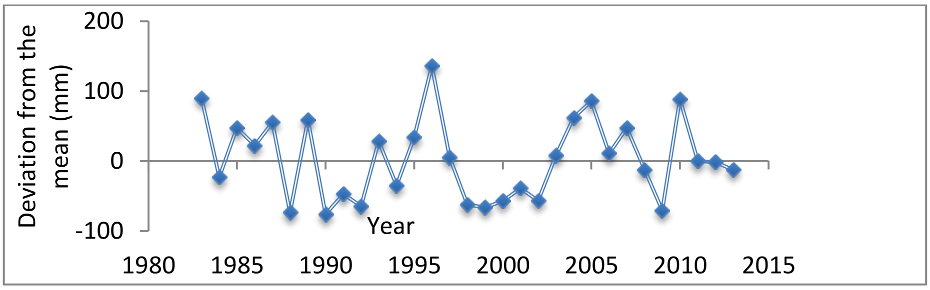
2. What are the perceived hindrances to adaptation & coping of climate variability and change? Give priority 1-6, 1 being the main hindrance and 6 the least hindrance.

Perceived hindrances to adaptation	Yes	Priority
2.1. Lack of access to dry grazing season area		
2.2. Absence of access to water for irrigation agriculture		
2.3. Absence of access to irrigation materials		
2.4. Absence of current knowledge on adaptation strategies		
2.5. Absence of information on weather occurrence		
2.6. Absence of cash to gain modern techniques		
2.7. Absence of assistance from government for indigenous range land		
2.8. Others (specify)		

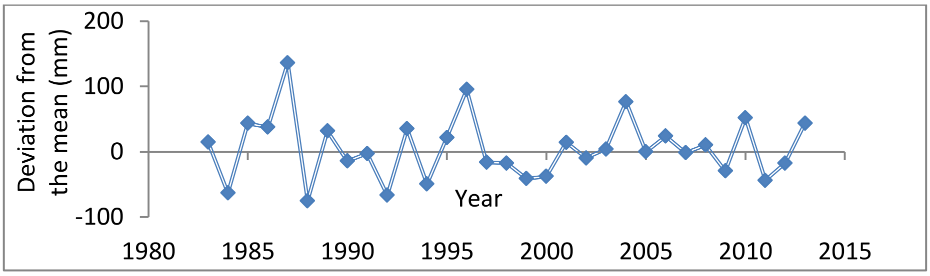
Appendix 4

TRENDS OF SEASONAL RAINFALL AN OMALIES IN THE AMIBARA AND GEWANE DISTRICTS

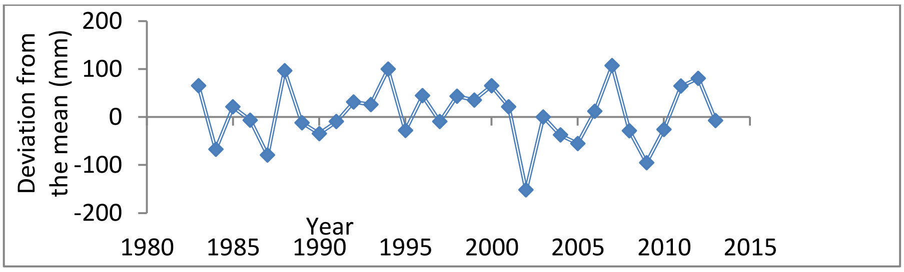
Appendix 4a: Deviations of spring season rainfall from the mean and trends in Amibara



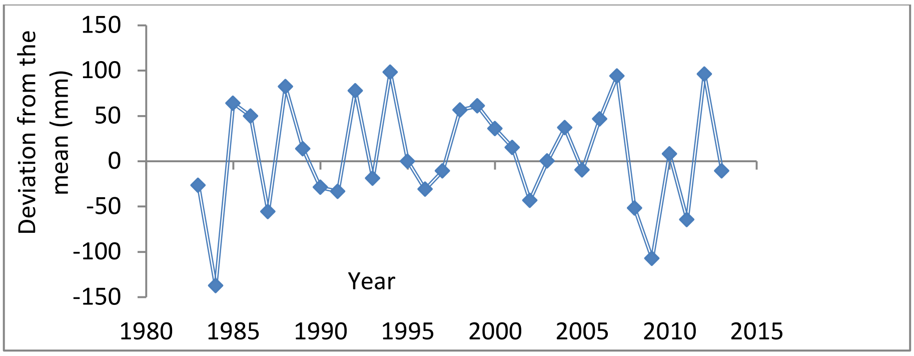
Appendix 4b: Deviations of spring season rainfall from the mean and trends in Gewane



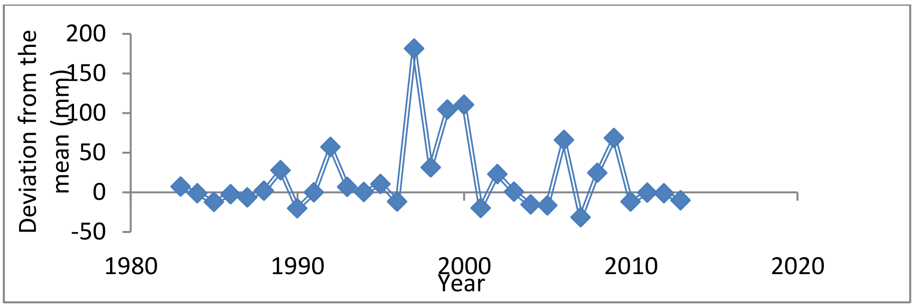
Appendix 4c: Deviations of summer season rainfall from the mean and trends in Amibara



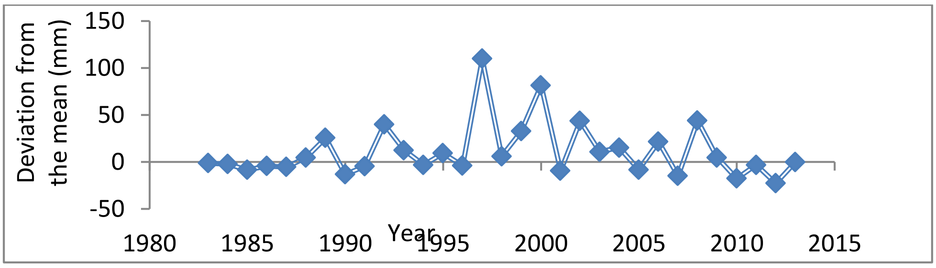
Appendix 4d: Deviations of summer season rainfall from the mean and trends *in Gewane*



Appendix 4e: Deviations of *Dadda* rainfall from the mean and trends trend in Amibara



Appendix 4f: Deviations of *Dadda* rainfall from the mean and trends trend in Gewane



Appendix 5

TRENDS OF ANNUAL RAINFALL FOR THE PERIOD 1983–2013

Study area	Mann-Kendall test statistic	Sen's slope
Amibara	–0.61[ns]	–0.911
Gewane	–0.95[ns]	–1.311

Slope (Sen's slope) is the change (mm)/annual; ns is non-significant at 0.05 Significance level.

Appendix 6

MANN-KENDALL TEST RESULTS FOR TEMPERATURE IN THE AMIBARA AND GEWANE DISTRICTS

Appendix 6a: Annual maximum temperature trend for the period 1983-2014

Study area	Mann-Kendall trend					Sen's slope estimate
Amibara	First year	Last Year	n	Test Z	Sig.	Q
	1983	*2014*	*32*	4.65	***	0.083
Gewane	First year	Last Year	n	Test Z	Sig.	Q
	1983	*2014*	*32*	6.28	***	0.095

*Note:-*** if trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance,* if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance*

Appendix 6b: Annual minimum temperature trend for the period 1983-2014

Study area	Mann-Kendall trend					Sen's slope estimate
Amibara	First year	Last Year	n	Test Z	Sig.	Q
	1983	*2014*	*32*	3.23	**	0.035
Gewane	First year	Last Year	n	Test Z	Sig.	Q
	1983	*2014*	*32*	3.39	***	0.061

*Note:-*** if trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance,* if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance*

Appendix 6c: Mean annual temperature trend for the period 1983-2014

Study area	Mann-Kendall trend					Sen's slope estimate
Amibara	First year	Last Year	n	Test Z	Sig.	Q
	1983	*2014*	*32*	4.75	***	0.054
Gewane	First year	Last Year	n	Test Z	Sig.	Q
	1983	*2014*	*32*	5.30	***	0.081

*Note:-*** if trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance,* if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance*